【Review】

The Rules Making Process and the Effect of Regional Differences on Maritime Transportation Safety

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Abstract

In this paper the maritime safety and the protection of marine environment are discussed from a general point of view with particular reference to the effect of ship typology and of the regional differences. Some contradictions and existing gaps are discussed with reference to explanations on hystorical basis. Foreseeable developments are presented with reference to examples of particular interest.

1. Introduction

Activities at sea, *as well as all human activities*, present some degree of risk. The probability of a fatality happening to a passenger is however very small if compared with other means of transportation. Different is the situation as far as the crews are concerned. Deep sea fishing and offshore oil and gas production are also quite dangerous activities, but these fatalities have a low impact on public opinion. From the societal point of view, it is not the frequency nor the number of fatalities in itself playing a relevant role, which is instead related to their combination or *risk*. Accidents to passenger ships, and to airplanes, often involve a great number of fatalities at the same time, hence the generally high public awareness.

Although there is no longer any significant long range passenger transportation, waterborne transportation is still the most widely used transportation means for freight on intercontinental routes, while freight and passenger transportation on short sea shipping is in constant expansion.

In spite of this, the safety at sea, with particular regard to the possibility of ship loss by sinking and capsizing both in intact and in damage condition, has been for long time addressed by means of interim solutions that did not incorporate the available technological solutions. Only with the incident of Titanic, about 100 years ago, the problem of ship safety is seen as an international problem and the first International Conference on the Safety of Life at Sea (SOLAS) is opened in London with specialists and regulators sitting at the same table. The progress is extremely low in the absence of a recognised international body and only after the 2nd World War, with the institution in London of the International Maritime Organisation (IMO - formerly IMCO) as United Nations Agency for the maritime safety, a set of international rules for ship safety start to build-up. For a few decades the approach continues to be based on the slow reaction to accidents, i.e. is re-active instead of being pro-active, with progress limited to the ship typologies most relevant in terms of economic revenue or in consequence of accidents to which public opinion is particularly sensitive like passenger ships and ferries.

2. The Rules Making Process

The rules making process at IMO is slow since it is based on a multistep process: technical people proposes solutions in terms of new or improved rules and codes of practice; diplomatic representatives approve the proposals which, at this point are issued as “recommendations”. Only after the relevant documents have been signed and incorporated in the national laws by a sufficient number of National Administrations representing a sufficient percentage of world ship tonnage, the recommendations become “mandatory”. There is, however, no international police to enforce the regulations. This duty is passed to the National Administration of which the ship carries the flag (Flag State Implementation). The National Administrations, in turn, usually act through a Classification Society which is the technical body. The Classification Societies, on the other hand, were born to provide Insurance Companies with the “assurance” that the ship construction is technically sound and that proper operation and maintenance is regularly done. As such, they are paid by the shipowner and representatives of the shipowners sit in the Administration Council of the Classification Societies, which makes the effectiveness and transparency of controls a puzzling problem[1]. The matter was made still more confuse with the passage from flag state Classification Society to Open Flag Classification Societies. This process, started with Panama and Liberia, spread extensively and now a number of Classification Societies, most of which goes under the meaningful name of Flags of Convenience (FOC), is based on developing Countries, often small islands, which belong to the “Fiscal Paradise” category. These offer big savings to the shipowners but don’t afford to have a sufficient technical staff. As a result, the fleets classified under this alternative umbrella are often older and less maintained, so that they incur in a higher percentage of casualties.

It is amazing to see that even Countries without direct maritime interests like Mongolia recently joined the list...

Following the International Transport Workers’ Federation (ITF)[4], a *flag of convenience ship* is one that flies the flag of a country other than the country of ownership. Cheap registration fees, low or no taxes and freedom to employ cheap labour are the motivating factors behind a shipowner’s decision to ‘flag out’. The ITF takes into account the degree to which foreign owned vessels are registered and fly their country flag, as well as the following additional criteria, when declaring a register an FOC:

- The ability and willingness of the flag state to enforce international minimum social standards on its vessels, including respect for basic human and trade union rights, freedom of association and the right to collective bargaining with bona fide trade unions.
- The social record as determined by the degree of ratification and enforcement of ILO (International Labour Organization) Conventions and Recommendations.
- The safety and environmental record as revealed by the ratification and enforcement of IMO Conventions and revealed by port state control inspections, deficiencies and detentions.

The IMO collection of data regarding Ship Detentions (usually for non-compliance with the standards) in the period 1997-99, reveals that the 75% of cases is shared by 5 of these “Open Registers”, one of which ended-up by deleting 42 ships...

If we look at the requirements to be classified with them, we find the following key-words:

“Straightforward”, “Flexible”, “Age limits prevail but exceptions are made”...

to be compared with the IACS Rules for “Transfer of Class, Suspension of Class, Reassignment of Class and Class Withdrawal and Reporting of Changes in Class Status”.

IACS introduced indeed a strict procedure in 1995, called the “Transfer of Class Agreement”, which significantly diminishes the possibility for substandard ships to “class hop” within IACS to avoid requirements.

Older ships have been competing with the modern fleet for the world’s cargo for many years. If owners of ships can neglect their maintenance and save those costs, the ships can obtain a commercial advantage over their competitors and continue to operate at low cost for longer periods[2,3]. When, as a result of survey, the classification society requires extensive repairs before it will issue new certificates, some ship owners may try to escape this strict enforcement by changing class. Such a strategy is well known in the industry as “class hopping”.

To prevent “class hopping”, IACS members must follow the Transfer of Class Agreement, which requires that one IACS society - the gaining society- cannot accept a ship into class from another society without making sure that all the requirements and conditions of class outstanding from the previous class-the losing class- are met, as if the vessel had not changed class.

This measures were not as efficient as expected if, after the ERIKA accident - the ship having transferred through four different classification societies, IACS further enhanced the transfer of class procedure...

It is interesting to note that since the beginning of IMO history the fighting against the open flag classification societies started. See for example the Case Summary of the Constitution of The Maritime Safety Committee of the Inter-Governmental Maritime Consultative Organization - Advisory Opinion of 8 June 1960 requested to The International Court of Justice.

The problem of safety at sea and protection of environment at sea is really international because in a big casualty involving heavy pollution, like the case of tankers, only little money can be obtained from the relevant bodies. Situation is often complicated by the difficulty of tracing back the real managing company of the ship, as is made evident in the case of two major accidents occurred to tankers:

- The *Prestige* was Bahamas flagged, American classed, Greek owned through a shell company based in Liberia, and chartered by a Russian/Swiss company. It took skilled researchers several weeks to uncover this information[4];
- The Amoco Cadiz was built in Spain, American owned, mainly Italian crew, flying Liberian flag, carrying Arabian oil for a Dutch refinery and trying to be towed by a German tug in French waters[5].

Of course, Flags of Convenience is often conjugated with Crews of Convenience...

To fight this unsatisfactory situation, the concept of Port State Control has been introduced. The Port State can make controls on the ships and impose actions as appropriate to improve safety of life and environmental protection at sea.

Recently IMO adopted the Formal Safety Assessment (FSA) as an instrument to facilitate the gathering of consensus. FSA is a structured and systematic methodology, aimed at enhancing maritime safety, including protection of life, health, the marine environment and property, by using risk and cost/benefit assessments. It should assist the rule-making process and facilitate proactive risk control. Nevertheless, this approach is entering very slowly in the rules making process which continues to be dominated by re-active approaches and with a very few exceptions ends-up with prescriptive rules instead of performance-based. The prescriptive rules are difficult to improve “rationally”, while performance based standards could in many cases lead to a substantial increase of safety without increasing the cost of con-

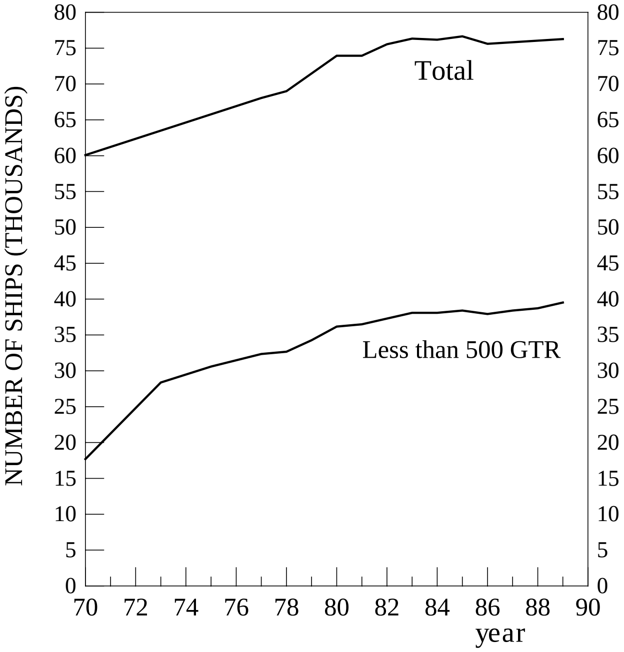

Fig. 1. Percentage of ships less than 500 GRT with respect to the total over the years (from[5]).

struction or the operational costs.

This way, the gathering of consensus is only possible if new rules are approved for new ships, leaving the majority of old ship free to fly and die at sea with the consequences everybody knows.

A substantial difference is connected with passenger and RoRo ships, where on the other hand the regional differences play a relevant role. The worst accident in terms of lives lost (roughly estimated in 4000) happened to a ferry in the Philippines in 1987 and majority of people even don't know it happened. The incident of RoRo Estonia in Baltic Sea in 1994 led to a number of new rules in SOLAS, most of which (slowly) retroactive, and to the enforcement of a regional agreement among European Nordic Countries (Stockholm Agreement) which is much more severe than SOLAS.

Another big problem is deep sea fishing for which no international rule of stability was up to now ratified in spite of having been approved and updated a regulation of safety known as Torremolinos Convention.

Finally, the international rules are relevant to international shipping and to ships above some minimum tonnage. For example, cargo ships of less that 500 gross tonnes are exempted from SOLAS. Unfortunately, as shown in **Fig. 1**, ships in this category are about 50% of total ...[5].

National shipping was never required to comply strictly high standards. Recently European Community incorporated SOLAS requirements in its law[6], so starting a sensible increase of the average standards of safety, filling a gap between Nordic Countries and Southern Europe but permitting the existence of very old passenger ships and allowing a consistent time to comply and again ... regional discounts to the old ships (in the age range 27-35 years) to a Country with large shipping interests. A big accident happened later on in this country ([7]) was advocated to improve the liability and the availability of life-saving devices[8] more than to shorten the time to comply or strengthening the intrinsic and operational safety standards.

This would be of course too heavy for developing Countries, where, on the other hand, the standards of safety are lower.

In this paper we will present some case studies which hopefully will highlight the different types of difficulties we encounter in the route to make activities at sea more safe and environmentally friendly. Even excluding security, the risk is connected with different sources: loss of buoyancy, loss of stability, fire, and problems connected with communications, life-saving devices, etc., it would be impractical to deal with each of them. Also in view of the specific activity of the author, we shall concentrate on some of the most significant buoyancy/stability problems presently under discussion. One of the most important points in nowadays discussion is that connected with the development of procedures for assessing ship stability. It is indeed important to discredit the common idea that improving safety increases costs. This is especially true for new designs, if we are able to develop tools for assessment of safety based on real behaviour, i.e. performance instead of prescriptions based on casualty statistics or on rough physical modelling. We could indeed end up *improving safety and saving money*[9,10]. Since ships are objects with a quite high index of reliability, this means that a few bad projects can be heavily conditioning the statistics of a sample[14].

This could be advocated as a partial justification of the negative consideration paid by the owners to improving stability criteria.

3. Development of Numerical and Experimental Procedures for Assessing Ship Stability

Safety at sea concerns all aspects of ship life. Ship safety in Design is traditionally divided in :

- “Structural safety”;
- “Hydrodynamic” safety which, by a long questionable tradition, is called “Stability” (“the use of “Stability safety” was indeed rejected!).

It is not the aim of this report to throw a bridge connecting the two aspects of the survivability of the same object, but the time to do that will hopefully come soon. Presently, the only interrelation is through the possibility of loosing the structural integrity and consequent flooding. This aspect is treated in modern approaches to ship survivability after damage through a probabilistic approach where damage position and dimensions are obtained from statistics of casualties at sea. The actual ship structure is considered through the presence of watertight bulkheads and no direct implication of shell plating thickness is considered. Only recently, due to a dramatic series of accidents involving bulk carriers in the nineties (and especially the case of the Derbyshire), the mutual interrelation between strength and flooding has been taken into consideration, leading to dramatic improvement of the Load Lines Rules.

We have not to forget, in any case, that[10]:

Safety is a global concept and fragmented attempts to tackling it tend to produce biased, incomplete and ineffective solutions.

The lack of a systematic and all-embracing approach to ship safety means that the wealth of information amassed over many years of research and development on stand-alone safety-critical areas remained under-utilised. In this respect, a methodology that allows for a strategic overview of safety and the derivation of effective solutions is the vehicle to put safety in the heart of the ship design process.

From an historical point of view, at the beginning there was a slow development of skills on the base of tradition. This slowly crystallized in construction codes of practice from which, even slower, safety became an individual item. Importance of safety grew along with the relevance of the mission profile and/or with the increasing awareness of the value (and the cost!) of human life (ship safety is in a transitional state reflecting the shift from design periphery to a core design factor and from a post-design consideration to a through-life design imperative). Rules were developed in the frame of a prescriptive approach to safety and rules based design and operation was the current practice until recent times.

Structural safety was the first to improve upon a prescriptive set of rules due to the following aspects:

- the development of offshore oil industry pushing the oil fields towards higher water depths and a more hostile environment made it necessary to answer in short time and with sufficient “reliability” to questions connected with the short and long term design of structures most of which “cannot choose” between going at sea or remaining in sheltered waters;
- the extension to ships of the design methodology based on direct calculations instead of using the classical dimensioning based on Classification Societies rules, had as immediate effect the reduction of steel weight.

The development progressed very fast and nowadays Structural safety is based on Reliability theory.

Very different is the history of Ship Stability. First of all here also there is a traditional division in:

- Damage stability;
- Intact stability;

The order corresponding to the order of appearance on the scene[11]. At the beginning there was the damage which came to the international consideration with the sinking of the Titanic in 1913. The first SOLAS Conference was called in 1914, but its effectiveness started with the second call in 1929 setting the basis for the factorial subdivision. Fast progress started with the third call in 1948 when Stability was just mentioned. Big changes on the consideration of Damage Stability were introduced in 1960, 1974, 1990. After 1990 the progress was continuous.

Intact stability as international concern came only much later as a request of SOLAS’60 and of SOLAS’74. As a consequence, the Intact Stability rules, as contained nowadays in the Intact Stability Code were progressively developed. Further on, the rules specialized for the different ship typologies: dry cargo and passenger ships, high speed craft, fishing vessels, tankers, Mobile Offshore Drilling Units, gas-carriers, etc.

The Intact Stability assessment is presently based on a deterministic approach and prescriptive rules. Damage stability assessment is presently based on different approaches depending on the ship typology and size, although we can say that the absolute majority of ships is presently designed with reference to prescriptive rules of the deterministic type even when alternative approaches of the probabilistic type (still mostly prescriptive!) is available.

It is evident that safety “assessment” is an operation connected with an existing set of regulations and that the development of new methodologies for the “evaluation” of safety should produce some change in the set of regulations. These changes can be of two main typologies:

- changes intended to allow partial or total alternative assessments of some “equivalent” level of safety without substantially modifying the basic structure of the regulation;
- changes intended to modify the basic structure of the regulation.

In the following we will first examine in general the possible methodologies to assess safety[9-14], then the present situation as per IMO and other international instruments and the foreseeable developments as per the working documents of the same Institutions.

3.1. Safety assessment methodologies

3.1.1. Prescriptive deterministic (Rules-based) assessment and design

This approach is based on prescriptive, semi-empirical rules and regulations deriving from statistical data and practical experience, but which in general lack.

The most popular method regarding the assessment of ship safety, namely the deterministic - rules-based approach, is based on the fundamental, but trivial concept that safety is achieved by the application of semi-empirical design rules and compliance with statutory rules and regulations devised by relevant international and national authorities. The latter are in general based on the experience regarding safety sufficiency of offered technical solutions in the past and follow the general "trial and error" concept. Because of the nature of the current rules and regulations, this approach is also referred to as the "prescriptive approach", owing to the fact that the standard of safety is prescribed by the regulating authorities. The designers, builders and operators have simply to demonstrate that their designs meet the set requirements.

In almost all cases, rules and regulations are based on past knowledge and experience. On the same norm, amendments and additions to the regulations are reactions to accidents that had a great societal impact (great loss of life, pollution to the environment).

Even though most classical ship design developed continuously over several years of practice, there are only few designs where safety has been taken properly into account. In fact, most designs tend to be governed by the minimum compliance with the rules concept and by inference safety is addressed as a necessary "burden", but surely not optimally in the sense of survival in case of emergency.

This has as a main drawback the impossibility to perform safely an optimisation in the frame of a Rules-Based Design. The dimensions and characteristics of the original specimen of ships from which the stability rule has been derived through long practice, statistical inference from statistics of casualties or other, are included in the safety standard in hidden way. In addition, due to the absence of a reliable cause-effect mechanism(s), the required standard can only account partially for the safety standard obtained. As a result, the search for "new" performances implied in any optimum searching, can push the results out of the safety or seaworthiness boundary, while complying with the standard of stability since this is included as a set of constraints[13,14].

The approach allows for an easy assessment of safety in ship design but it does not account for a uniform measure of safety in the set of ships and, given the ship, among the different areas of ship design, construction and operation.

3.1.2. Prescriptive probabilistic-based assessment and design

This approach is similar to the one previously described, except that the explicit probabilistic format of all or part could allow, in principle, further development into a Risk-Based approach. Unfortunately, very often the probabilistic aspects are quite rough and don't allow a simple and reliable formulation of the assessment as a Risk-Based one.

3.1.3. Risk-based assessment and design

It consists in the adoption of frameworks of probabilistic description and of risk assessment methods for the purpose of scientific quantification and unification of the measures regarding the safety level achieved by a vessel.

It can be based on statistical analysis of casualties or on first principles (performance based).

The achieved levels of risk and safety are compared to acceptable individual and societal levels.

Damage stability rules for passenger ships were based on a prescriptive approach until 1974. From

1974, two alternative routes are possible to assess ship safety:

- the prescriptive one, based on the concept of floodable lengths and factorial subdivision;
- the probability based one, where the probability of surviving a damage is roughly evaluated on the basis of statistical analysis of a set of available data from previous casualties. This is in principle the basis for the development of a risk-based approach.

In 1990 the probability-based approach was extended to dry cargo and presently discussion at IMO concerns the development of a unified approach of the same type, still based on statistics of casualties and not on first principles/performance.

3.1.4. Performance-based (Simulation-based) assessment and design

It consists in the use of numerical and/or physical model testing to assess safety performance based on the inherent characteristics of the vessel under consideration to respond safely to given scenarios and environmental conditions.

The safety level of a ship under consideration should account for specific operational aspects and can be evaluated by the execution of a series of specified physical and numerical tests for given scenarios and environmental conditions. The philosophy of this approach is based on the principle of limit-state performance of a system, i.e. the system has been designed in a way that the extreme level of one or more quantifiable qualities that characterise system’s performance has been achieved, a concept well-introduced in structural engineering. Performance standards are based on the minimum acceptable performance of a ship or its sub-systems under given operational conditions. The benefits that the performance-based approach can offer to the assessment of safety in ship design are two-fold:

- Firstly, a performance-based approach can directly be applied for the <u>effective and efficient development of new concepts</u>, where as it has already stated there is lack of a rational prescribed framework to base the development on.
- Secondly, a performance-based method developed for a specific aspect of ship design can be easily <u>integrated into the current practice design environment</u>. In this way, rational decisions can be made cost-effectively without compromise on safety.

A by-product is that the probabilistic nature of some results of a performance-based assessment, i.e. the associated levels of confidence, allows for their direct consideration in the risk analysis.

The development of performance-based approaches and standards in ship safety is a process far from being complete and requires the joint effort of all players in the field of ship safety. The way forward is to aim at developing advanced technological tools able to predict the performance of any given vessel under specified operational conditions and then to apply relative performance criteria to compare the derived design to the route and mission standards in question.

The performance-based approach is the most appropriate and only rational methodology to assess the inherent capabilities of a system. Up to now it was only used to develop regulations for fire safety, but in view of previous considerations it is expected to have a brilliant future.

3.1.5. Formal safety assessment

This has been adopted by IMO as the standard for new developments and for comparison of different alternatives. Up to now only marginally considered in developing ship stability regulation/assessment methodologies!

4. Present Situation and Foreseeable Developments Concerning Intact Stability

4.1. At the beginning there was the damage

The intact stability at IMO was originated, as Adam’s rib, by a recommendation contained in the conclusions of SOLAS’60. “The Conference, having considered proposals made by certain governments to adopt as part of the present Convention regulations for intact stability, concluded that further study should be given to these proposals and to any other relevant material which may be submitted by international Governments.

The Conference therefore recommends that the Organization should, at a convenient opportunity, initiate studies on the basis of the information referred to above, of:

a) intact stability of passenger ships;
b) intact stability of cargo ships;
c) intact stability of fishing vessels, and
d) standards of stability information...”

The evidence presented at SLF 44 in September 2001 by a number of national delegations and in particular the documents prepared by Germany and Italy gathered sufficient consensus to propose to the Maritime Safety Committee the introduction of the item “Revision of Intact Stability Code for the next SLF 45” (held on July 2002).

Both an Ad Hoc Working Group and an Intersessional Correspondence Group were constituted under the chairmanship of the author and of Mr. Mains (Germany) respectively.

4.2. The intact stability in present IMO instruments

There is general consideration about nomenclature. The term “Stability” in ship stability matters has not the same meaning as in theoretical mechanics. It could be more appropriately be represented by “boundedness” of a relevant motion, usually rolling[13,14]. Anyway, the intact stability provisions grew in time, starting almost in 1968 with IMO Res A.167 and are now collected in the Intact Stability Code[15] and an MSC Circular[16]. Actually, the Intact Stability Code covers several ship typologies, but the core of the recommendations can be grouped in three main typologies which, apart considerations on their being mandatory or not, are to be applied simultaneously. Each of these possesses pros and cons, but undoubtedly constituted a step forward in the road of increasing safety of navigation.

4.2.1. IMO Res. A.167 (“Statistical Criterion”) 1968

This recommendation originated from the studies of Rahola[17] and was developed in terms of global quantities related to in initial metacentric height, static and dynamic stability arms satisfying a set of standards obtained empirically from statistics of casualties.

It is simple to use. On the other hand it is difficult to improve, has no physical modelling, no mention to sea state[18] and the level of safety is *presently* unknown (although there is some claim of 60-70% to 80-85% with respect to the *original* sample of ships).

The introduction of A.167 constituted a tremendous improvement of previous state of art regarding stability at international level (practically ...nothing!). In comparison all subsequent changes and new introduction can be considered *smooth* changes...

4.2.2. IMO Res. A.562 (“Weather Criterion”) 1985

Again, this recommendation originated as an answer to a recommendation given in the conclusions of SOLAS’74:

"(IMO) Recommends that steps be taken to formulate improved international standards on intact stability of ships taking into account, *inter alia*, external forces affecting ships in a seaway which may lead to capsizing or to unacceptable angles of heel".

Weather Criteria were already enforced in several countries including Japan and Australia. We just mention here[20] that present Weather Criterion was obtained merging the Japanese standard, which still constitutes the "backbone", with the Russian standard especially for the evaluation of roll-back angle and the effect of appendices on roll damping.

It is simple to use, it is based on a (although rough) physical modeling and it can be improved and "updated" to some extent for new ship typologies. On the other hand, the simplified modeling takes into account only beam waves and wind, while no internal degree of freedom is introduced (shifting of cargo, water on deck, etc.). Finally it concerns only one mode of ship loss. Here too the level of safety is to a large extent unknown, although some studies[20,21] try to quantify it with quite different figures, also depending on ship typologies. In principle, the level of safety (probability of non-capsizing) is "computable" once assumed a mission profile[22] or in general terms connected with the expected operational life of the ship in the environment assigned by the criterion rules.

4.2.3. MSC Circular 707 of 1995

This addresses the operational indications to avoid dangerous phenomena occurring in longitudinal/quartering waves. Stability is not directly addressed but safety in the mentioned environmental conditions is the primary concern. This circular is relatively simply to use. On the other hand, no provision is included for head seas, for stability standards or for manoeuvrability standards.

4.2.4. General comments on these instruments

The general outcome of Res. A.167 and A.562 is typically in the form of a limiting curve for the initial metacentric height GM or KG as a function of ship draught. Comparisons have been made for families of ships of same typology between statistical and weather criteria requirements generally finding that the second one is more severe. Comparisons have also been made between A.562, A.167 and SOLAS'90 for particular types of ships, like the modern large passenger cruise ships. In this case it was found that weather criterion is exceedingly more severe that SOLAS'90.

It has to be observed that the A.167 is usually only marginally subjected to criticism, while the other two instruments are severely criticized. On the other hand, the set A.562+MSC Circ.707 in the original Japanese formulation[23] constitute a set of complementary rules giving:

- indications of operational value to avoid parametric rolling/surf riding/broaching, i.e. guidance on route/speed;
- provisions for ship survival in the extreme case of loss of ship controllability (failure in the set engine/propulsion/rudder) as a consequence of which the ship falls at zero speed in quasi beam sea condition.

In addition, the weather criterion was supplemented by a GM and a GZ criteria (something relative of A.167).

4.2.5. Recommended versus mandatory

An additional item adds some confusion to the picture: the question of being mandatory or only recommended. There is overlapping of competencies between International rules, national rules, rules of the Classification Societies, the International Society of Classification Societies and recently the role of European Community. The IMO Intact Stability Code itself is a recommendation, but many national codes, the IACS, etc., make it mandatory...

4.3. Simplicity versus physical modeling

As a general rule IMO approach to change safety rules is based on the statement "New regulations should provide the same average level of safety of existing ones". There are indeed several factors behind the endorsement (and the success) of new approaches in addition to reliability and sound physical basis:

- simplicity;
- economic implications;
- connection with engineering design practice.

As an example of importance of simplicity and connection with engineering design practice, we can consider the introduction and the development of new subdivision and stability rules based on probability to replace the traditional SOLAS'60 approach based on the concept of floodable length. After many years work and contemporary to SOLAS'74, IMO Res. A.265 was produced. It took into account the new ship typologies, the probabilities, the environmental action, the different distribution of spaces on board (engine rooms!) with respect to the formulas used in SOLAS'60, etc.

The new formulation was more sound, but much more complicated, without simple connection with design and with a puzzling "equivalent level of safety" to SOLAS.

As a result, very few applications were made up to now and it is still under discussion at present, although very deep studies progressed on the subject in the last almost 30 years!

Finally, we can consider the factor "simplicity" versus "physical modelling" considering the fact that A.167 practically gives rules so that the righting arm in calm water stays "sufficiently high" in a "sufficiently large range of angles". As such, it cannot be reasonably improved. On the contrary, it is just the typical standard that, used in "optimisation procedures" can produce horrible results in terms of safety although satisfying the rules. The statistical criterion, in fact, is an "a posteriori" one. In addition, it expresses a correlation between observed ship losses, in a particular class of ships sailing a very restricted region, and computed static stability characteristics. The main criticisms can be synthetically expressed as:

a) there is no direct connection between the requests and the needs. The criterion does not involve seakeeping qualities, the forcing effect of meteomarine environment, trim variations, coupling among different motions, course keeping ability, shifting of cargo, etc;

b) the statistical nature of the correlation averages between good and bad projects (with respect to safety), as a result, the good projects are penalized;

c) as long as the ship remains intact, the probability of casualty at sea is usually quite low as regards the mentioned mechanisms. Since ships are objects with a quite high index of reliability, this means that a few bad projects can be heavily conditioning. This means that even a small subset of casualties only explainable as a wrong correlation attempt as per a), can render the system almost "incompressible" in the sense that a very strong additional request (i.e. a very low KG reducing drastically the payload) contributes to a negligibly small increase in the observed safety at sea[14].

This could be advocated as a partial justification of the negative consideration paid by the owners to improving stability criteria.

Lets go back to 1982[24] (the square brakets in the reported text are by the author):

"Investigations into accident sometimes reveal that the relationships between safety, a word often used in an abstract way, and design, constructional and operational aspects are not always fully appreciated by those who are responsible. Furthermore, over-simplified [at the time A.167 and the still to come but under discussion A.562] regulations or codes of practice may inhibit sufficient original thought being directed to safety.

Ship stability [this issue is a recurrent one in ship stability debates] is, unfortunately, a property which is not amenable to simple definition. From the protracted debates at IMCO over the last 20 years it is evident that there has been developing world wide a desire to seek a better solution than is reflected in existing stability criteria."

As an answer to this, in UK the SAFESHIP Project was undertaken. SAFESHIP Project was a very valuable one, on the other hand, no substantial change in IMO rules was produces from its results.

On the other hand[25]:

"Ship designers and approving authorities need to have guidance on what are acceptable safe minimum values of stability properties for the many different types and sizes of ships".

4.4. Previous history

Depending on the philosophical doctrine, history can be seen as continuous progress, discontinuous progress or even complete chaos. In the first case we say that it is monotonic (in agreement with mathematical analysis), while it tends to be monotonous when same things happen repeatedly. This is to some extent the case of development of stability rules, as we shall see in this paragraph.

4.4.1. Time needed for previous changes

A great amount of work on ship stability was done in the frame of IMO and outside, as it is witnessed by the huge volumes containing the proceedings of the 8 International Conferences on Stability of Ships and Ocean Vehicles or "STAB", of the 6 International Workshops on Ship Stability and Operational Safety or "IWS", by the investments and results obtained from Research Programs (mainly at national level) in Japan, UK (SAFESHIP), Norway, etc.

Nevertheless, the progress in IMO regulations was slow with an average time interval of 20-30 years between scientific evidence and practical application:

- A.167 from Rahola PhD Thesis[17] (1939) to 1968;
- A.562 from Yamagata[23] paper (1959) to 1985
- MSC 707 from Takaishi[26] paper (1982) to 1995.

4.4.2. Two-ways approach

Both Kobylinski[27] and Bird[24], who played a relevant role in IMO/SLF working groups at the time (starting 1962), report that, following the SOLAS'60 recommendation, a working group was formed with a short and a long term goals. In order to make available usable criteria in the short term the Sub-Committee decided that "as a first step simple stability criteria applicable to ships under 100 m in length should be formulated". These were to be based on an analysis of casualty data. For longer term development of improved criteria the Sub-Committee agreed "to continue studies on ships' stability, paying particular attention to the effect of external forces and on variations of displacement on stability with a view to developing improved (rational) stability criteria". The short term ended in A.167, while the long term was passed to a new working group in 1975.

Again the short term approach was devoted to immediate problems like the offshore supply vessels for which making compliance with the A.167 was impracticable. Due to the difficulties of progressing the long term fundamental program [qualified as rational, risk-based, taken probabilities into account, containing a satisfactory physical modeling, etc] it was decided, as an interim solution, to develop a weather criterion. This took several sessions to complete. The view of IMO was that it should complement A.167 instead of replacing it.

It was also decided that the most dangerous situations, beam and following sea, were to be addressed separately, while the head sea condition was not interesting inasmuch as it was not present in the records of casualties.

In a series of papers[28-30] Kobylinsky debates his view of developing "rational" criteria, reporting also the difficulties to correctly understanding the exact meaning of this term in IMO discussions. Finally he gives-up[30] "From the above discussion the conclusion could be drawn that there is practically no chance to develop new rational (probabilistic?) criteria which would substantially improve safety against capsizing. To assure safety only by inbuilt features is unfeasible; no ship could be built which can not be capsized by negligence or bad operation (difference between *artificial intelligence* and *natural one* in[13]). It seems on the other hand that the existing criteria serve quite satisfactory the design purposes, although they do not assure absolute safety. Therefore in order to increase safety against capsizing the stress should be put elsewhere."

Attention should thus be moved to operational measures...

4.4.3. Time needed to next (substantial) change

The papers presented at SLF 45 by German delegation[31] call for a substantial change in IMO attitude towards Intact Ship Stability passing from prescriptive rules to *performance based* rules. As we have seen in this paper, something similar was in the long term program several times, but contingency and theoretical limitations always stopped its development.

Subdivision and stability rules are slowly migrating from a deterministic environment to a (mild) probabilistic one taking also into account the presence of waves.

A probabilistic approach for intact stability, based on time domain simulation, has been introduced in the long term part of a two ways program of revision of intact stability code. The initial prevision of time needed to complete the exercise is 5 to 10 years depending on the degree of complexity of phenomena required to simulate in efficient way. Again international cooperation is called to overcome the many difficulties and to produce a tool useful to evaluate the effect of ship design parameters (not limited to KG) on ship safety in a seaway. These should in principle take into account the phenomena in sea from any direction, including head seas.

4.5. Polishing versus deleting

Some documents presented at SLF45 required the modification/updating of Weather Criterion, while the discussion in plenary opened also the possibility of its deletion *tout court*.

The discussions in the working group and the final discussions in plenary rejected this possibility in the short term on the basis that this is a criterion containing at least a rough physical modeling and it can thus be improved by changing some formulas and tables, while leaving as it is the general philosophy.

Additional evidence is thus required as regards all details of its application:

- computation of roll-back angle;
- computation of wind effect;
- evaluation of gust effect;

especially for ships with parameters (B/T, Roll period, CB, ...) out of the ranges used at the time of initial formulation.

The choice made by SLF for the short term does not mean that in the long term present criteria could not be substituted by performance based criteria, but the evaluation of the equivalent level of safety rests on the presently unknown level of safety, and there are still many aspects that need to be clarified in developing a performance based criterion.

4.6. Why intact stability

Unlike other means of transportation, ships are complex objects operating at the surface of separation between water and air and frequently traveling in high waves and hostile environment. This unique peculiarity entails big problems as regards safety of navigation, and yet ships are usually a highly reliable mean of transportation and recreation. It is not easy, however to model the behavior in an environment characterized by waves and wind taking into account the relevant differences in ship typologies and scope. The conclusion of SAFESHIP Project was[25]:

"The SAFESHIP project has confirmed how complex a subject is stability when attempt is made to account adequately for wind, waves and dynamic motions".

Damage stability criteria only consider a limited environmental action and don't take into account properly the dynamics of motion that can lead to a ship loss through a chain of factors even in the intact ship condition. There is thus a continuous need to develop stability criteria, design recommendations and codes of practice to ensure safety taking into account extreme environment but also ship route and speed controllability, cargo securing, water on deck, effects of liquid or semi-liquid cargoes, etc.

In the safety of a complex system some level of redundancy is in any case acceptable to account for unforeseen effects.

The proposal of formulating rational ship stability criteria based on performance or of building a rational alternative to the weather criterion based on nonlinear systems theory and the requirement to include head sea among the dangerous situations are again on the table.

4.7. For new direction

4.7.1. Difficulties connected with new proposals

Some important problems are waiting a clarification.

Numerical time domain simulation tools indeed:

- are very attractive;
- allow to improve physical modeling both intensively and extensively;
- are versatile and, differently from existing prescriptive rules, allow effective design optimization preserving or improving the level of safety;

On the other hand there are also problems connected with:

- proprietary software;
- reliability;
- rough simplifications presently required (3D nonlinear hydro+aero-dynamics for extreme motions in extreme weather is not around the corner);
- difficulty/ambiguity in defining the "non-return threshold";
- the performance standard are so different from prescriptive standards?
- design optimisation/level of safety connected with mission profile, but what happens changing mission profile?

4.7.2. Chances of success

A look to previous history as reported in this paper could appear disheartening at first glance. Many things are changed, however, at scientific level. Present state of the art, benefiting from the previous intensive research, shows great improvements in the capability of simulating complex phenomena in time domain. The possibility to conduct a direct assessment based on analytical, numerical, experimental or combined approaches accepted during the discussion at SLF45, reaffirmed at SLF46, is also a key factor for future developments.

A look to[32,33] the proceedings of the 5th International Workshop on Ship Stability or of the 23rd ITTC Specialist Committee on Extreme Motions and Capsizing where a comparative exercise was undertaken to check the ability of time domain simulations to predict capsize is not encouraging, and the solution is not around the corner. The time domain simulation is indeed much more effective in the simpler case of damage stability, which to some extent ends as a quasi-static phenomenon, than in the intact stability case, where complex dynamics and multi degrees of freedom approach is heavily involved. There is of course a need of international cooperation and of standardization of computer codes and experimental procedures.

4.7.3. First steps in new direction

The High Speed Craft Code has undergone a deep review as a consequence of some major accidents at sea. In particular, the new IMO Code HSC 2000, states that:

“Other means of demonstrating compliance with the requirements of any part of this Chapter (Buoyancy, Stability and Subdivision) may be accepted, provided that the method chosen can be shown to provide an equivalent level of safety. Such methods may include:

.1 mathematical simulation of dynamic behaviour;
.2 scale model testing; and
.3 full-scale trials.

Model or full-scale tests and/or calculations (as appropriate) shall also include consideration of the following known stability hazards to which high-speed craft are known to be liable, according to craft type:

.1 directional instability, which is often coupled to roll and pitch instabilities;
.2 broaching and bow diving in following seas at speeds near to wave speed, applicable to most types;
.3 bow diving of planning monohulls and catamarans due to dynamic loss of longitudinal stability in relatively calm seas;
.4 reduction in transverse stability with increasing speed of monohulls;
.5 porpoising of planning monohulls, being coupled pitch and heave oscillations, which can become violent;
.6 chine tripping, being a phenomenon of planning monohulls occurring when the immersion of a chine generates a strong capsizing moment;
.7 plough-in of air-cushion vehicles, either longitudinal or transverse, as a result of bow or side skirt tuck-under or sudden collapse of skirt geometry, which, in extreme cases, can result in capsize;
.8 pitch instability of SWATH (small waterplane area twin hull) craft due to the hydrodynamic moment developed as a result of the water flow over the submerged lower hulls
.9 reduction in effective metacentric height (roll stiffness) of surface effect ship (SES) in high speed turns compared to that on a straight course, which can result in sudden increases in heel angle and/or coupled roll and pitch oscillations; and
.10 resonant rolling of SES in beam seas, which, in extreme cases, can result in capsize.

Suitable calculations shall be carried out and/or tests conducted to demonstrate that, when operating within approved operational limitations, the craft will, after a disturbance causing roll, pitch, heave or heel due to turning or any combination thereof, return to the original attitude.”

A similar route is under way for the general approach to Intact Ship Stability[34,35].

4.8. Identified gaps

It appears from previous analysis that the existing panorama of international ship stability regulations is absolutely dominated by prescriptive rules of deterministic type or of probabilistic type but not based on first principles/performance.

This has as a main drawback the impossibility or difficulty to perform safely an optimisation in the frame of a Rules-Based Design.

Only risk-based performance-based approaches can produce safety-oriented design and an uniformity in terms of demand-capability as regards stability (safety) issues. The real risk-based approaches, however, are missing (exception to a limited extent is HSC), while the performance-based approaches are just the new born of the family. Previous ITTC Specialist Committee identified big gaps in the numerical simulation tools which should constitute the main route to the development of performance-based stability assessment methodologies.

The assessment of ship stability versus “classical” prescriptive rules either deterministic or probabilistic in nature does not need the development of any significant new methodology.

Recent work at IMO opened the possibility of assessing some of existing rules through alternate “equivalence” routes, mostly based on experimental approaches. This concerned the rule as a whole, like it was approved in the case High Speed Code and of the Stockholm agreement or like it is under discussion for the Intact Stability of conventional ships, or parts of the rule, like it was recently proposed as interim solution for the Weather Criterion.

This requires the development of the following methodologies:

- a general one consisting in the evaluation of the level of safety implied in an assessment mode (for example prescriptive versus experimental equivalent). The statement “average equivalent level of safety” is indeed often put as basic requirement of new developments, but it is very seldom verified!
- A specific one concerned with the development of an experimental, reliable (in terms of guaranteeing compliance with previous point and at the same time a uniformity in the stability assessment).

More recently, the possibility of fully performance-based new regulations has been opened, with specific reference to Intact Stability. This requires the development of numerical procedures for stability assessment (simulation codes) and their testing (apart robustness, reliability, etc.) versus the presently existing ones.

5. The Effect of Ship Typology and of Regional Differences

5.1. Risk and F-N curves

We just remind that risk is a measure of the likelihood that an undesirable event will occur together with a measure of the resulting consequence within a specified time i.e. the combination of the frequency and the severity of the consequence.

FN-curves are a graphical presentation of information about the frequency of fatal accidents in a system and the distribution of the numbers of fatalities in such accidents. They plot the frequency F(N) of accidents with N or more fatalities, where N ranges upward from 1 to the maximum possible number of fatalities in the system. Values of F for high values of N are often of particular political interest, because these are the frequencies of high-fatality accidents. Because the values of both F and N sometimes range across several orders of magnitude, FN-graphs are usually drawn with logarithmic scales.

FN-curves themselves are simply a means of presenting descriptive information about fatal accident frequencies and fatality distributions. Once drawn FN curves, the criteria by which to decide whether the risks in the system represented by the FN-curve are tolerable or not are called ‘societal risk criteria’. The most obvious and tempting type of criterion is a line on the FN-graph. Usually criterion lines are chosen to have a slope of -1. Typically an upper line and a lower line define the As Low As Reasonably Practical (ALARP) zone, where risk control options are very effective. Above ALARP there is the zone where risk is intolerable, whereas in the lower part the risk is negligible. The boundaries of ALARP zone have been discussed in several papers (see for example[36,37]).

FSA can be used as a tool to help in the evaluation of new safety regulations or making comparison between existing and possibly improved regulations, with a view to achieving balance between the various technical and operational issues, including the human element and between safety and costs[38].

FSA procedure consists of five steps that we represent here in FSA language and in layman language and in comparison with typical re-active approach (**Table 1** from[37]):

5.2. Implied cost for averting a fatality (ICAF)

It looks unpleasant, but any discussion on the cost/benefit evaluation is centred on the quantified value of human life. Different approaches has been developed to this problem, but, having in mind the regional differences, i.e. mainly the differences in the average gross income per person of a country, the approach based on ICAF looks more appropriate. Implementation of risk assessment techniques in decision-making processes requires that risk-based decision criteria be developed. Decisions in the so-called ALARP region are considered here. The Life Quality Index Criterion[36] is a decision criterion, which is based on information aggregated in societal indicators, and which lends itself easily for development into a decision criterion in terms of ICAF.

This paper presents the Life Quality Index together with its associated decision criterion. It is demonstrated how this criterion can be further developed to form a decision criterion based on ICAF. This criterion is expressed in terms of an upward limiting value for ICAF for deciding in favour of implementation of a safety measure. The upward limiting value for ICAF may be interpreted as the optimum amount of money to be spent to avoid a fatality.

Table 1. Scheme of formal safety assessment procedure.

Step	layman	FSA	Current reactive approach
1	What *might go* wrong?	Hazard identification	What *did* go wrong
2	How often, how likely? How bad	Risk analysisFrequencies, probabilitiesConsequences	
3	How can matters be improved?	Risk control options (*Reducing frequency - Mitigating consequences*)	How can matters be improved?
4	How much? How much better?	Cost/benefit evaluation	
5	What actions are worthwhile to take?	Recommendation	What actions are worthwhile to take?

Several compound societal indicators as a function of aggregated social indicators have been developed by United Nations Development Programme along the years:

- Human Development Index as a function of Life Expectancy, the Adult Literary and other Indexes[39]
- The Life Quality Index L is a compound societal indicator, which is defined as a monotonously increasing function of two aggregated societal indicators, namely the gross domestic product per person per year, g, and the life expectancy at birth, e[40].

This latter appears

$$L=g^{w} \cdot e^{1-w}$$

The exponent w is the proportion of life spent in economic activity.

The Life Quality Index Criterion for acceptable risk implies that an option is preferred or accepted as long as the change in L owing to the implementation of the option is positive. As an example, consider the safety of an existing ship and the marginal cost of improving this safety by implementation of a particular measure. The improved safety by implementation of this measure is expressed through a positive change, Δe, in the life expectancy, e. The cost of implementing the measure is expressed through a change, Δg, in the gross domestic product, g. The Life Quality Index Criterion implies that the measure is implemented when

$$\frac{\Delta e}{e} > -\frac{\Delta g}{g} \cdot \frac{w}{1-w}$$

which comes about by differentiation of the expression that defines the Life Quality Index L and requiring $\Delta L>0$. It appears that by use of this criterion for decision-making about a particular option, one may reach a different conclusion about implementation in a highly developed country than in a poorly developed country. It also appears that the Life Quality Index Criterion implies that one is willing to take on an increased risk, expressed in terms of a negative Δe, if the associated gain or compensation Δg is large enough. Optimality is achieved when the inequality of the Life Quality Index Criterion is turned into an equality, as then the implementation of the considered option implies that status quo is just maintained for the Life Quality Index. The optimality is illustrated by the fact that if a less cost-effective safety measure is implemented than the optimum, then the implementation would lead to reduction of the Life Quality Index.

The Life Quality Index Criterion is very suitable for assessment safety related risks when risks are neither judged to be intolerable nor negligible, but are to be reduced to an ALARP level.

Rough calculations for a developed country give a figure of 2 million USD, whereas in a developing country the same calculations give a figure in the range 40,000 USD to 300,000 USD.

5.3. Regional differences

As explained in the preamble, ships are quite reliable means of transportation. The world annual rate of ship losses can be estimated in about 0.3% , slowly decreasing in number, but not in tonnage[41]. The average number of fatalities can be estimated in 1,000 per year, excluding small ships and fishing vessels. The ICAF for a developed country is very high, nevertheless pressure of public opinion forces governments to strong and immediate actions, sometimes excessive actions under the wave of emotion after an accident with a large number of casualties. On the contrary, in poor or developing countries the

ICAF is much lower, but the concern for human life is also poor and same amount of money can probably be better employed to save a greater number of lives by actions more relevant to health than to safety. With a few exceptions it deals with accidents with a small number of casualties which don't generate a strong public concern and pressure, similarly to the fatalities in car and domestic fatalities which can be estimated in 7000/year *each* in a country like Italy.

5.3.1. Philippines

Philippines, the country of seven thousand islands, was for long time famous for its negative record of safety at sea, especially after the sinking of the ferry Dona Paz in 1987[42], followed by a number of other casualties. Situation was recently improved but the annual rate of incidents remains quite high (3-4%) together with the number of fatalities which exceeds 100 but reaches 300-400 including the missing persons. The fact that the 90% of the fleet is below 500 GRT and that many vessels are still made of wood partly explains the high risk and the small societal concern which translates in slow reactions from the relevant bodies. The situation has been efficiently described by Spouge[42] and in a number of web pages.

5.3.2. Bangladesh

This is a country on the delta of a river, so that transportation by small boats is very popular. The age and low maintenance of the "fleet", conjugated with the bad weather especially in the season of monsoons and again the low concern for the value of human life, make dramatic ship casualties almost a weekly event. Typical press statements are like "Ferry accidents are common in Bangladesh, where some 3,000 passenger boats are a key means of transport over the country's hundreds of rivers. Most wrecks are blamed on overloading or unskilled skippers". Here again the average annual rate of fatalities exceeds 100.

5.4. Ship typologies

5.4.1. Fishing Vessels

A comparison between fatality statistics in the fishing industry and general occupational fatality rates of other occupational categories shows that fishing is one of the most dangerous professions. The ILO's Occupational Safety and Health Branch[43] estimates that fishing has a worldwide fatality rate of 80 per 100,000 workers or approximately 24,000 deaths per year, and estimates that there are 24 million non-fatal accidents in the sector annually. During the same period the average total occupational fatality rate was only 14.5 per 100,000 workers.

The Torremolinos International Convention for the Safety of Fishing Vessels (Torremolinos Convention), agreed in 1977, establishes a safety regime for fishing vessels of a length of 24 metres or more. The Convention contained detailed regulations concerning the standards of construction to be applied essentially to new vessels, including the type and nature of equipment of all types which has a bearing on vessel safety. In the ensuing years, the Convention did not receive sufficient ratifications to enter into force, as many States claimed it *to be too stringent*.

The lack of ratifications, as well as the need for some technical changes, led to a Conference, held again in Torremolinos in 1993, which adopted a Protocol to the 1977 Convention. The Protocol includes provisions concerning construction, watertight integrity and equipment; stability and associated seaworthiness; machinery and electrical installations and periodically unattended machinery spaces; fire protection, fire detection, fire extinction and fire-fighting; protection of the crew; life-saving appliances and arrangements; emergency procedures, musters and drills; radio communications; and shipborne navigational equipment and arrangements. The requirements for protection of the crew concern certain aspects of vessel construction which influence safety: lifelines, deck openings, bulwarks, rails, guards, stairways and ladders.

The Protocol restricts the obligatory provisions of the Convention to vessels of 45 metres and above. For vessels with a length between 24 and 45 metres, the application of the safety requirements *is left to regional decisions*. It will enter into force one year after 15 States with at least an aggregate fleet of 14,000 vessels (roughly 50 per cent of the world fishing fleet of vessels 24 metres in length and over) have ratified it. As of 2 February 1999, it had been ratified by only five countries.

Regional decisions have indeed been taken:

- In 1997, the Conference on the Safety of Fishing Vessels Operating in the East and South-East Asia Region, organized by Japan, was held in Tokyo in order to adopt uniform regional standards for the safety of fishing vessels as called for in the Torremolinos Protocol of 1993. The Conference adopted the Guidelines for the Safety of Fishing Vessels of 24 metres and over but less than 45 metres in length Operating in the East and South-East Asia Region. These vessels are to comply with certain chapters of the Annex to the Torremolinos Protocol and with the Guidelines. The areas covered are: general provisions; machinery and electrical installations and periodically unattended machinery spaces; fire protection, fire detection, fire extinction and fire-fighting; life-saving appliances and arrangements; and radio-communications. *Stability is not included*.
- European Community adopted Council Directive 97/70/EC of 11 December 1997 setting up a harmonised safety regime for fishing vessels of 24 metres in length and over following the adoption of the Protocol to the Torremolinos Convention modified by European Commission Directive 2002/35/EC of 25 April 2002 which extended to vessels in the range 24-45 m previous application mostly related to vessels 45 m in length or more.

Unfortunately, the majority of human lives lost concerns vessels below 24 m. Active research is in progress, but the results cannot crystallize in international regulations, especially for the length range up to 12 m, which often defy *any* regulation...

5.4.2. Ferries

Together with airplanes, this is the most publicized sector of ship safety, although the percentage of accidents is extremely low (a bit more than 1% of total accidents).

We will not spend much words to remind that SOLAS was originated by the loss of Titanic and then big changes were produced by the European Gateway (1982 with 6 victims), the Herald of Free Enterprise (1987 with 180 victims), and the Estonia (1994 with approximately 900 victims). As a consequence of these last three accidents entire chapters of SOLAS have been rewritten. The Stockholm agreement imposing the verification of SOLAS'90 stability standard with water on deck is a consequence of the Estonia accident.

The loss of Toya Maru in Japan in 1954 with more than 1,000 victims originated the formulation of Weather Criterion as a Japanese standard[23] which put Japan 30 years ahead international standards of safety.

On the contrary, the losses of Don Juan (1980) and Doña Paz (1987) in the Philippines and of a ferry in Haiti (1993), all exceeding 1,000 victims, had no impact in safety regulations.

5.4.3. Bulk carriers

In the period 1990-94 more than 25 bulk carriers were lost with approximately 532 fatalities. This prompted a number of changes in IMO Rules in 1995. In 1999 a new Chapter XII “Additional Safety Measures for Bulk Carriers” was added to SOLAS[44]. The revision of Load Lines rules was also in line with the findings connected with these casualties.

On January 16, 1998, the bulk carrier *Flare* broke in half and sank off Nova Scotia in heavy weather with the loss of 21 people, but it was the *second* investigation on an previous casualty (the first ended without relevant conclusions), the loss of the Derbyshire which prompted huge changes.

The MV DERBYSHIRE, British flagged, owned and crewed, disappeared virtually without trace when the vessel became involved with Typhoon Orchid, south of Japan on about 9 September 1980. All on board, 42 crew and two wives, were lost. The DERBYSHIRE was a modern (built 1976), fully equipped and well-managed ore-bulk-oil (OBO) combination carrier. At over 90,000 gross tons she was, and remains, the largest UK ship to have ever been lost at sea.

The study led, among others, to reconsider or consider the need of forecastle, ballast system capacity, protection of foredeck fittings, reinforcement of hatch covers, water ingress alarm, immersion suits, free-fall lifeboats, application of bulkhead structural standards, etc.

It is worth noting that a great number of fatalities was needed before feeling making mandatory the installation of simple and cheap safety devices like the water ingress alarm...

“1 Bulk carriers shall be fitted with water level detectors:

.1 in each cargo hold, giving audible and visual alarms, one when the water level above the inner bottom in any hold reaches a height of 0.5 m and another at a height not less than 15% of the depth of the cargo hold but not more than 2 m;

.2 in any ballast tank forward of the collision bulkhead, giving an audible and visual alarm when the liquid in the tank reaches a level not exceeding 10% of the tank capacity. An alarm overriding device may be installed to be activated when the tank is in use; and

.3 in any dry or void space other than a chain cable locker, any part of which extends forward of the foremost cargo hold, giving an audible and visual alarm at a water level of 0.1 m above the deck. Such alarms need not be provided in enclosed spaces the volume of which does not exceed 0.1% of the ship.s maximum displacement volume.

2 The audible and visual alarms specified in paragraph 1 shall be located on the navigation bridge.

3 Bulk carriers constructed before 1 July 2004 shall comply not later than the date of the annual, intermediate or renewal survey of the ship to be carried out after 1 July 2004, whichever comes first.”

Double hull is presently under discussion, following its introduction in tankers.

6. Final Remarks

More than presenting some conclusions, we would like inviting the reader to reflect on some issue, pert of which was highlighted in this paper:

- The effect of social impact of incidents, based on the number of fatalities (or in general on the consequences) *in a single shot* more than on the cumulative effects. This effect, something similar to the law of perception of human senses (Fechner-Weber law) which is logarithmic in nature, is the base for the present definition of risk and its representation in F-N diagrams. As a result, political choices are more prone to react and reward spectacular accidents more than rationally protecting human life in general. This is evident from the above comparison of state of the art for ferries and for fishing vessels, but the situation as far as marine environment pollution is also striking. Strict rules were drawn as a consequence of regional response (USA unilaterally approving Oil Pollution Act) in response to a big oil spill consequent to the accident to the tanker Exxon Valdez in 1989.

The following accidents to tankers had similar consequences. If we analyse the sources of marine pollution, however, we discover that only a minor fraction of marine pollution comes from marine transportation and that *only a minor fraction of the oil pollution is due to the spectacular accidents*, the majority coming from *deliberate routine operations* (like tanks washing...). This last fraction is on the other hand comparable to the marine pollution coming from land sources like discarded lubricants...

- Ships, unlike other modern transportation means, came early in human history. As a consequence, they construction spread all over the world in a pre-competitive era. Presently, although competition had devastating effects, a very large number of shipyards still survive, especially in the small to medium size range, building ships and boats at very different technical level. Airplanes and cars were produced at a very different stage of human development and competition was very effective in shrinking the network of producers, which nowadays can be counted on the fingers of one hand. As a result, any innovation spreads immediately to all the interested parties. Moreover it is not possible to go on the road or in air with a car or plane self-made or of primitive construction... Airplanes safety on the other hand benefits also from the above mentioned *spectacularity of accident factor*, whereas cars share the low social impact of accidents with small boats and fishing vessels.
- Re-active and prescriptive is still the case of the majority of methodologies for assessment of ship safety and marine environment protection, although something new is becoming to be put on the agenda. On the contrary, research is very active on pro-active approaches, like the performance based procedures, and on *second lines of defence,* like time-to-sink and mustering and evacuation for large passenger ships.
- Long ago American Society of Naval Architects and Marine Engineers promoted the publication of a Code of Ethics, probably followed by other relevant Institutions. IACS also has a quite strict Code of Ethics. Situation is quite different for Flags of Convenience, Shipowners, Shipping Companies...
- Long ago many accidents at sea were classified *acts of God* (quoted in a standard dictionary as: "an extraordinary interruption by natural cause (as severe flood or earthquake) of the usual course of events that experience, prescience or care cannot reasonably foresee or prevent - compare INEVITABLE ACCIDENT"). It is interesting to note the accurate balancing of the terms in the definition: *extraordinary* but *reasonably*; see above definition of the ALARP region, where risk reduction is *possible and convenient*. It is evident the impact of advancements of science and technology, however nowadays most accidents are classified as *human error*...

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