Safety considerations of Nile cruisers

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This paper reviews the types and causes of accidents that Nile cruisers may experience during their operational lifetime. It also presents the role of the human error and some design factors in impairing safety assurance of these vessels. Special attention is paid to the role of environmental conditions and the special characteristics of the navigational channel of the river Nile. Stability criteria for Nile cruisers for the intact and damaged conditions are studied and quantified deterministically and probabilistically. The importance of establishing national stability regulations for Nile cruisers is stressed.

Keywords: Nile cruisers; ship safety; stability criteria; human factor; risk

Introduction

Safety assurance of Nile cruisers depends not only on the rules and regulations to be applied at all stages of the design but also on the relevant stability criteria required to be fulfilled in all expected operating conditions of the vessel. It also depends on the quality and suitability of materials used and the implementation of good construction and building practices adopted in the building yards and workshops. Safety assurance also depends on the procedures and quality used for maintenance and repair of these vessels as well as the safety management system and the, competency of the master and the crew.

Safety assurance of Nile cruisers should also be based on a degree of risk accepted by the society and public opinion and all the bodies and authorities associated with the insurance and safe operation of these vessels. In order to ensure that no accident similar to the sinking in the river Nile of the two vessels *Nobya* in 1988 and *AlAmira Jeyhan* in 1996 requires conducting a thorough investigation of the causes of accidents that occurred in the last 20 years. It is essential at this stage to focus on the role played by the human factor in the occurrence of these or similar accidents so as to avoid serious repercussions and the negative impact on tourism and the national economy of Egypt.

It should be realised that the investment cost required to achieve an acceptable and realistic degree of safety of Nile cruisers might seem at first glance to be high and operationally non-economic, but we must take into account the cost and repercussions of failure to achieve a degree of safety sufficient to prevent serious accidents from occurring in the future.

Types and causes of accidents experienced by Nile Cruisers

Nile cruisers may be exposed to any one of the following types of accidents: grounding, fire, collision, listing, sinking, loss of stability followed by sinking, structural failure followed by sinking or loss of stability and explosion. Figures 1–3 show some of the typical catastrophic accidents. The main causes that lead to such accidents can be divided into human errors (operational causes), technical causes (design, construction and equipment), environmental causes and organisational causes (see Figure 4). The main environmental causes are darkness, mist, fog, rain, wind, gusts, sudden changes of weather, shallow water and narrow navigation channel.

Nile cruisers have a limited capability for manoeuvring and course keeping. Therefore, in order to prevent accidents induced by the chaos caused by manoeuvring the cruisers during their accumulation next to each other at the time of berthing at and departure from the various tourist sites, particularly in Kumombo, Edfu and Esna (see Figures 5 and 6), it is necessary to have a number of ports and berths commensurate with the current and expected number of future vessels. It is also necessary to dredge the navigation channel of the Nile in the distance between Luxor and Esna.

Analysis of the causes of accidents that have involved Nile cruisers has indicated that several design factors have a direct bearing on the safety of this non-conventional type of ship. Some of these factors can be controlled by the designer, and others require careful study.

Most accidents experienced by Nile cruisers have led to either sinking of the ship or loss of stability of the ship and

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Figure 1.   Fire accident.

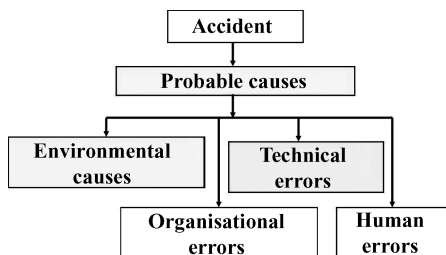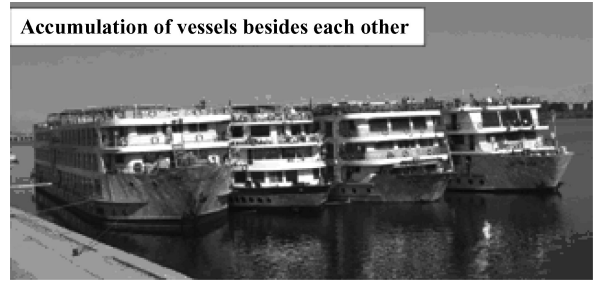Figure 2.   Capsizing accident.

Figure 3.   Ship losing stability.

Figure 4.   Main causes of accidents.

Figure 5.   Accumulation of vessels.

then capsizing accompanied by loss of human life, injuries to passengers and crew and disruptions of the navigation channel of the Nile. Other accidents have led to the withdrawal of the ship from commercial operation to carry out the necessary repairs of the damaged parts resulting from the accident. However, the occurrence of any accident involving a Nile tourist vessel has a direct detrimental effect on the economics of Nile tourism due to the inability to execute the advertised tourist programmes of these vessels. This causes frustrations amongst tourists coming from all over the world to discover the ancient civilisation of Egypt in the various towns and locations along the Nile.

To avoid the occurrence of further accidents of Nile cruisers, study and analysis of some of the accidents occurred in the past is required so as to find out the correct answers to the following set of questions for each accident: What exactly happened? When did it happen? Where did it happen? How did it happen? Why did it happen? What are the conditions and circumstances that led to the accident? What is the role of the human factor in the accident? What is the role of the company management and safety management system in the accident? What are the roles of administration departments related to tourism activities and the Nile in the accident? What is the role of environmental conditions in the accident? What is the role of the technical aspects of the ship in the accident?

The answers to all of these questions should be collected from all possible sources connected with the vessel in question and should also be based on facts, documents, reports and the like.

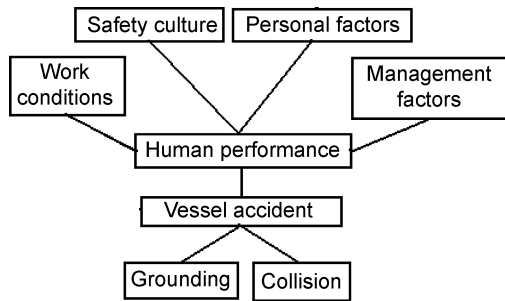Figure 6.   Chaos at the arrival/departure of vessels.

Figure 7.   Factors affecting human performance.

The human factor

The human factor represents the major element responsible for causing most ship accidents in the Nile and also seas and oceans. (Most of the literature reports about 80%–85% of the causes of accidents result from human errors.) Figure 7 shows the main factors affecting human performance that may lead to accidents. Figure 8 shows the consequences of human error in manoeuvring particularly in restricted navigational channels. Human errors result mainly from disregard for safety and quality, carelessness, underestimation of difficult situations, laziness, exhaustion, illness, passivity, stress, tiredness, miscalculation of the consequences, negligence, inaction, psychological problems, lack of understanding of instructions, taking wrong decisions and health problems.

Absence of a work culture that values safety and lack of skill and competency amongst the personnel involved in any of the activities of Nile cruisers result mainly from inadequate qualification, education and training.

The safety management system of Nile cruisers and the companies that own them should cover the main factors required to ensure the safety of passengers and crew, the vessel and the navigational channel of the river Nile. This could be achieved by conducting a high-quality training system

(1) for the crew to cover all aspects of safety measures and enhance their ability to act skilfully and efficiently in case of emergency;
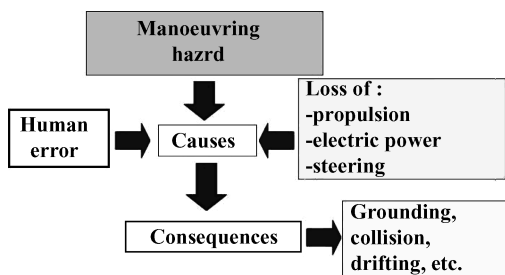

Figure 8.   Human error in manoeuvring.

(2) for the administrative personnel responsible for safety assurance to ensure professional quality of the ship and its equipment and outfitting as well as the maintenance work; and

(3) to ensure the validity of all certificates issued for the vessel from all relevant authorities and quality of all safety, communication, warning and rescue equipments onboard.

Therefore, safety assurance of Nile cruisers could be significantly improved by inculcating a safety culture and ensuring the qualification, education, training, skill, efficiency and capability of the personnel involved in all phases of design, construction, operation and insurance of the ship and the control of all the factors impairing its safety.

The lack of fulfilment of the acceptable degree of safety for Nile cruisers may lead to disasters with serious implications for the reputation of Nile tourism and the national economy of Egypt, especially if the accident causes human fatalities and obstruction of the navigational channel of the river Nile.

Design and construction of Nile cruisers

The key design key factors that affect the safety of Nile cruisers are:

- main parameters of hull design and construction;
- modifications and alterations of ship construction to facilitate the installation of equipment, outfitting and decorative appearances needed to improve tourism operational requirements in the severe competitive market of tourism in Egypt;
- the nature, characteristics, water current speed and variation of water depth of the navigational channel of the river Nile; and
- legislations, laws and regulations issued by the administration of the river Nile to rationalise the demands for land irrigation and other uses of the Nile water.

In order to guarantee an acceptable degree of safety without impairing the economic operation of Nile cruisers, the design should ensure an acceptable balance between the conflicting requirements of the owner, the building yard, the quality of construction and outfitting, the laws and regulations issued by the ministry of maritime transport, the international classification societies certifying the vessel and the determinants of the navigation channel of the river Nile.

Figures 9 and 10 show two Nile cruisers under construction in two different workshops on the river Nile. Figure 11 shows a typical Nile cruiser operating in the river Nile. It is evident from Figure 11 that the traditionally equipped building facilities of the workshops have produced luxury Nile cruisers.

Figure 9.   Vessel under construction.

Figure 10.   Vessel under construction.

To achieve the required balance between the design requirements of all bodies involved with owning, operation and certification of these vessels, the following key design elements must be satisfied:

(1) Freeboard and reserve buoyancy of the vessel must be sufficient so as not to allow the ship to sink immediately upon the occurrence of any accident. This means that the design of the vessel must be based on the fail-safe concept of design.
(2) The design must be able to absorb acceptable operational mistakes without leading to sinking or capsizing.
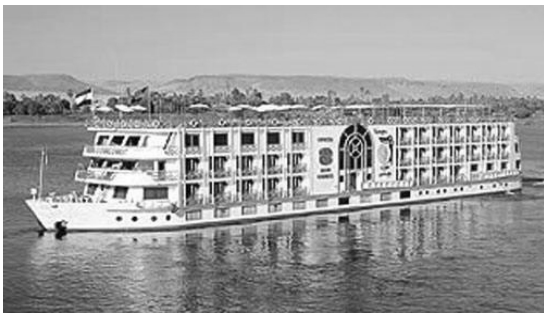

Figure 11.   A typical Nile tourist vessel.

(3) Design must rely on accurate information on draught and trim and the change in draught in various operating conditions.
(4) Such vessels must be designed on the grounds that they are not immobile floating hotels but passenger vessels operating in the navigational channel of the river Nile which has its own characteristics and problems.
(5) It is obvious that the structural design of these ships must provide an acceptable degree of structural safety that could allow a limited amount of structure failure in any part of the hull without causing serious and hazardous consequences. The construction of the vessel should also be capable of allowing minor adjustments to the construction system to accommodate mechanical, electrical, accommodation-related and decorative outfitting required to meet the demands of tourism and safe operation of the vessel without impairing the structural integrity of the hull.
(6) Safety assurance could be significantly improved by prohibiting the use of uncertified or inflammable materials in the construction and outfitting of Nile cruisers.

Structural design and safety

There is no known record of the occurrence of a major structural failure or a hull girder collapse of any Nile cruiser, as these vessels are normally over-designed and operate in the waveless calm water of the river Nile at speeds not exceeding 11 knots.

The hull girder and local loadings are basically static, and the absence of wave forces and dynamic loadings makes it possible to treat the loadings deterministically. The internal loadings are basically due to the weights of passengers and their luggage. Neither heavy nor dangerous cargo is carried by these vessels.

The engine room structure is normally over-designed so as to reduce the probability of the occurrence of unacceptable vibration, noise and fatigue fractures.

The structural design of these vessels is very conventional, and the scantlings of the structural members are determined using the published rules of classification societies and are based on the static local loadings only. The design and the construction of the hull are required to be approved by an international classification society. The hull girder shear forces, bending moments and torsion loadings do not represent major design parameters. No global idealisation or structural analysis of the hull girder is required to be carried out.

The structural deterioration of the steel hull is very limited, as the operational environment is neither corrosive nor hostile. These vessels are normally docked every 5 years to check on the presence of any structural problems, failures or serious deterioration.
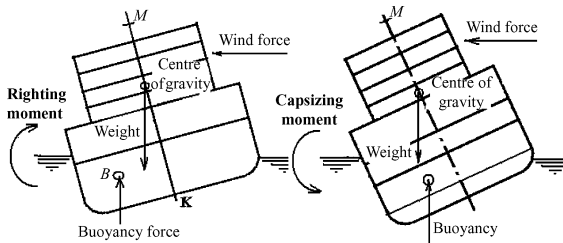
Figure 12.   Basic elements of ship stability

Assurance of adequate stability

Ship stability is considered one of the major seagoing properties of a ship. Ship stability normally refers to the ability of a floating vessel to resist the overturning forces encountered in the course of its operation. These forces may arise from weather (wind and waves), towlines, abrupt changes of course, shifting of cargo or passengers and flooding due to damage.

Stability calculations quantify these forces and apply them to a mathematical model of the ship, so that the response of the vessel can be examined for various magnitudes of overturning moments (see Figure 12).

When approached as a hydrostatic problem, static or quasi-static stability is considered to be sufficient to prevent capsizing in the presence of the actual dynamic environment.

At small angles of inclination, the stability of displacement vessels is measured by GM, the metacentric height (see Figure 13). The magnitude of GM depends on the geometry and form of vessel and weight distribution. The presence of free surface in slack tanks has impairing effects on GM.

At large angles of inclination, the static stability curve is normally used for assessing ship stability and measured by the righting lever GZ (see Figure 13). It can be easily seen that the magnitude of GM has a significant effect on the shape of the static stability curve as well as on the magnitude of the angle of vanishing stability.

However, while positive GM is the necessary condition for stability at small angles of heel, it is not necessarily a sufficient measure of stability for larger angles of heel.
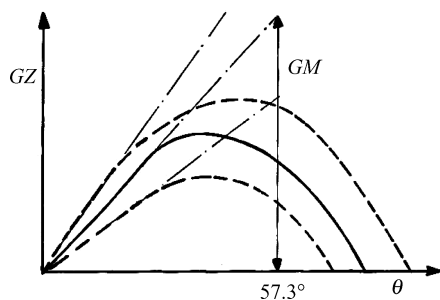

Figure 13.   Effect of GM on $GZ - \theta$ curve.
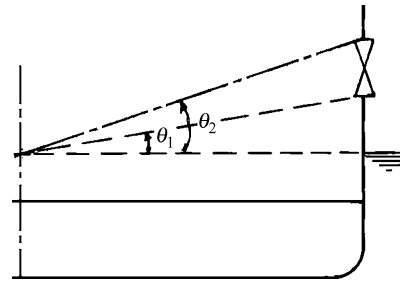

Figure 14.   Downflooding angle.

Under dynamic conditions, ship stability is measured by the area under the static stability curve.

It is axiomatic that any ship must be stable under all normal operating conditions by satisfying all static and dynamic stability requirements of the vessel.

Ship stability criteria required to ensure adequate safety against capsizing could be based on either a deterministic or a probabilistic approach

Deterministic approach

In the deterministic approach, ship stability criteria should be based on the ship type, vessel design parameters and environmental conditions of the zone of operation. The basic ship stability criteria commonly used in the deterministic approach are:

- GM;
- main characteristics of the static stability curve;
- dynamical stability;
- downflooding angle (see Figures 14 and 15);
- weather criteria;
- angle of heel due to crowding of passengers on one side of the vessel; and
- angle of heel due to turning of vessel.

Probabilistic approach

It is axiomatic that no ship anywhere in the world has a 100% guarantee against sinking or capsizing. However, the safety assurance system must ensure a reasonable degree of risk against sinking and/or capsizing, acceptable to the administrative state agencies as well as the owners, banks financing the large investments required to build
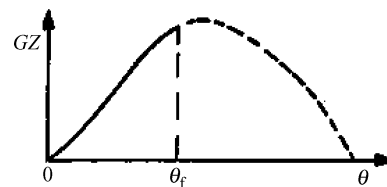

Figure 15.   Effect of downflooding angle.

these luxurious Nile cruisers, insurance companies, public opinion and society.

The designer must consider that all design parameters are not predetermined fixed values but are subject to errors and elements of uncertainty. This requires conducting a sensitivity analysis on all parameters affecting the safety of the vessel so as to be able to evaluate the degree of the risk of losing ship stability under all operating conditions.

Risk assessment is mainly based on the following:

- Development of accidental scenarios, which could potentially lead to hazardous situations.
- Taking into account the likelihood of accidental scenarios.
- Estimation of consequences such as human fatalities, human injuries, environmental contamination and economic loss.

The procedure commonly used to reduce and control risk is based on:

(1) elimination of the causes of the hazard;
(2) elimination/reduction of the consequences of the hazard; and
(3) reduction of hazard frequency and probabilities to acceptable levels.

The probabilistic approach of ship stability is directed to establish a set of stability criteria in the intact and damaged conditions.

Probabilistic criteria in the intact condition

In the intact condition, ship stability criteria are based on the evaluation of the risk of capsizing due to either loss of initial stability or loss of the reserve of dynamic stability as follows:

Risk of capsizing due to loss of GM
$= P\,(GM \leq 0).$

A simple probabilistic model for evaluating the risk of capsizing due to the loss of GM is shown in Figure 16. The probability of losing the initial metacentric height GM_o is given by

$$P(GM_o{\leq}0) = \int_{-\infty}^{0} p(GM_o).dGM_o,$$

where $p\,(GM_o)$ is the probability density function (p.d.f.) of GM_o.

Capsizing could also occur when the ship loses her reserve of the intact dynamic stability, D_R.

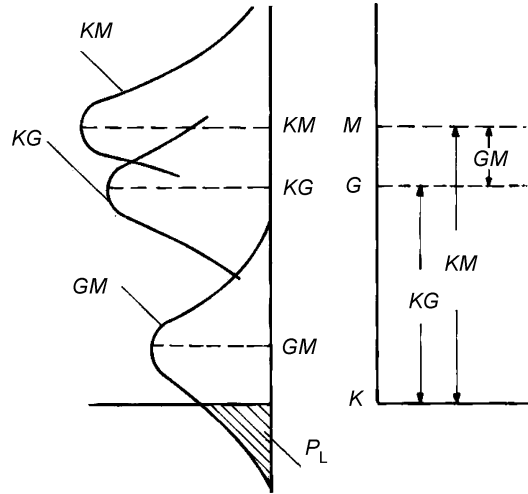The reserve of dynamical stability is given by

$$D_R = D_S - D_H > 0,$$

Figure 16. Variation in *GM* due to the variation in *KM* and *KG*.

where D_S is the dynamic stability (see Figure 17) and D_H is the dynamic heeling moment.

The risk of capsizing due to loss of reserve of dynamic stability is given by

$$P_c = P(D_R{\leq}0) = \int_{-\infty}^{0} p(D_R) \cdot dD_R,$$

where $p(D_R)$ is the p.d.f. of D_R.

Stability criteria in the damaged condition

If a vessel is damaged so that part of its internal volume is flooded, it will either sink or develop a list until it reaches an equilibrium condition in which the reserve of buoyancy has been brought into effect to offset the lost buoyancy (see Figure 18). The weight and restored buoyancy forces are then once again equal.

In the damaged condition, the risk of capsizing is given by

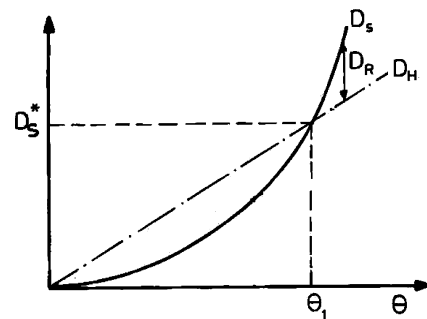$$P(G_{MR} \leq 0) \leq \text{ and}$$
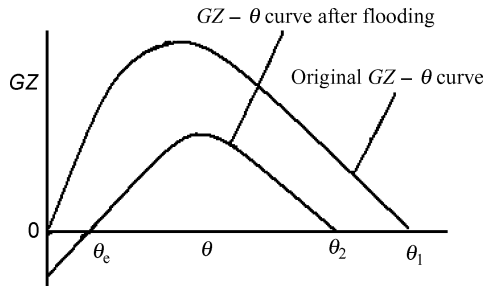

Figure 17. Dynamic stability.

Figure 18. Effect of flooding on $GZ - \theta$ curve.

$$P(D_R \leq 0).$$

The risk of sinking is given by

$$P(Residual\ buoyancy \leq 0),$$

where GM_R is the residual GM and D_R is the residual dynamic stability.

With the damaged vessel upright, GM is likely to decrease because the water admitted by flooding reduces the second moment of area of the water plane.

Capsizing is likely to occur if the loss of water plane area due to flooding is sufficiently large so that GM becomes negative with the vessel upright, and the movement of the centre of buoyancy with increasing heel is inadequate to restore positive GZ. The various scenarios of the consequences of vessel damage and flooding are shown in Figure 19.

Safety assurance after damage

The likelihood of unacceptable damage occurring can be determined from ship structural configuration and the p.d.f of:

- occurrence of accident;
- position of damage;
- length of damage;
- penetration of damage;
- permeability of damaged zone; and
- crew competence.

The procedure for safety assurance after damage could be realised by applying the following condition:

$$A > R$$

i.e. A ≥ R, where A is the attained subdivision index and R is the required subdivision index.

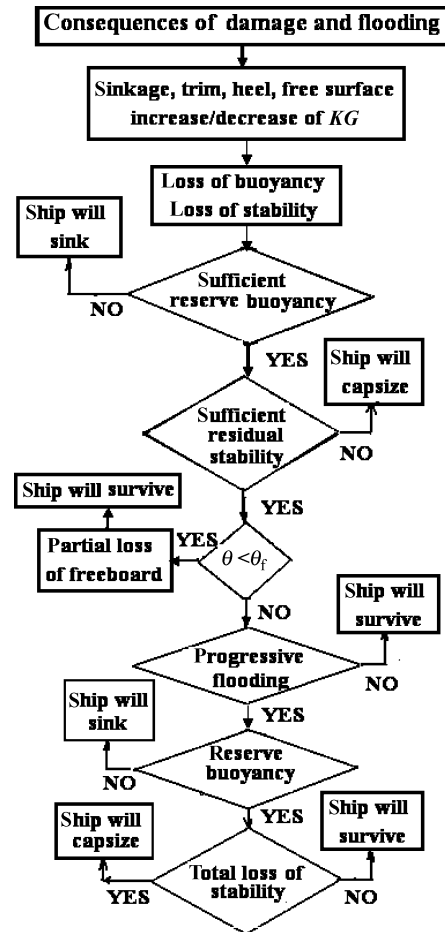Figure 19. Consequences of damage/flooding.

Attained index A

The attained index is obtained by the summation of the partial indices A_s, A_p and A_1 and is defined as follows:

$$A = 0.4A_s + 0.4A_p + 0.2A_1$$

A_s, A_p and A_1 are the indices calculated for the deepest subdivision draught (d_s), partial subdivision draught (d_p) and light service draught (d_1). These three conditions are defined by the draught, metacentric height and trim. Basically, the calculation of the attained index, for specific damages, is continued until the attained index reaches the required index. Each partial index is a summation from all considered damage cases, using the following formula:

$$A = \sum (p_i \cdot s_i),$$

where i is the compartment or group of compartments under consideration; p_i is the probability that only the compartment or group of compartments under consideration may be flooded; and s_i is the probability of survival after flooding

Figure 20. Ship and passengers safety.

the compartment or group of compartments under consideration.

Required index

The required index, R, is a ship specific constant depending only on the subdivision length, L_s. The computation of the subdivision index involves calculations and analysis of "residual stability" in a large number of unique damage scenarios:

$$R = (C_1 + C_2 L_S)^{1/3},$$

where $C_1 = 0.002$, $C_2 = 0.0009$ and L_s is the subdivision length.

Safety considerations of Nile cruisers

Safety of Nile cruisers depends on several factors covering design, construction, crew competency, operation, management and the like (see Figure 20).

In order to improve the safety of Nile cruisers, it is essential to establish new regulations and rules that will overcome the shortcomings of the presently adopted safety system.
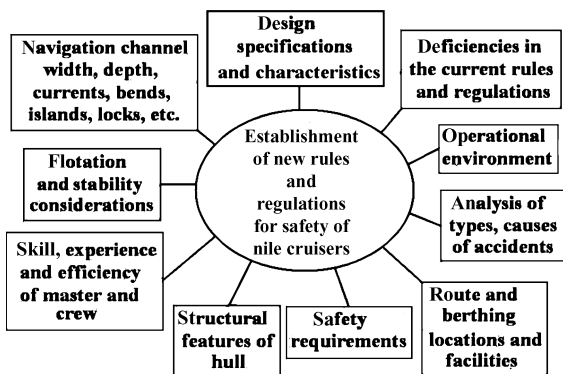

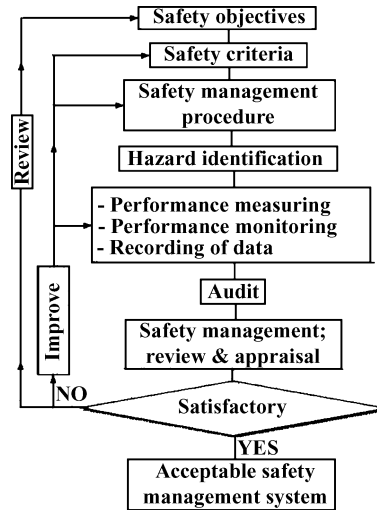Figure 21. Main elements of safety regulations.

Figure 22. Appraisal of safety management.

Figure 21 shows the main elements required to be considered when establishing new rules and regulations to ensure adequate safety. Ship stability is considered one of the main elements of the ship safety system required to be enhanced.

It is essential that the ship-owning company should establish a safety management system for the safe operation of each ship of the fleet of Nile cruisers. Figure 22 shows the main elements of appraisal of a safety management system that should be ensured:

- Adequate safety.
- Reduced hazards.
- Acceptable risk values.

Stability criteria of Nile cruisers

Adequate stability of Nile cruisers depends not only on design considerations but also on ship operation and the operational environment (see Figure 23).

The operational zone of Nile cruisers, apart from having seasonal variations, is subjected to high winds, gust winds and also sudden, severe change of weather. The prevailing
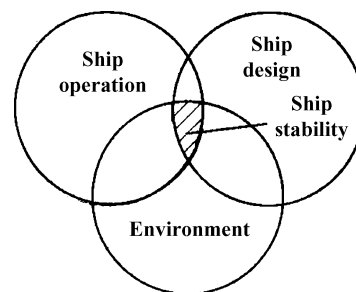

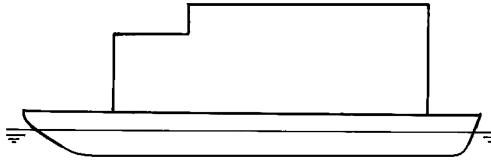Figure 23. Factors affecting ship stability.

Figure 24. Profile of a Nile cruiser.

wind direction is from north/northwest to south/southeast. The water current flows from south to north.

Therefore, the environmental conditions of the zone of operation of Nile cruisers are:

- wind speed and direction;
- wind intensity;
- water current speed and direction;
- width and depth of the navigation channel;
- presence of bends and islands; and
- seasonal variations.

It should be mentioned here that compliance with stability criteria does not ensure total immunity against capsizing. Inadequate ship stability has caused many ships to sink or capsize with loss of lives of passenger and crew. Masters therefore should exercise good seamanship with regard to the operational environmental conditions.

Nile Cruisers are characterised by small drafts, large superstructures, very high ratio of B/T and D/T (B = breadth, D = depth, T = draft), very small downflooding angle and very small reserve buoyancy.

These vessels have a large windage area (see Figure 24) and a high location of the centre of gravity, especially when the vessel is fitted with a large swimming pool in the upper deck and outfitted with high-density materials.

In order that Nile Cruisers have adequate stability, the following parameters must be taken into account:

- The particular characteristics of the navigation channel of the river Nile.
- The unpredictable severe weather conditions (see Figure 25).
- The presence of a strong water current going from south to north (see Figure 26).
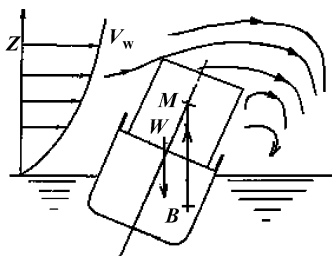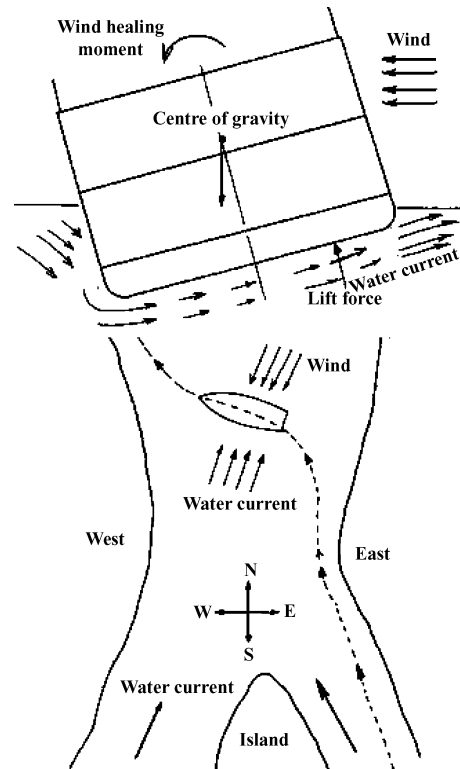

Figure 25. Effect of wind.

Figure 26. Effect of sailing in a curved course.

- The effect of the presence of several bends and many scattered islands in the navigation channel of the river Nile (see Figures 26 and 27).
- The variation of water depth along the navigation channel of the river Nile.

The presence of bends and islands compels vessel masters to sail in a curved course with implications on ship stability. The effect on ship stability of the presence of severe weather conditions accompanied by strong gusts of wind and high-speed water currents should not be ignored, particularly when the vessel is running in a curved course (see Figure 26). The combined effects of all or some of these factors can have a detrimental effect on ship safety. This was the case of the Nile Tourist vessel *Nobia* which sank in 1988 near Edfu.

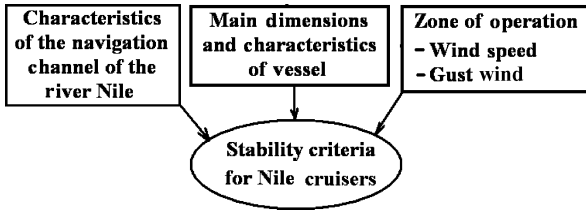Figure 27. An island in the river Nile.

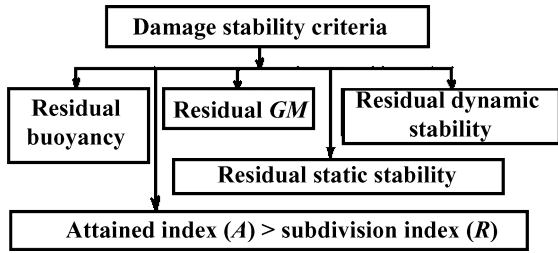Figure 28. Factors affecting stability criteria.

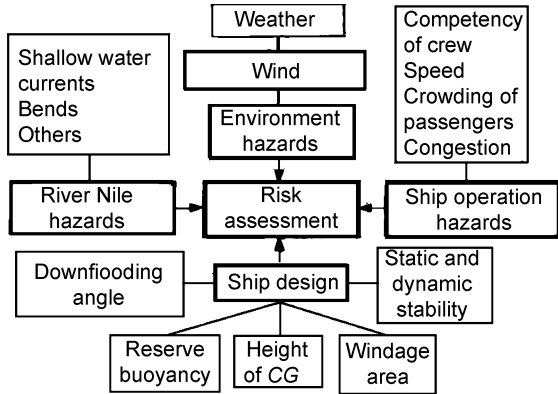Figure 29. Damage stability criteria.

Figure 30. Design and operational hazards.

Therefore safety assurance of Nile cruisers must be based on well-established stability criteria suitable for the operational zone, characteristics of the navigation channel and the special characteristics of this type of vessel such as shallow draft and large windage area (see Figure 28). The main stability criteria in the damaged condition is shown in Figure 29. The IMO Resolution A 167 criterion is neither applicable nor sufficient to ensure adequate safety of Nile cruisers.

The risk of capsizing of a Nile cruiser is based on the assessment of design and operational hazards (see Figure 30). These hazards include characteristics of the river Nile, weather variations and the main design parameters of the vessel. Figure 31 shows a process of evaluation of acceptable risk.

The main elements of ship stability criteria in the damaged condition are given in Figure 29, and the assessment of the risk of sinking or capsizing is based on the concept of demand and capability as given in Figure 32.
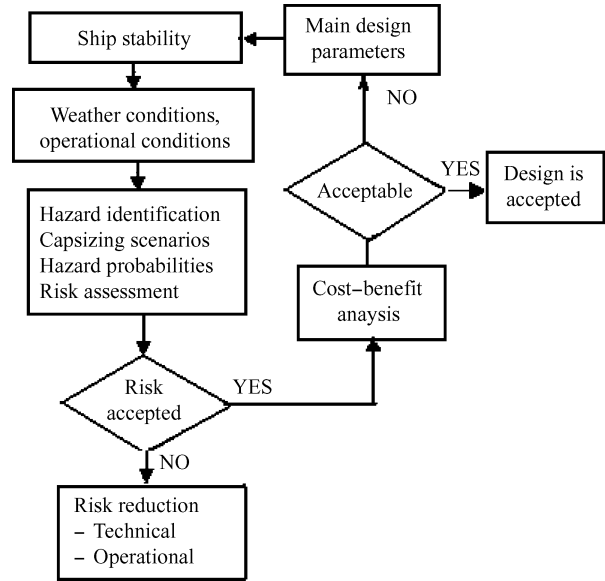
Figure 31. Risk acceptance process.

The risk of capsizing can be reduced by increasing the range of stability, by reducing the loss of water plane area due to flooding, by increasing reserve of buoyancy and freeboard to the bulkhead deck and also by avoiding asymmetry of flooding.
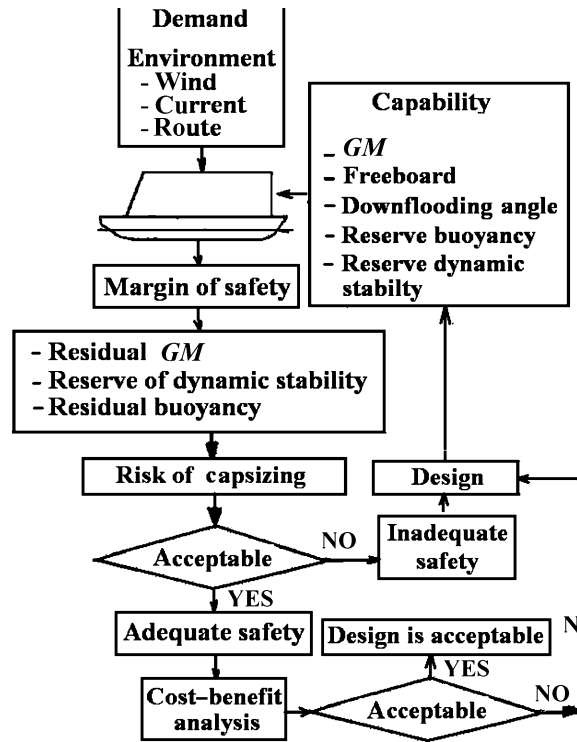
Figure 32. Main elements of risk assessment.

Concluding remarks

It is obvious from the foregoing analysis that there is a need to establish an integrated design and safety system to ensure adequate safety of Nile cruisers and avoid the deficiencies of the currently used safety procedures and standards, which have led to and could still lead to the occurrence of accidents.

Because of the serious consequences of the lack of adequate safety, it is necessary to treat the design and operational parameters affecting vessel safety probabilistically so as to be able to determine an acceptable value of the risk of losing stability.

The achievement of a degree of risk acceptable by the society and public opinion as well as by all bodies concerned with river Nile cruisers can be fulfilled by ensuring that the key design parameters of the vessel provide appropriate values for reserve buoyancy; safe downflooding angle; adequate initial, static and dynamic stability; and subdivision of the hull into an appropriate number of watertight compartments.

There is a need to deal with Nile cruisers not as immobile floating hotels but as passenger ships operated by a crew whose skill, competency and efficiency depends on limited qualifications, training and experience.

An important aspect of safety in the event of damage is the existence of a damage control plan. This plan should give information on the possible consequences of flooding and instructions on how to control it.

Nile cruisers operate in the navigation channel of the river Nile which is characterised by varying water depth, presence of water currents, many bends and islands and the frequent presence of sudden and severe changes in weather conditions. The effect of all these factors should be taken into account individually and collectively when determining an acceptable value of the degree of risk against sinking and/or capsizing.

It is necessary to increase the number of ports and berths in the tourist locations along the river Nile so as to cope with the limited capabilities of manoeuvring and course keeping of the current and expected number of future tourist ships and also to dredge the navigation channel particularly in the distance between Luxor and Esna.

There is a need to ensure that all engineers and crew members working on Nile cruisers and those assigned to ensure the safety and safe operation of these vessels have adequate qualifications, training, experience, skill and a knowledge of the safety culture.

Because of the absence of a national body responsible for ensuring adequate safety of Nile cruisers combined with the lack of adequate qualifications and training of engineers assigned to review, control and ensure safe operation of these vessels, it is necessary that these vessels to be classed by international classification societies so as to guarantee quality of construction and adequate operational safety.

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