Guidelines on Alternative Design and Arrangements of Life-Saving Appliances

March 2010

Guidance Note
NI 560 DT R00 E

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MARINE DIVISION
GENERAL CONDITIONS

ARTICLE 1

1.1. - BUREAU VERITAS is a Society the purpose of whose Marine Division (the "Society") is the classification (" Classification ") of any ship or vessel or structure of any type or part of it or system therein collectively hereinafter referred to as a "Unit" whether linked to shore, river bed or sea bed or not, whether operated or located at sea or in inland waters or partly on land, including submarines, hovercrafts, drilling rigs, offshore installations of any type and of any purpose, their related and ancillary equipment, subsea or not, such as well head and pipelines, mooring legs and mooring points or otherwise as decided by the Society.

The Society:

- prepares and publishes Rules for classification, Guidance Notes and other documents ("Rules");
- issues Certificates, Attestations and Reports following its interventions ("Certificates");
- publishes Registers.

1.2. - The Society also participates in the application of National and International Regulations or Standards, in particular by delegation from different Governments. Those activities are hereafter collectively referred to as " Certification ".

1.3. - The Society can also provide services related to Classification and Certification such as ship and company safety management certification; ship and port security certification, training activities; all activities and duties incidental thereto such as documentation on any supporting means, software, instrumentation, measurements, tests and trials on board.

1.4. - The interventions mentioned in 1.1., 1.2. and 1.3. are referred to as " Services ". The party and/or its representative requesting the services is hereinafter referred to as the " Client ". **The Services are prepared and carried out on the assumption that the Clients are aware of the International Maritime and/or Offshore Industry (the "Industry") practices.**

1.5. - The Society is neither and may not be considered as an Underwriter, Broker in ship's sale or chartering, Expert in Unit's valuation, Consulting Engineer, Controller, Naval Architect, Manufacturer, Shipbuilder, Repair yard, Charterer or Shipowner who are not relieved of any of their expressed or implied obligations by the interventions of the Society.

ARTICLE 2

2.1. - Classification is the appraisement given by the Society for its Client, at a certain date, following surveys by its Surveyors along the lines specified in Articles 3 and 4 hereafter on the level of compliance of a Unit to its Rules or part of them. This appraisement is represented by a class entered on the Certificates and periodically transcribed in the Society's Register.

2.2. - Certification is carried out by the Society along the same lines as set out in Articles 3 and 4 hereafter and with reference to the applicable National and International Regulations or Standards.

2.3. - **It is incumbent upon the Client to maintain the condition of the Unit after surveys, to present the Unit for surveys and to inform the Society without delay of circumstances which may affect the given appraisement or cause to modify its scope.**

2.4. - The Client is to give to the Society all access and information necessary for the safe and efficient performance of the requested Services. The Client is the sole responsible for the conditions of presentation of the Unit for tests, trials and surveys and the conditions under which tests and trials are carried out.

ARTICLE 3

3.1. - **The Rules, procedures and instructions of the Society take into account at the date of their preparation the state of currently available and proven technical knowledge of the Industry. They are not a standard or a code of construction neither a guide for maintenance, a safety handbook or a guide of professional practices, all of which are assumed to be known in detail and carefully followed at all times by the Client.**

Committees consisting of personalities from the Industry contribute to the development of those documents.

3.2. - The Society only is qualified to apply its Rules and to interpret them. Any reference to them has no effect unless it involves the Society's intervention.

3.3. - The Services of the Society are carried out by professional Surveyors according to the applicable Rules and to the Code of Ethics of the Society. Surveyors have authority to decide locally on matters related to classification and certification of the Units, unless the Rules provide otherwise.

3.4. - **The operations of the Society in providing its Services are exclusively conducted by way of random inspections and do not in any circumstances involve monitoring or exhaustive verification.**

ARTICLE 4

4.1. - The Society, acting by reference to its Rules:

- reviews the construction arrangements of the Units as shown on the documents presented by the Client;
- conducts surveys at the place of their construction;
- classes Units and enters their class in its Register;
- surveys periodically the Units in service to note that the requirements for the maintenance of class are met.

The Client is to inform the Society without delay of circumstances which may cause the date or the extent of the surveys to be changed.

ARTICLE 5

5.1. - The Society acts as a provider of services. This cannot be construed as an obligation bearing on the Society to obtain a result or as a warranty.

5.2. - The certificates issued by the Society pursuant to 5.1. here above are a statement on the level of compliance of the Unit to its Rules or to the documents of reference for the Services provided for.

In particular, the Society does not engage in any work relating to the design, building, production or repair checks, neither in the operation of the Units or in their trade, neither in any advisory services, and cannot be held liable on those accounts. Its certificates cannot be construed as an implied or express warranty of safety, fitness for the purpose, seaworthiness of the Unit or of its value for sale, insurance or chartering.

5.3. - The Society does not declare the acceptance or commissioning of a Unit, nor of its construction in conformity with its design, that being the exclusive responsibility of its owner or builder, respectively.

5.4. - The Services of the Society cannot create any obligation bearing on the Society or constitute any warranty of proper operation, beyond any representation set forth in the Rules, of any Unit, equipment or machinery, computer software of any sort or other comparable concepts that has been subject to any survey by the Society.

ARTICLE 6

6.1. - The Society accepts no responsibility for the use of information related to its Services which was not provided for the purpose by the Society or with its assistance.

6.2. - If the Services of the Society cause to the Client a damage which is proved to be the direct and reasonably foreseeable consequence of an error or omission of the Society, its liability towards the Client is limited to ten times the amount of fee paid for the Service having caused the damage, provided however that this limit shall be subject to a minimum of eight thousand (8,000) Euro, and to a maximum which is the greater of eight hundred thousand (800,000) Euro and one and a half times the above mentioned fee.

The Society bears no liability for indirect or consequential loss such as e.g. loss of revenue, loss of profit, loss of production, loss relative to other contracts and indemnities for termination of other agreements.

6.3. - All claims are to be presented to the Society in writing within three months of the date when the Services were supplied or (if later) the date when the events which are relied on of were first known to the Client, and any claim which is not so presented shall be deemed waived and absolutely barred. Time is to be interrupted thereafter with the same periodicity.

ARTICLE 7

7.1. - Requests for Services are to be in writing.

7.2. - **Either the Client or the Society can terminate as of right the requested Services after giving the other party thirty days' written notice, for convenience, and without prejudice to the provisions in Article 8 hereunder.**

7.3. - The class granted to the concerned Units and the previously issued certificates remain valid until the date of effect of the notice issued according to 7.2. here above subject to compliance with 2.3. here above and Article 8 hereunder.

7.4. - The contract for classification and/or certification of a Unit cannot be transferred neither assigned.

ARTICLE 8

8.1. - The Services of the Society, whether completed or not, involve, for the part carried out, the payment of fee upon receipt of the invoice and the reimbursement of the expenses incurred.

8.2. Overdue amounts are increased as of right by interest in accordance with the applicable legislation.

8.3. - The class of a Unit may be suspended in the event of non-payment of fee after a first unfruitful notification to pay.

ARTICLE 9

9.1. - The documents and data provided to or prepared by the Society for its Services, and the information available to the Society, are treated as confidential. However:

- clients have access to the data they have provided to the Society and, during the period of classification of the Unit for them, to the **classification file** consisting of survey reports and certificates which have been prepared at any time by the Society for the classification of the Unit;
- copy of the documents made available for the classification of the Unit and of available survey reports can be handed over to another Classification Society, where appropriate, in case of the Unit's transfer of class;
- the data relative to the evolution of the Register, to the class suspension and to the survey status of the Units, as well as general technical information related to hull and equipment damages, are passed on to IACS (International Association of Classification Societies) according to the association working rules;
- the certificates, documents and information relative to the Units classed with the Society may be reviewed during certificating bodies audits and are disclosed upon order of the concerned governmental or inter-governmental authorities or of a Court having jurisdiction.

The documents and data are subject to a file management plan.

ARTICLE 10

10.1. - Any delay or shortcoming in the performance of its Services by the Society arising from an event not reasonably foreseeable by or beyond the control of the Society shall be deemed not to be a breach of contract.

ARTICLE 11

11.1. - In case of diverging opinions during surveys between the Client and the Society's surveyor, the Society may designate another of its surveyors at the request of the Client.

11.2. - Disagreements of a technical nature between the Client and the Society can be submitted by the Society to the advice of its Marine Advisory Committee.

ARTICLE 12

12.1. - Disputes over the Services carried out by delegation of Governments are assessed within the framework of the applicable agreements with the States, international Conventions and national rules.

12.2. - Disputes arising out of the payment of the Society's invoices by the Client are submitted to the Court of Nanterre, France.

12.3. - **Other disputes over the present General Conditions or over the Services of the Society are exclusively submitted to arbitration, by three arbitrators, in London according to the Arbitration Act 1996 or any statutory modification or re-enactment thereof. The contract between the Society and the Client shall be governed by English law.**

ARTICLE 13

13.1. - **These General Conditions constitute the sole contractual obligations binding together the Society and the Client, to the exclusion of all other representation, statements, terms, conditions whether express or implied. They may be varied in writing by mutual agreement.**

13.2. - The invalidity of one or more stipulations of the present General Conditions does not affect the validity of the remaining provisions.

13.3. - The definitions herein take precedence over any definitions serving the same purpose which may appear in other documents issued by the Society.

BV Mod. Ad. ME 545 k - 17 December 2008

TABLE OF CONTENTS

1. General

1.1. Scope and objective of the guidelines

- These guidelines are intended to support LSA manufacturers, shipowners, shipyards and the Flag State administrations in dealing with the approval of alternative design and arrangements for LSAs.

- The provisions adopted in SOLAS Chapter I Part A Regulation 5 and in the 2006 MSC.1/Circ.1212 circular draw on the principle of equivalency to demonstrate that a trial alternative design or arrangement is as safe / effective as prescriptive designs or arrangements.

- The present guidelines elaborate on the new regulatory framework and put forward effective solutions to implement the approval process consistently.

1.2. Definitions

- *Novel Life-Saving Appliance (LSA) or arrangement* is a life-saving appliance or arrangement which embodies new features not fully covered by the provisions of SOLAS chapter III or the LSA Code but which provides an equal or higher standard of safety.

- *Life-saving system (LSS)* designates the system composed of all LSAs installed on a ship and the corresponding arrangements. A LSS is usually composed of different types of LSAs.

- *Prescriptive design* means a design of safety measures which comply with the regulatory requirements set out in chapter III of SOLAS.

- *Alternative design and arrangements* means measures which deviate from prescriptive requirements of SOLAS, but are suitable to satisfy the intent of these requirements. The term includes a wide range of measures, including alternative shipboard structures and systems based on novel or unique designs, as well as traditional shipboard structures and systems that are installed in alternative arrangements or configurations.

1.3. Overview of the main issues

- LSA designs have not much evolved since the first SOLAS convention of 1974. Several major catastrophes involving passenger ships pointed out the lack of proper assessment of existing systems. Despite training and maintenance, LSA design has not benefited enough from R&D investments compared to the rest of the ship design.

- The rapid development of the cruising industry has pushed the construction of giant passenger ships causing a growing concern about the suitability and performance of conventional LSAs. Innovative solutions for LSA design and arrangement could contribute to generate more profit for the ship.

- The current approval framework is prescriptive and draws on existing LSA designs (lifeboats and life rafts). In this context, the IMO has however opened the door for the approval of alternative LSA design and arrangements.

2. The regulatory framework

2.1. Regulatory framework for the approval of conventional LSAs

2.1.1. The SOLAS convention

- The last SOLAS convention was adopted in 1974 and addresses LSAs in Chapter III with statutory requirements. Important revisions were adopted in 1983, 1996 and 2006.

- The objective of chapter III is to prescribe the requirements for ship approval with respect to LSA installation and operation.

- Its requirements are specific to different LSA types (personal LSAs, lifeboats, liferafts, Marine Evacuation Systems) and ship types (passenger ships, cargo ships,).

2.1.2. The LSA Code (and associated guidelines for testing and evaluation)

- The "International Life-Saving Appliance Code" was adopted by IMO MSC in June 1996 by resolution MSC.48(66) in order to provide international standards for the life-saving appliances required by SOLAS chapter III.

- The Code was made mandatory through SOLAS Regulation III/34 (resolution MSC.47(66)) and entered into force on 1 July 1998.

- The testing of life-saving appliances was carried out through IMO resolution A.689(19) but a "Revised recommendation on testing of life-saving appliances" (resolution MSC.81(70)) has now effectively replaced this resolution.

- The "Code of practice for the evaluation, testing and acceptance of prototype novel life-saving appliances and arrangements" (resolution A.520(13)) was adopted in 1983 in order to address prototype novel life-saving appliances and arrangements which may be developed and do not fully meet the requirements of chapter III of the 1974 SOLAS Convention but provide the same or higher safety standards.

2.1.3. The European Marine Equipment Directive

- In the European Union, the conformity assessment of some types of marine equipment is regulated by the European directive 96/98/EC, called Marine Equipment Directive (MED), and adopted in 1996. Some LSAs are covered by the MED.

- The MED provides an approval scheme within the EU based on (1) the principle of mutual recognition between EU Member States and, (2) the designation of Notified Bodies to undertake conformity assessment procedures. The scheme set out in the directive ensures that certificates issued by notified bodies, are acceptable to each member state through the harmonization of their approval requirements.

- Marine equipments covered by the MED are listed in two distinct groups:

Category of marine equipment	Approval scheme
Annex A.1: “equipment for which detailed testing standards already exist in International instruments”	EC harmonised type approval scheme as described in Annex B of the MED
Annex A.2: “equipment for which no detailed testing standards already exist in International instruments”	National type approval scheme

Table 1 : MED approval schemes for different categories of marine equipment

- In this framework, conventional LSA equipments (including life rafts, lifeboats and rescue boats) are listed in Annex A.1. Alternately, according to Article 14 of the MED, non-conventional LSA equipment (whose design criteria deviate from IMO requirements) remains to National approval scheme.

2.2. Regulatory framework for the approval of alternative LSA design and arrangements

2.2.1. The principle of equivalency

- The SOLAS convention allows contracting member States to approve materials, arrangements or appliances that deviate from the requirements prescribed in the convention under certain conditions. Yet, this type of approval should satisfy the so called ‘principle of equivalency’ between the prescriptive requirements and the proposed design. This is expressed in general terms as follows:

> *“The Administration may allow any other fitting, material, appliance or apparatus […] to be fitted or carried […], if it is […] at least **as effective as** that required by the present regulations”.*
>
> SOLAS, Regulation I/5 on “Equivalents”

- Thus, the principle of equivalency states that a proposed alternative design should provide compliance with the overall criteria for safety and suitability for intended service established in the applicable rules. In other words, the trial alternative design should demonstrate to provide equivalent levels of safety or effectiveness with those ensured by a prescriptive design.

2.2.2. The regulation SOLAS III/38

- As presented in section 2.1.1, SOLAS Regulation I/5 defines the principle of equivalency in general terms

- It was further refined under the concept of "alternative designs and arrangements" that was explicitly included in several chapters of the convention such as Fire Safety, Machinery and Life-Saving Appliances.

- The aim was to provide a common framework in order to ensure a harmonised approach for assessing the effectiveness and safety level of such innovative or novel designs that are out of the scope of prescriptive requirements.

- For LSAs, this concept is addressed by SOLAS, Regulation III/38 below "Alternative design and arrangements for life-saving appliances" that was adopted by resolution MSC.216(82) (Entry into force 1st of July 2010).

> *"Life-saving appliances and arrangements may deviate from the requirements set out in part B* [of SOLAS Chapter III]*, provided that the alternative design and arrangements* ***meet the intent of the requirements*** *concerned and* ***provide and equivalent level of safety****"*
>
> *"When alternative design or arrangements deviate from the prescriptive requirements of part B, an* ***engineering analysis, evaluation and approval*** *of the design and arrangements shall be carried out in accordance with this regulation."*
>
> SOLAS, Regulation III/38

2.2.3. IMO Guidelines MSC.1/Circ.1212

- Regulation SOLAS III/38 “Alternative design and arrangements for life-saving appliances” (section 2.1.2) requires to perform an “engineering analysis” to demonstrate equivalency with the prescriptive design. This “engineering analysis” is supported by a methodology outlined in the “Guidelines on alternative design and arrangements for SOLAS chapters II-1 and III” (MSC.1/Circ.1212), adopted in December 2006. The content of these guidelines as well as the detail of the required qualitative and quantitative analyses are presented on Figure 1 below:

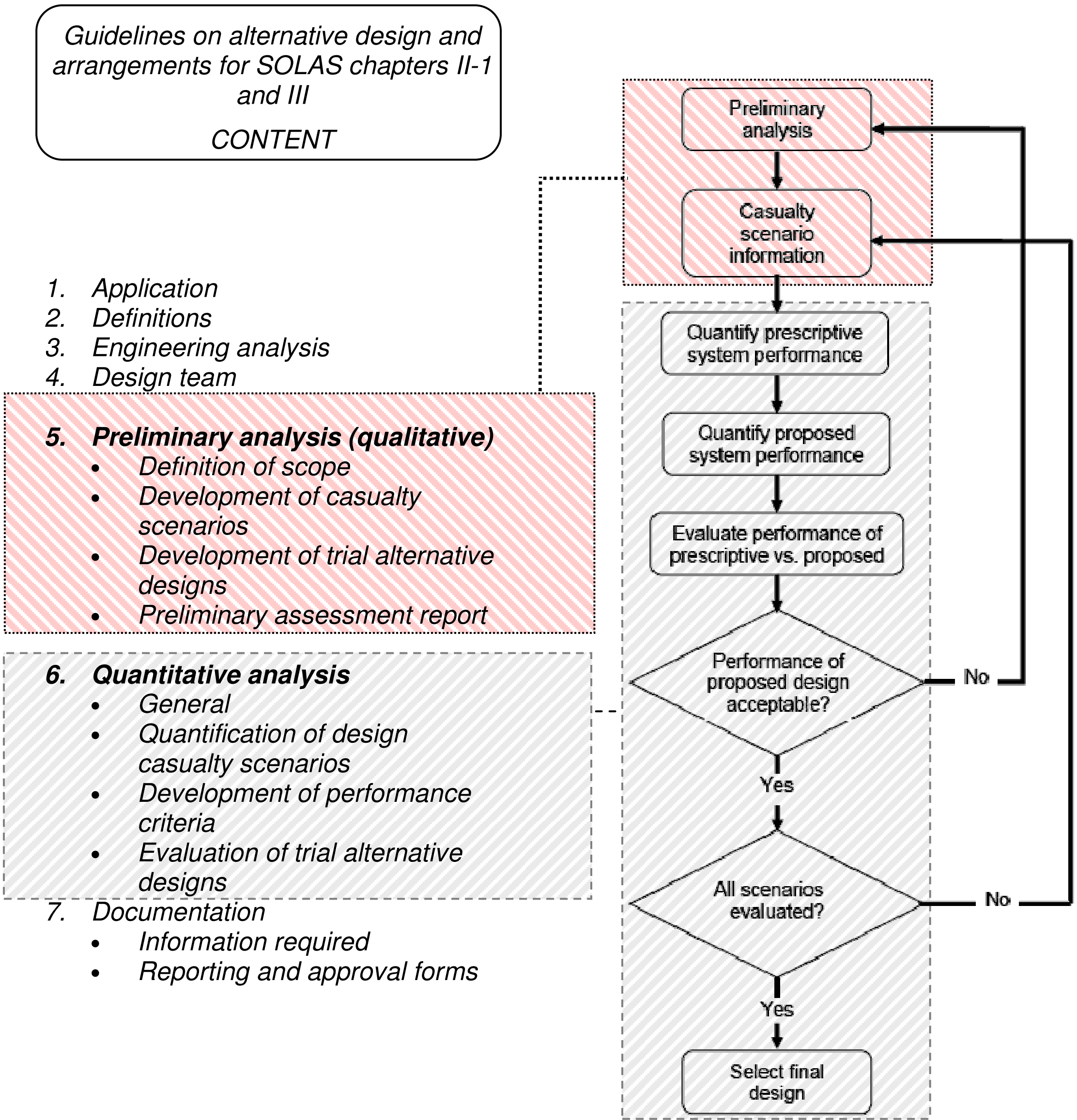

Figure 1 : Guidelines on alternative design and arrangements for SOLAS chapters II-1 and III (MSC.1/Circ.1212)

- It must be noted that *"these guidelines are not intended to be applied to the type approval of individual materials, components or portable equipment"* (MSC.1/Circ.1212, §1.2). This means that the approval scheme that is further described in these guidelines are not suitable for the type approval of LSA but for *"the approval of an alternative design deviating from the prescriptive requirements of SOLAS […] (chapter) III"* (MSC.1/Circ.1212, §1.1) on a case by case basis.

2.2.4. Testing, evaluation and approval of life-saving appliances according to the amended regulation SOLAS III/4, §3

- As the new SOLAS regulation III/38 was introduced in 2006, the provisions of III/4, §3 related to the approval of novel LSA by Flag State Administrations were amended accordingly:

> *"§3 Before giving approval to novel life-saving appliances or arrangements, the Administration shall ensure that such:*
>
> *.1 appliances provide **safety standards at least equivalent to the requirements of this chapter and the Code** and have been **evaluated and tested** based on the **guidelines developed by the Organization***; or*
>
> *.2 arrangements have successfully undergone an engineering analysis, evaluation and approval in accordance with **regulation 38**.*
>
> ** Refer to the guidelines to be developed by the Organization."*
>
> SOLAS, Regulation III/4 as amended by MSC.216(82)

- This regulation is split into two distinct paragraphs dealing with respectively appliances and arrangements. However, it should be noted that the requirements for appliances and arrangements are quite similar: §3.1 requires explicitly demonstration of safety equivalency for appliances and §3.2 requires that arrangements undergo an analysis as presented in regulation 38 which in fact also intends to demonstrate safety equivalency. Therefore, the same type of tools can be used for the approval of both life-saving appliances and arrangements.

- It should also be noted that during the period until the "guidelines to be developed by the Organisation" as mentioned in regulation III/4, §3, are developed, the evaluation and testing of the life-saving appliances should at least comply with the current "Code of Practice for the evaluation, testing and acceptance of prototype novel live-saving appliances and arrangements" (A 520(13)).

2.3. Summary of the regulations for the approval of life-saving appliances

- Table 2 summarises the regulatory framework for the approval of LSA design and arrangements:

Approval of:		Until July 2010	From July 2010 onwards
Conventional features	Life-saving Appliances and arrangements	• MSC.81(70) • A.689(17) • LSA Code • SOLAS III/4 §2	• MSC.81(70) • A.689(17) • LSA Code • SOLAS III/4, §2
Novel features	Life-Saving Appliances and arrangements	• Resolution A.520(13) • SOLAS III/4 §3 • SOLAS I/5	• **MSC.1/Circ.1212 (2006)** • **SOLAS III/38 (2006)** • **Amended SOLAS III/4, §3 (2006)** • SOLAS I/5 • **IMO guidelines (yet to be developed)** OR resolution A.520(13) (if the IMO guidelines are not developed)

Table 2 : Regulatory framework for the approval of alternative LSA design and arrangements

- Regarding all the different interrelated regulations applying to the approval of novel life-saving appliances and arrangements, it is helpful to draw a global view of all of the regulatory requirements. Figure 2 below is intended to present such a view.

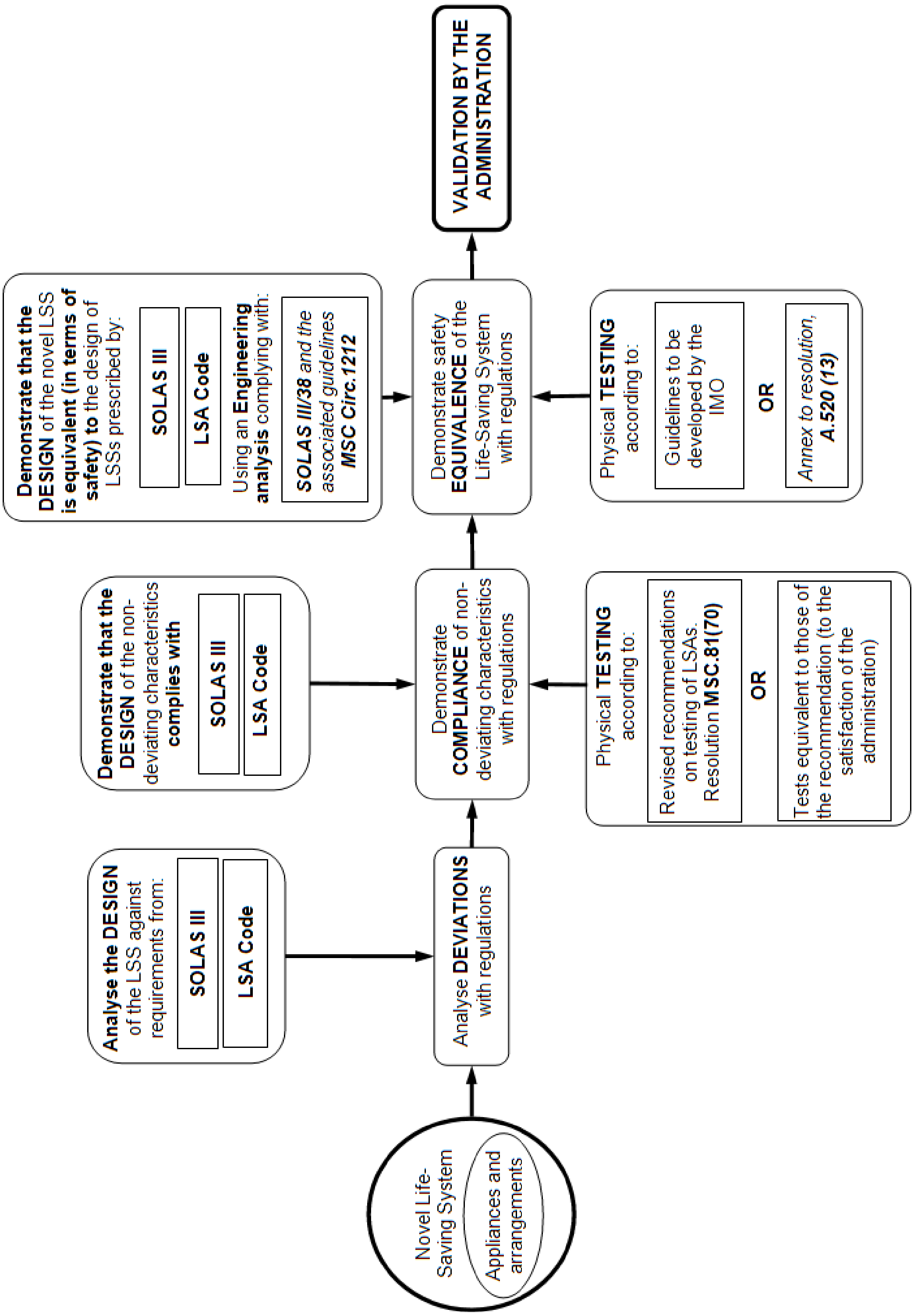

Figure 2: Regulatory framework for the approval of alternative LSA design and arrangements

3. Guidelines for the approval of alternative LSA design and arrangements

3.1. Introduction

- Before a novel Life Saving System (LSS) can be approved onboard a vessel, it should be tested and evaluated to the satisfaction of the Flag State Administration, as explained in section 2.2.4.

- For the stakeholders taking part into projects bringing in novel life-saving systems like LSA manufacturers and shipyards for instance, it is important to follow a comprehensive approval process supporting the development of innovative products and complying with the international regulations.

- The present guidelines are intended to help stakeholders and Flag State Administrations carry out the process for the approval of life-saving appliances and arrangements by introducing:

    1. A global approval scheme for life-saving appliances and arrangements complying with IMO regulations presented in section 3.2 and section 3.3.

    2. A suggested assessment method for Life Saving Systems, that fits into the approval scheme as the backbone of the engineering analysis that is required for the quantitative assessment by IMO regulations (see section 2.2.3, IMO circular MSC.1/Circ.1212). This assessment method was developed in SAFECRAFTS European research project (FP7).

3.2. General description of the approval scheme

- This section describes a global approval scheme suggested by Bureau Veritas for novel life-saving systems.

- The approval scheme complies with the various requirements of the regulatory framework presented in section 2 and is shown on Figure 3 below.

- The scheme describes the suggested approval process. It is basically based on requirements from the SOLAS regulation III/4 §3, SOLAS regulation III/38, IMO circular MSC.1/1212 and its structure is inspired from classical approval processes.

- The scheme can be seen as a dialogue between stakeholders and the Flag State Administration: for a successful approval of the life-saving system, all along the process, the Administration reviews each step of the evaluation and testing activities carried out by the stakeholders who then take the appropriate action/decision in order to comply with the Administration’s expectations expressed during the review.

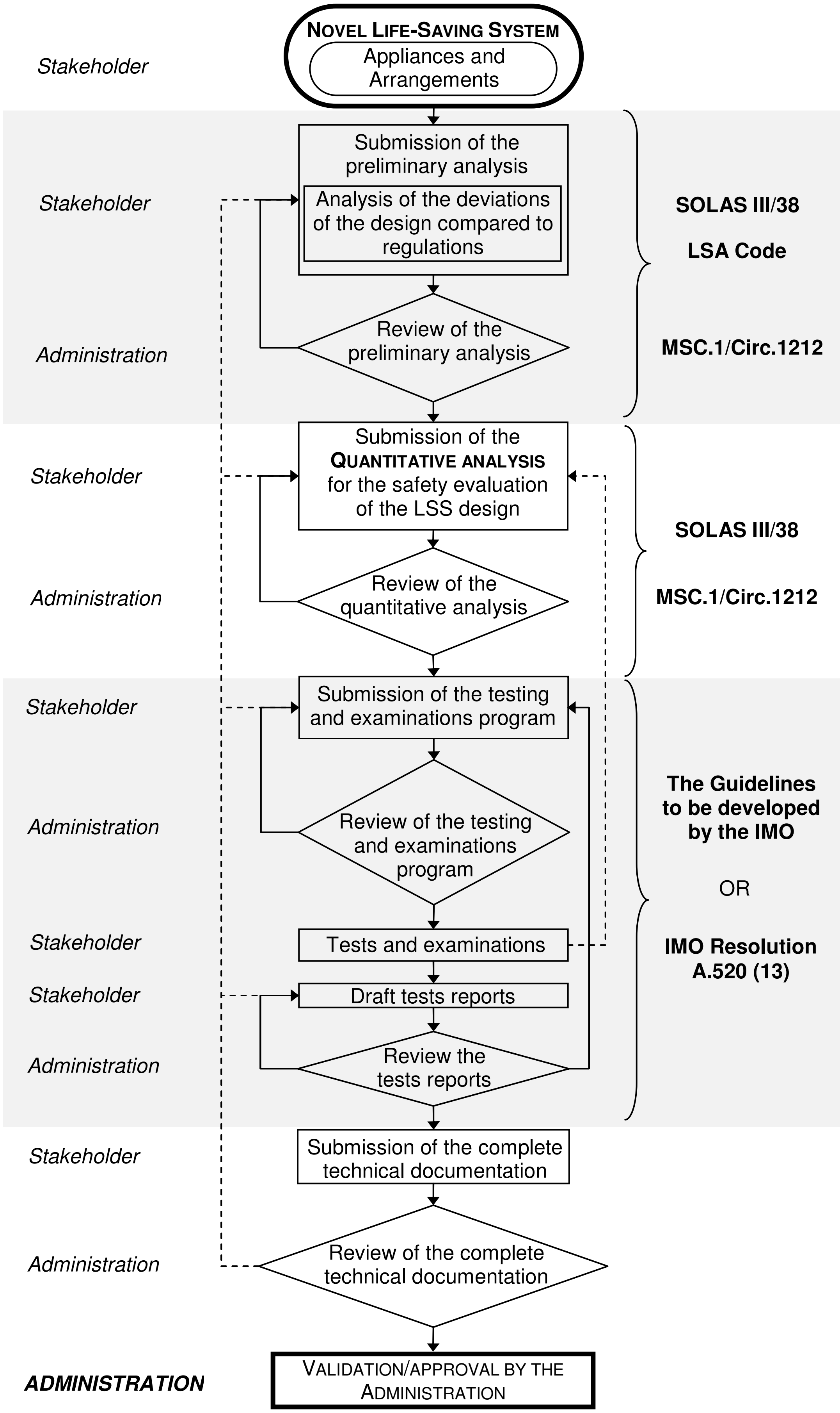

Figure 3 : Alternative LSA design and arrangements approval scheme

3.3. Detailed description of the approval scheme

3.3.1. Introduction

- Novel life-saving appliances and arrangements have to be demonstrated equivalent to prescriptive appliances and arrangements in terms of safety in order to be approved by the Maritime Administrations. In this purpose, an engineering analysis complying with the alternative design principles is required by regulation SOLAS III/38 that is carried out along the approval process.

- Moreover, in order to demonstrate equivalency, the engineering analysis should be based on an assessment method allowing the performance evaluation (in terms of safety) of novel concepts of LSS as well as conventional prescriptive LSS as described in MSC Circular 1212 (See section 2.2.3).

- Bureau Veritas participated in a European Research Project called SAFECRAFTS (2004 to 2008) in which they developed a methodology for the assessment of life-saving systems that they could apply on a lifeboat, a liferaft and two novel concept in development at that time.

- Section 3.3 describes some of the main steps required for the stakeholders to carry out the approval process as described on Figure 3 and in the IMO circular MSC.1/1212 (see Figure 1), along with the assessment methodology for the performance evaluation of Life-Saving Systems developed in SAFECRAFTS project.

3.3.2. The stakeholders

- Before starting the evaluation and testing of the novel life-saving system dealt with, it is very important to identify all the stakeholders of the project: the interested parties and the Design Team.

3.3.2.1. Interested parties in the ship design project

As mentioned in section 2.2.3, the approval scheme in the IMO guidelines on alternative design and arrangements for SOLAS chapters II-1 and III is relevant to a ship design project for which alternative LSA design or arrangement is sought.

- In this context, *"all interested parties […] should be in continuous communication from the onset of a specific proposal to utilise these guidelines"* (MSC.1/Circ.1212, §1.4).

- This should include: (1) The Administration or its designated representative, (2) Owners, (3) Operators, (4) Designers, and (5) Classification societies.

3.3.2.2. The design team

- The Design Team (DT) is in charge of performing and reporting the evaluation of trial alternative designs to the Administration (or its designated representative).

- In the IMO guidelines, the DT is established by the owner and should include:
  - A representative of the owner (or building or designer).
  - Expert(s) having the required competencies and experience in safety, design and/or operation regarding the evaluation case.
  - Other members including marine surveyors, ship operators, safety engineers, equipment manufacturers, human factors experts, naval architects and marine engineers.

- More precisely, it would be recommended that the DT includes:
  - A representative of the owner
  - A representative of the LSA manufacturer(s) involved in the system development.
  - A representative of the Classification society competent in risk-based approval (or an external consultant if the Classification society is acting on behalf of the Administration to assess the conformity of statutory rules).
  - A specialist in human factors with a sound background in biomechanics.

3.3.3. The preliminary analysis

- The preliminary analysis stands in the first step of the approval process. It will allow the qualitative assessment of the novel life-saving system being studied. From this analysis, both stakeholders and the Administration will have a first idea of the advantages and drawbacks of such a novel concept as well as an estimation of the resources required for carrying out the quantitative analysis and the tests for demonstrating the safety equivalency. The preliminary analysis is composed of the following steps:

3.3.3.1. Scope definition

It is important to begin the preliminary analysis with the definition of the technical, operational, environmental and regulatory main characteristics and limits of the study.

3.3.3.1.1. System definition

- The system definition aims to provide the DT participants with the necessary information regarding the LSS (prescriptive and alternative), its components and the operational procedures:
  - Plans and drawings of the ship, LSA, stowing arrangement, launching devices, and general arrangement;
  - Ship operating characteristics and conditions of operation;
  - Operating and maintenance procedures of LSA in drill and casualty situations;
  - Personnel assigned to the operation of LSA and evacuation process;
  - Accidental and failure data of lifeboat and system associated.

- The evacuation and rescue process: including abandonment (of the mother ship), survival at sea (in survival craft), and retrieval (by a rescue vessel) should also be defined clearly.

- In this context not only individual LSAs but also the whole evacuation and rescue system or Life-Saving System (LSS) should be studied.

- Since two or more different types of LSA can be fitted on a ship. The capacity of each LSA unit, the location onboard, and the means of transfer from the survival craft to a rescue ship are critical to characterise the Life Saving System (LSS).

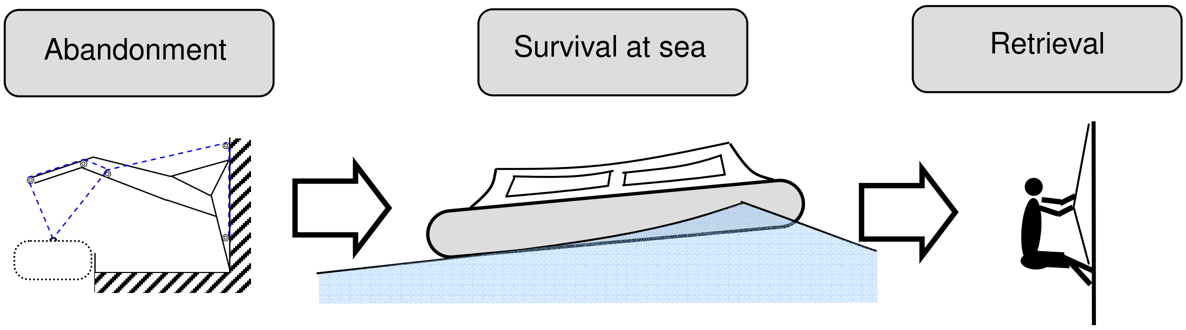

Figure 4 : Example of a Life-Saving System (LSS)

- The performance assessment method detailed in the following sections is based on the physical capacities of people evacuating. As the approval scheme is specific to a ship design project, the proposed method takes into account the physical capabilities of the population expected to be onboard the ship: the age distribution of the population onboard is a parameter of the system definition. Special attention should be given to the increased vulnerability of elderly people or people with reduced mobility.

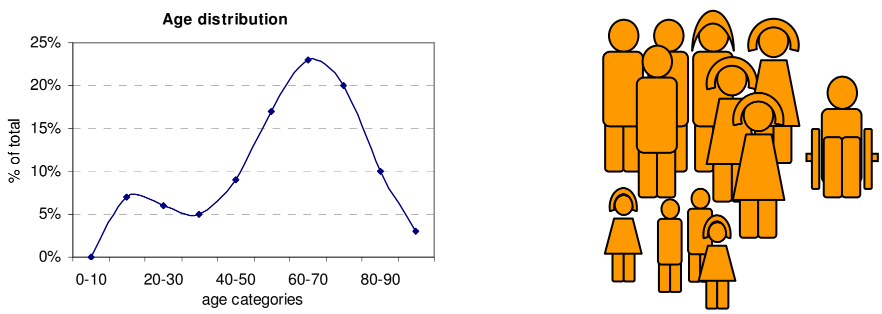

Figure 5 : Example of population description

- The present guidelines focus on the Life-Saving System as a whole in order to account for the complete evacuation and rescue process of the entire population onboard a ship. The global performance of a LSS is also the level of analysis that allows objective comparison between conventional systems and concepts under development.

3.3.3.1.2. Regulatory analysis (deviations from prescriptive rules)

- The regulatory analysis aims to identify the prescriptive requirements not complied with by the proposed alternative design. SOLAS chapter III and the LSA Code should be screened and any deviation reported together with a comprehensive description of the deviation.

- The technical documentation should be analysed in detail in order to identify deviations.

- Depending on the extent of the deviations, two situations are possible:
  - Only a few provisions are affected and/or the regulations affected provide explicitly the related safety objectives (measurable). In that case, the alternative design is directly comparable to an existing conventional design and the analysis may be limited to assess the safety performance of the alternative design against these safety objectives.

or

  - The proposed alternative design is so innovative that is deviates from the majority of the prescriptive provisions. The safety objectives are either not explicitly stated or the provisions are simply irrelevant. In that case, the implicit safety objectives will be made explicit and the safety performance can be assessed against them.

- In the following sections, a method is presented to tackle any type of deviation in a systematic way. The method is however presented as if the trial alternative design is radically novel, so that the full potentialities of the method can be presented. It is however flexible enough to tackle simpler cases of deviation.

3.3.3.2. Development of design casualty scenarios

After having defined the scope of the engineering analysis, the Design Team needs to identify the significant hazards to be taken into account for assessing the life-saving systems (prescriptive and novel concept). The design casualty scenarios are then derived from these hazards.

3.3.3.2.1. Definition

- Design casualty scenario means a set of conditions that defines the development and severity of a casualty within and through ship space(s) or systems and describes specific factors relevant to a casualty of concern.

3.3.3.2.2. Hazard identification and ranking

- Hazid (hazard identification) should be used (brainstorming exercise aiming to select and specify design casualty scenarios) for both the hardware component of the system (mechanical failure, structural failure, etc.) and the human vulnerability towards hazards faced during the process (impacts, accelerations, hypothermia, seasickness, etc.).

- This process aims to name and specify the hazards that may affect the correct functioning of the LSS system. Recognised Hazid techniques shall be used within the working group to carry out the hazard identification (FMEA, SWIFT...).

- Hazards identified are assessed qualitatively in terms of probability and consequence, so that they can be ranked in a risk matrix.

- As referred to in the IMO guidelines, hazards shall be grouped into incident severity classes: localized, major or catastrophic. In the case of a cruise ship, only localized and/or major incidents need to be considered.

3.3.3.2.3. Specification of design casualty scenarios

To help formalizing the process of building casualty scenarios, the concepts of Escape & Rescue Route and Obstacles are introduced:

- Escape and rescue route: The sequence of operations to be performed with the LSS in order to evacuate safely the entire population onboard (from the muster station to the rescue vessel). It involves the passengers, the crew and the hardware components of the LSS. Each LSS is associated with a specific escape & rescue route. Conventional existing systems have similar escape & rescue routes but novel concepts can differ radically in this respect. The escape & rescue route elements (deployment, boarding, lowering, clearing, etc) that are identified for each LSS type can be grouped together within the three generic phases: (1) Abandonment; (2) Surviving at sea; (3) Retrieval.

- Obstacles. As the hardware systems and the humans proceed along the escape & rescue route, they may face hazards and subsequent damages. Thus, the escape & rescue route can also be considered as the series of obstacles that the hardware and humans must overcome for the evacuation & rescue to be completed. An obstacle is characterized by the hazard generated when the system meets with it. Some hazards directly affect the human body (like seasickness), whereas some primarily affect the hardware system (like mechanical failure), as shown in Table 3:

Phases	Elements	Obstacles	Type
Leaving the vessel	Deployment	Malfunction	Hardware
		Fail to start engine	Hardware
	Boarding	Mobility failure	Human factor
	Lowering	Premature release	Hardware
		Failure /impact hull	Hardware
		Injuries / impact hull	Human factor
	Release	Fail to release	Hardware
		Injuries / Slamming	Human factor
Survival at sea	Clear ship	Fail manoeuvring	Hardware
	At sea	Capsizing	Hardware
		Seasickness	Human factor
		Tossed around	Human factor
Rescue	Recovery	Climbing pilot ladder	Human factor

Table 3 : Example of escape & rescue route relevant for a davit-launched lifeboat

- Assessment scenarios: A set of scenarios for which the performance along the escape & rescue route will be assessed is defined. This approach follows the IMO guidelines that refer to the definition of Design Casualty Scenarios against which prescriptive and trial alternative designs must be assessed.

  "Design Casualty Scenarios" ⇔ "Obstacles" x "Assessment Scenarios"

- These scenarios should characterise the ship and environmental conditions during the evacuation & rescue process. Possible scenario parameters may include at least the following:
  - Sea and wind conditions
  - Period of survival at sea
  - Sea/air temperature
  - Mother ship heading angle in waves (including dead ship condition)
  - Mother ship list and trim conditions (representing damaged ship conditions)

- By varying and selecting the most appropriate values for the scenario parameters, a limited number of assessment scenarios should be derived, as shown in Table 4.

Scenario	Sea state (Beaufort scale)	Period of survival at sea (h)	Abandoned ship		
			Heading angle	List (°)	Trim (°)
Sc 1	0-1	24	../.	0	0
Sc 2	3	24	Beam	0	0
Sc 3	5	24	Head	10	5
Sc 4	5	24	Beam	20	10
Sc 5	6	24	Beam	20	10

Table 4 : Example of assessment scenarios and related sea and wind conditions

- It should be emphasized that the assessment scenarios should be selected in the view of assessing both the prescriptive design and the alternative LSS design. This means that they should allow the assessment of these systems' performance against hazards identified for 1) the prescriptive LSS design and 2) the alternative LSS design.

- Design casualty scenarios: They represent the set of obstacles to be considered in the assessment scenarios.

- Since each escape and rescue route is *a priori* specific to one type of life-saving appliance and/or arrangement, design casualty scenarios are intrinsically specific to one LSA as well. Thus, the systems' performance should be assessed regarding, on the one hand the obstacles of the E&R route, and on the other hand the assessment scenarios (see section 3.3.5).

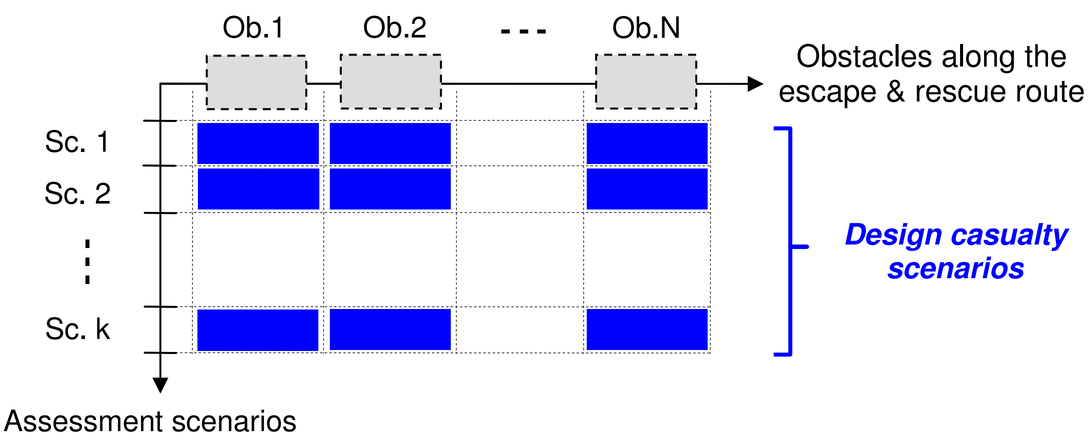

Figure 6 : Design casualty scenarios for a given LSA

- It should be noted that the hazard identification and the specification of the design casualty scenarios are critical phases for the assessment of the life-saving systems. They may seem time-consuming, however experience shows that success of the whole assessment strongly relies on these phases.

3.3.4. Submission of the preliminary analysis for review by the Flag State Administration

After having carried out the preliminary analysis, according to the suggested approval scheme as described in Figure 3, the following items should:

- Scope of the analysis

- Description of the alternative design including drawings and specifications

- Results of the preliminary analysis: This should include the technical documentation, the discussion of regulations (SOLAS and LSA Code) complied with and not complied with, the identification and selection of hazards and the development of design casualty scenarios.

3.3.5. Example of quantitative analysis

3.3.5.1. Introduction

- The quantitative analysis is required to demonstrate the equivalency of the trial alternative design with the prescriptive design.

- It should *"follow an established approach to safety design […] (and be) based on sound science and engineering practice incorporating widely accepted methods, empirical data, calculations, correlations and computer models". "Other safety engineering approaches recognised by the Administration may be used"* as quoted form the IMO guidelines on alternative design and arrangements for SOLAS chapters II-1 and III (MSC.1/Circ.1212, §3.1-2)

- The paragraph above opens the door for the use of standard risk assessment techniques with the view to integrate various input data from experiments, calculations and simulations. With this in mind, it is also true that no comprehensive approach is readily available for the assessment of LSA or alternative LSA design and arrangements.

- Section 3.3.5 presents the risk-based quantitative assessment methodology for life-saving systems developed by Bureau Veritas in SAFECRAFTS research project. This methodology stems in the deriving a performance index from the assessment of people's health degradation during the escape and rescue.

3.3.5.2. Performance quantification

- Considering the "intent" of the prescriptive requirements, it is normal to focus on the primary function of life-saving appliances which is to provide a means of escape and life support until rescuers arrive, in a situation when the mother ship is no longer habitable. In this regard, the quantification of the LSS performance for each design casualty scenario should reflect the degradation of the human health of the population engaged in the evacuation and rescue process.

3.3.5.2.1. The Human Health Status

- It is a metric of the state of health of the population being evacuated: for each obstacle along the route a proportion of the population will succeed without any trauma whereas others will be injured, perhaps fatally.

- The Human Health Status (HHS) is therefore defined as the distribution of population (in %) in the following four categories: Good Health, Moderately Injured, Severely Injured and Dead (see Table 5).

- The HSS of a particular population can be seen as a 4-dimensional vector that is transformed step-by-step through each obstacle (see Figure 7).

- The comparison between the initial and final HHS characterises the HHS degradation (see Figure 7).

HHS categories	Description	Related mobility
Good Health (GH)	Good physical and mental health	Good mobility
Moderate Injury (MI)	Moderate bleeding No fracture, no trauma	Mobility impaired
Severe Injury (SI)	Fractures and/or trauma	Mobility requiring assistance
Deceased (D)	Fatal injury	No mobility

Table 5 : Example of Human Health Status Scale

3.3.5.2.2. The global health degradation functions

- The overall degradation of the HHS can be seen as a 4-dimensional application that is applied to the initial HHS vector. The transformation can be written using matrix format as shown in Figure 7.

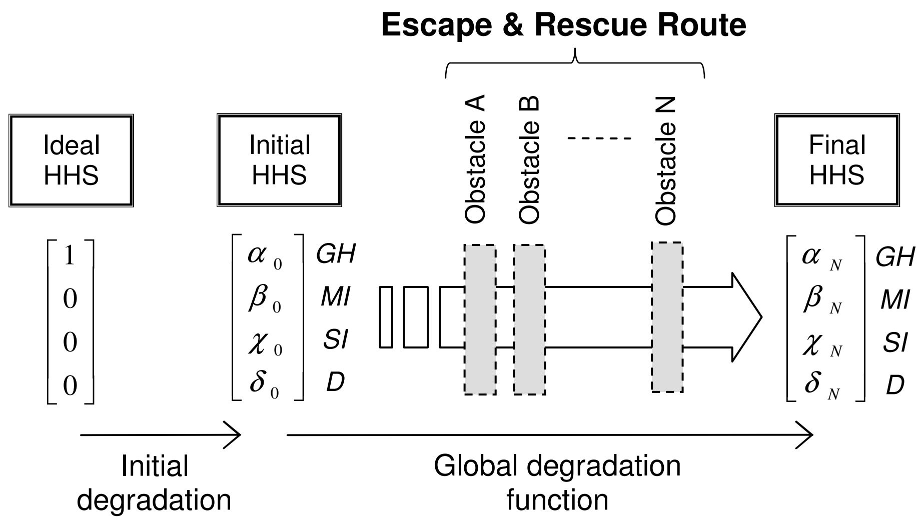

Figure 7 : Global degradation function and the escape & rescue route

- It is obvious that:

$$\alpha_0 + \beta_0 + \delta_0 + \chi_0 = 1 \qquad \alpha_N + \beta_N + \delta_N + \chi_N = 1 \qquad (1)$$

- As the population cannot get healthier in the course of the evacuation and rescue process, the global degradation function matrixcan be simplified as shown below.

$$f = \begin{bmatrix} a & 0 & 0 & 0 \\ b & f & 0 & 0 \\ c & g & m & 0 \\ d & h & n & 1 \end{bmatrix} \quad \text{With} \quad \begin{cases} a+b+c+d=1 \\ f+g+h=1 \\ m+n=1 \end{cases} \qquad (2)$$

- Then the final HHS can be obtained with a simple matrix calculation:

$$\begin{bmatrix} a & 0 & 0 & 0 \\ b & f & 0 & 0 \\ c & g & m & 0 \\ d & h & n & 1 \end{bmatrix} * \begin{bmatrix} \alpha_0 \\ \beta_0 \\ \chi_0 \\ \delta_0 \end{bmatrix} = \begin{bmatrix} \alpha_N \\ \beta_N \\ \chi_N \\ \delta_N \end{bmatrix} \quad \text{With} \quad \begin{cases} a+b+c+d=1 \\ f+g+h=1 \\ m+n=1 \end{cases} \qquad (3)$$

- The global degradation function is a risk assessment tool because the coefficients of the matrix are determined according to the expected degradation of the HHS through the sequence of obstacle and the likelihood of such degradation.

3.3.5.2.3. The local health degradation functions

- Local degradation functions account for the local degradation of the HHS when passing through each obstacle.

- The global degradation function can only be derived from the determination of the local degradation functions associated with individual design casualty scenarios.

- If the sequence of obstacles is deemed linear, the global degradation is equivalent to the successive degradations caused by the local degradations – in mathematical terms, the matrix product of the local degradation functions. Practically, it is possible to characterise one obstacle and determine the coefficients of the matrix by means of engineering methods and models.

$$\left[f \right] = \left[f_N \right] * \ldots\ldots * \left[f_B \right] * \left[f_A \right] \qquad (4)$$

3.3.5.2.4. Matrix coefficients of local health degradation functions

- A typology of local degradation functions can be drawn depending on the type of obstacle described:

  - (1) **Hardware obstacles** refer to a failure or a hazard that directly affects the hardware components of the system, for instance a mechanical failure in the deployment system. The effect is binary with respect to the HHS of the people "inside" the hardware. If the hardware fails all occupants are deemed lost and furthermore the phenomenon does not depend on the HHS before the obstacle; This leads to a simplified structure of the matrix associated with the local degradation function, so that only one coefficient is needed instead of nine ("a" being the failure probability associated with the considered hardware obstacle).

$$\begin{bmatrix} 1-a & 0 & 0 & 0 \\ 0 & 1-a & 0 & 0 \\ 0 & 0 & 1-a & 0 \\ a & a & a & 1 \end{bmatrix} \qquad (5)$$

  - (2) **Human factor obstacles** are associated with a number of phenomena that degrade HHS while the hardware part of the system remains operational. This includes impact forces, accelerations, seasickness, hypothermia and other mobility failures. Subsequently, the HSS before the obstacle is relevant because an injured person is more likely to "fail" the next obstacle than a healthy person. The related matrix cannot be simplified and nine coefficients must be determined.

$$f = \begin{bmatrix} a & 0 & 0 & 0 \\ b & f & 0 & 0 \\ c & g & m & 0 \\ d & h & n & 1 \end{bmatrix} \quad \text{With} \quad \begin{cases} a+b+c+d=1 \\ f+g+h=1 \\ m+n=1 \end{cases} \qquad (6)$$

3.3.5.3. Performance criteria

- Performance criteria are quantitative expressions of the regulatory safety requirements from IMO regulations, used for demonstrating equivalency between the trial alternative design and the prescriptive design. A criterion called "performance index" is presented in this section. This criterion is the basis for evaluating safety performance of the novel LSS against the prescriptive design's one.

3.3.5.3.1. Performance index

- Considering that the primary function of a Life-Saving System is to save lives, the comparison between the final and the initial HHS (see section 3.3.5.2) should be an adequate measure reflecting the LSS' performance.

- To ease the assessment, it is useful to transform the HHS vector into a single value that is called the Performance index (PI). This requires converting injuries into "equivalent fatalities" using the example index from the IMO Formal Safety Assessment methodology [MSC 83/INF.2].

- The Performance index is defined as the percentage of the initial ship's population in "equivalent Good Health" which is still in "equivalent Good Health" at the end of the rescue process. It reflects the global degradation of the HHS along the escape & rescue route and therefore the global performance of the LSS. The formal expression of the Performance index is given below with reference to one assessment scenario "k".

Initial HHS — Global degradation function for scenario k — Final HHS

$$\begin{bmatrix}\alpha_0\\ \beta_0\\ \chi_0\\ \delta_0\end{bmatrix}\begin{matrix}GH\\ MI\\ SI\\ D\end{matrix} \qquad \begin{bmatrix}a_k & 0 & 0 & 0\\ b_k & f_k & 0 & 0\\ c_k & g_k & m_k & 0\\ d_k & h_k & n_k & 1\end{bmatrix} * \begin{bmatrix}\alpha_0\\ \beta_0\\ \chi_0\\ \delta_0\end{bmatrix} = \begin{bmatrix}\alpha_{N,k}\\ \beta_{N,k}\\ \chi_{N,k}\\ \delta_{N,k}\end{bmatrix}\begin{matrix}GH\\ MI\\ SI\\ D\end{matrix}$$

Effects on human safety	Equivalent fatalities	Performance index (assessment scenario "k")
Single or minor injuries	0.01	$PI_k = \dfrac{1-\left(\delta_{N,k} + 0.1 \cdot \chi_{N,k} + 0.01 \cdot \beta_{N,k}\right)}{1-\left(\delta_{0,k} + 0.1 \cdot \chi_{0,k} + 0.01 \cdot \beta_{0,k}\right)}$
Multiple or severe injuries	0.1	
Single fatality	1	

Table 6 : Performance index definition

3.3.5.3.2. Initial Human Health Status

- The initial HHS is an important input that has to be determined with precision since it accounts for the Performance index's denominator (explicitly) as well as its numerator (implicitly), as presented in Table 6 above. Indeed, the final HHS is a calculated output derived from the initial HHS through the degradation functions.

- Ideally, the initial HHS should be 100% in the category "Good Health".

- However, in realistic conditions, the typical population onboard cruise ship cannot be considered 100% in Good Health. Indeed, elderly people and people with impaired mobility are deemed more vulnerable to the physical stress and efforts required by the evacuation and rescue process.

- When the information on disabled people or people with impaired mobility is available, it is then possible to determine the initiation HHS using the definition of the Human Health Status (See section 3.3.5.2.1)

- In practice, it is possible to use generic data as for instance in the IMO guidelines for evacuation analysis [MSC.1/Circ.1238], which estimate that 55% of the population older than 50 years old onboard cruise ship has impaired mobility.

3.3.5.3.3. Definition of the performance criteria

- In the most general case of alternative design, it is only possible to compare prescriptive and alternative design at global level that is the performance level of LSS modelled by the Performance index.

- In order to have a valid comparison, the reference ship for the prescriptive design should be at least very similar and ideally the same as the reference ship for the alternative design comprising novel concepts of LSAs. Thus, if the alternative design involves a novel ship, the prescriptive design should be assessed by extrapolation, as if the conventional systems were installed on the same novel ship (or a 'virtual sister ship').

- Hence, the performance criteria shall be the Performance indexes obtained by one or several conventional systems for a set of design casualty scenarios fully documented and accepted by all stakeholders.

- With this approach, the safety level intended by the prescriptive regulations correspond to the Performance index values obtained by conventional prescribed systems: PI(Prescribed Design) or PI(PD).

Design casualty scenario	Performance criteria
Sc. 1	$PI_1(PD)$
Sc. 2	$PI_2(PD)$
…	…
Sc. k	$PI_k(PD)$

Table 7 : Different performance criteria for different scenarios (prescriptive design)

- The result format may be similar to Figure 8 below:

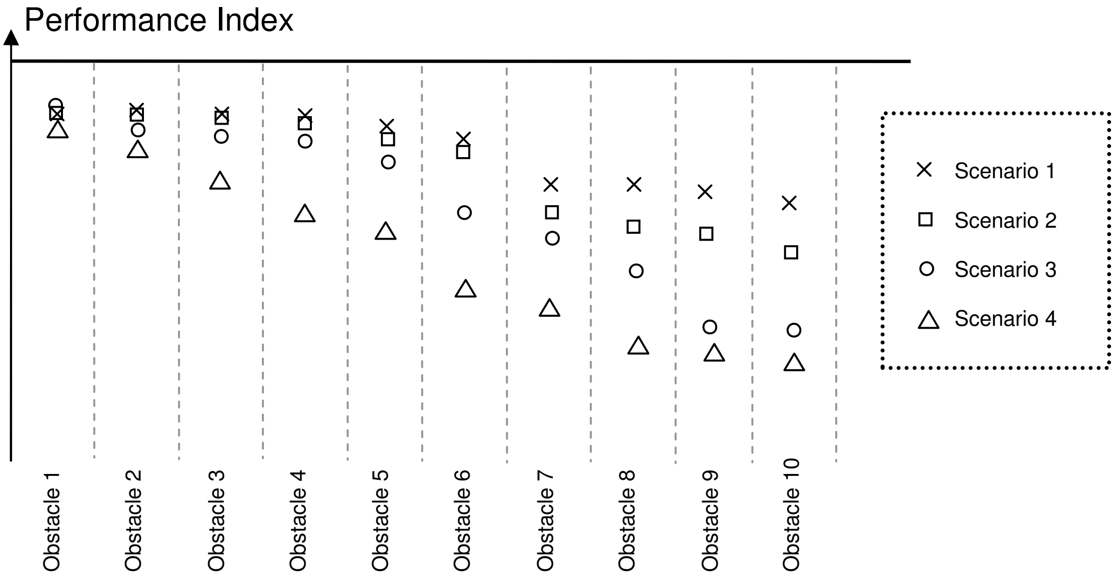

Figure 8 : Example of performance index evolution along the escape & rescue route for different scenarios

3.3.5.4. Evaluation

3.3.5.4.1. Principle

- The trial alternative design should be analysed against the same design casualty scenarios in order to derive the associated Performances Indexes.

- The comparison between the Performance indexes for the prescriptive design and the alternative design should enable the Design Team (see section 3.3.2.2) to formulate a judgment regarding the application of the equivalency principle.

Design casualty scenario	Performance criteria
Sc. 1	$PI_1(AD)$
Sc. 2	$PI_2(AD)$
…	…
Sc. k	$PI_k(AD)$

Table 8 : Performance criteria for different scenarios (alternative design)

3.3.5.4.2. Recommended acceptance criteria

- There are different ways of deriving acceptance criteria from the Performance indexes obtained for the prescriptive and alternative LSA designs. If there are many scenarios to consider, a multi-criteria analysis may be useful to derive consistent acceptance criteria.

- As prescribed by MSC.1/Circ.1212, the simplest rule however consists in considering all assessment scenarios independently and comparing the Performance indexes two by two:

"Each selected trial alternative design should be analysed against the selected design casualty scenarios to demonstrate that it meets the performance criteria with the agreed safety margin, which in turn demonstrates equivalence to the prescriptive design."

MSC.1/Circ.1212 ANNEX § 6.4.2

- **If the performance of an alternative design is deemed equal or higher than that of conventional systems for each assessment scenario, then the new design is proved of an equivalent level of safety.**
- **The scenarios definition and selection appear here as very important since the alternative design should perform better than the prescriptive design <u>for every scenario</u> in order to demonstrate an equivalent or higher level of safety.**

Assessment scenario	Acceptance criteria
Sc. 1	$PI_1(AD) \geq PI_1(PD)$
Sc. 2	$PI_2(AD) \geq PI_2(PD)$
…	…
Sc. k	$PI_k(AD) \geq PI_k(PD)$

Table 9 : Acceptance criteria for different scenarios

3.3.5.5. Quantification of uncertainties

- During the performance assessment of the Life-Saving Systems, some uncertainties have been introduced. The methodology adopted requires much input data as well as different types of models describing the effects of hardware and human factors obstacles on the health status of passengers. Some of them are systematic uncertainties (only depending on the model used) while others are dependent upon the type of obstacle analysed and consequently the escape route and the type of LSA studied.

- Thus, it is crucial when comparing Performance indexes of prescriptive designs with Performance indexes of alternative designs to quantify data and model uncertainties on these Performance indexes. Otherwise, the comparison and therefore the whole engineering analysis cannot be reasonably validated.

- Obstacles are represented by local degradation matrices. Due to data and model uncertainties, the coefficients of the associated local degradation matrices are likely to be different from the nominal values used. Depending on the type of uncertainties introduced, coefficients can take different values above and below the nominal so that the obstacle is more or less favourable for the assessment of the LSAs' performance.

- The uncertainties associated with the global degradation matrices representing the entire escape & rescue routes are derived from the combination of the uncertainties on the local degradation matrices

- The uncertainties on the Performance indexes are derived from the uncertainties on the global degradation matrices.

- As an example, Figure 9 and Figure 10 below show the two significant cases one can encounter when carrying out the assessment:

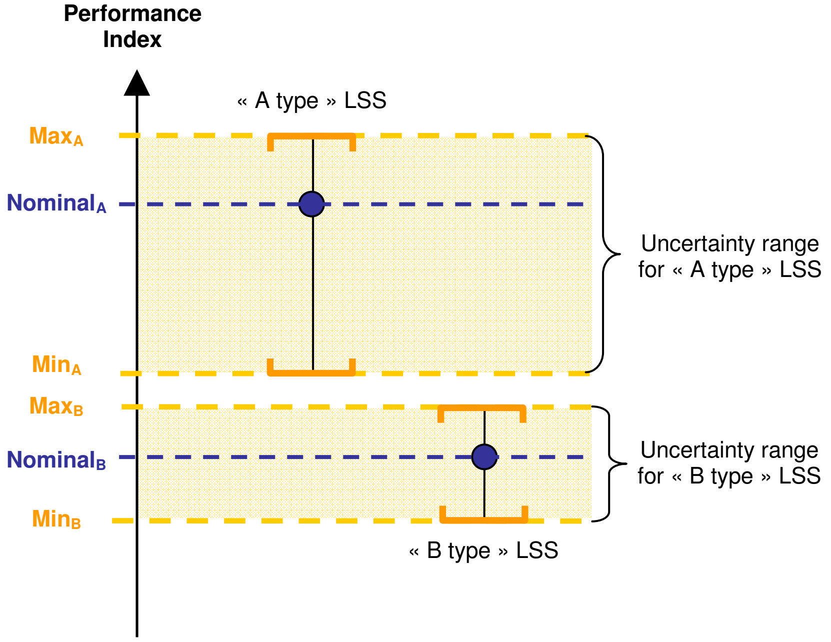

Figure 9: Comparison of two life-saving systems – no overlap

- In Figure 9, despite the uncertainties, it appears clear that the 'A type' LSS performs more safely than the 'B type' LSS for this scenario. No further refinement of the assessment is required.

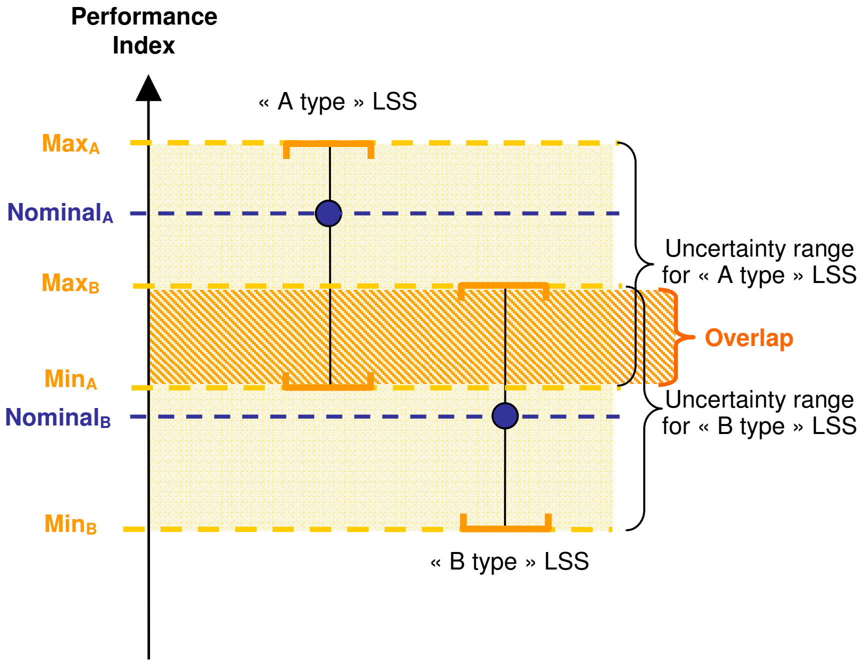

Figure 10: Comparison of two life-saving systems – significant overlap

- In Figure 10, regarding the overlapping zone due to uncertainties on the performance index, it appears that no conclusion can be clearly drawn out of the assessment for this scenario. This case requires that the Design Team focuses on the obstacles introducing the more uncertainties for this scenario and refine their assessment until a clear judgment can be made.

3.3.6. Submission of the quantitative analysis for review by the Flag State Administration

After having carried out the quantitative analysis, according to the suggested approval scheme as described in Figure 3, the following items should:

- Scope of the analysis
- Description of the alternative design including drawings and specifications
- Technical reports dealing with the data, the assumptions, the simulations, the experiments and the calculations required for the assessment of all hardware and human factors obstacles (for both prescriptive and alternative designs).
- Results of the quantitative analysis: This should include the calculation of performance indicators, the determination of performance criteria and the evaluation of the trial alternative design.
- Documentation of operational and maintenance requirements

3.3.7. Testing

- In the approval scheme suggested by Bureau Veritas (see Figure 3), the novel life-saving system should be tested and examined according to the requirements of the "Code of Practice for the evaluation, testing and acceptance of prototype novel life-saving appliances and arrangements (annex to resolution A.520 (13))" as far as practicable (some novel concepts may not fit in some of them due to their intrinsic innovative character) or the IMO Guidelines (not yet developed when this guidance note was published).
- During the tests, particular attention should be paid to the issues raised by the operation of the novel life-saving system. Indeed, these systems are likely to require new skills from seafarers. These skills should be taught in accordance with the requirements from the International Safety Management (ISM) Code. In the engineering analysis, even if human error may be considered as an obstacle on the escape and rescue route, it is assumed that the seafarers in charge of guiding passengers and launching life-saving appliances are efficiently trained.
- The testing and examination program should be submitted to the Flag State Administration for review and validation before carrying out the test.
- After having carried out the test, the draft test reports should be submitted to the Flag State Administration (FSA) for review and validation. The FSA may ask the stakeholder to modify and re-submit a test and examination program if necessary.

3.3.8. Submission of the complete technical documentation

- The stakeholders should submit the complete technical documentation to the Flag State Administration for final validation and approval of the novel life-saving system.

- The technical documentation should include all the documents previously submitted that should be amended according to the recommendations made by the FSA during the previous reviews.

- It should be noted that the safety performance assessment is valid only for a given project, therefore, the validation and approval from the FSA is also valid only for this project and the results cannot be entirely and systematically re-used for the approval of a similar system on a different vessel.

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