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An analysis of the implementation and future development of IMO goal-based standards

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AN ANALYSIS OF THE IMPLEMENTATION AND FUTURE DEVELOPMENT OF IMO GOAL-BASED STANDARDS

By

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DECLARATION

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

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

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ABSTRACT

Title of dissertation: **An Analysis of the Implementation and Future Development of IMO Goal-based Standards**

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This dissertation conducts a comprehensive analysis of the application of goal-based standards (GBS) in the maritime world, which will change the mode of standards development and bring great effects to the entire maritime regulatory system, focusing on the potential problems in implementation and the future development of the GBS system.

Key progress during the development of the GBS is presented emphasizing the five-tier structure of the GBS system and the latest approved IMO instruments. Then an overview of the current GBS system is summarized as a basis for further analysis.

The effects of the application of GBS are discussed including the advantages such as stronger control on ship construction, technical transparency and the freedom of technical innovation, as well as the corresponding challenges and limitations.

The potential problems in the forthcoming implementation of the GBS verification audit scheme are analyzed taking into account the controversial issues and practical aspects such as related workload and resources. Feasible solutions are recommended based on the analysis.

The limitation of the current GBS framework in ship regulation system is assessed and the future tasks for GBS development are anticipated in regards to the application of safety level approach (SLA) to GBS and the generalization of the GBS regime. The difficulties in the development of SLA and its associated Formal Safety Assessment (FSA) are elaborated and recommendations are provided to facilitate their development. A recommended scheme on GBS generalization is suggested considering the necessity and feasibility of the expansion process.

KEYWORDS: Goal-based standards, GBS verification audit scheme, Safety level approach, Formal safety assessment, GBS generalization

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LIST OF ABBREVIATIONS

ALARP	As Low As Reasonably Practical
CAF	Cost of Averting a Fatality
ClassNK	Nippon Kaiji Kyokai
CSR	Common Structure Rules
FSA	Formal Safety Assessment
GBS	Goal-Based Standards
HSR	Harmonized Common Structural Rules
IACS	International Association of Classification Societies
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
IEC	International Electrotechnical Commission
IMO	International Maritime Organization
ISSC	International Ship and Offshore Structure Congress
MSC	Maritime Safety Committee
RBA	Risk-Based Approach
RBD	Risk-based Design
RCOs	Risk Control Options
SLA	Safety Level Approach
SOLAS	International Convention for the Safety of Life at Sea
SRA	Structural Reliability Assessment
UK	United Kingdom

CHAPTER I INTRODUCTION

1.1 Application of GBS in the maritime world and related problems

Standards, which include statutory regulations, rules and other guidance instruments, play a very important role in the maritime field with respect to safety, security and environmental protection. After several major accidents such as Exxon Valdez, Erika and Prestige, the structural strength of ships was refocused by the public and there came a view that the International Maritime Organization (IMO) should play a larger role in determining the fundamental standards to which new ships are built (Kontovas, Psaraftis, & Zachariadis, 2007). As a result, the notion of Goal-Based Standards (GBS) was subsequently introduced in IMO in 2002, and since then IMO started to develop GBS systems for ship construction.

After many years of effort, great progress on GBS has been made recently. On 20 May 2010, The IMO Maritime Safety Committee (MSC) formally adopted International Goal Based Ship Construction Standards for Bulk Carriers and Oil Tankers at its 87th session, along with amendments to SOLAS Chapter II-1, making their application mandatory. MSC also adopted guidelines for the verification of compliance with the aforementioned GBS. With the adoption of the SOLAS amendment, the GBS regulation system has come into its implementation period, and will give its great effects to the shipping industry. In order to facilitate the implementation and further development of GBS, MSC also developed a future work plan regarding GBS verification audits and the application of the Safety Level

Approach (SLA) for the next several MSC sessions.

However, the achieved progress is just a start for the application of GBS in the maritime field and in the current GBS system there are still potential problems and limitations to be addressed:

First, there are still practical problems in implementing the GBS audit scheme, such as the resources and expertise of the audit team, and the workload control of IMO regarding GBS verification, which have important influences on the successful implementation of GBS (International Maritime Organization, 2010a). There were discussions focusing on such issues but the detailed solution is still to be further consulted.

Second, the current Goal-based Ship Construction Standards for Bulk Carriers and Oil Tankers are based on a prescriptive approach. According to the parallel work plan, the SLA should be validated by comparison with the prescriptive approach, and the safety level of the current rules/regulations should be determined. Up to now there are still many practical difficulties in adapting SLA to GBS system, such as the availability of data to feed the risk models, accuracy of risk analysis, and definition of ship types. There is still no acceptable safety level for ships approved and no uniform model justified for the determination of the safety level.

Last but not least, the current GBS system only covers the structural aspects of two main ship types. In order to accomplish the entire goal-based regulatory system, the application of the GBS should be extended to other ship types and aspects (such as machinery and equipment). Then new concerns and problems were raised regarding issues including the scope of GBS generalization and scheme of expansion progress, and no specific perspective is agreed.

These three series of issues are of great significance for the further development and application of the GBS system, and also will have important influences on the maritime world at large. There were some articles addressing the

GBS in maritime academia, but most of them were issued in earlier years when the GBS framework was just constructed, discussing the potential impacts of GBS and the use of risk-based approach (Hoppe, 2005; Kelly, McDermid & Weaver, 2005). No paper came forth recently providing a comprehensive analysis on the implementation and generalization of GBS. Since the GBS has been made mandatory and come to an implementation stage, it is of great significance to conduct a synthesized analysis addressing these issues and provide recommendations on feasible solutions.

1.2 Purpose and methodology of the dissertation

Aiming at the aforementioned issues, this dissertation will summarize the progress of GBS development and provide an overview of the current GBS system; analyze the potential problems in the implementation of GBS; assess the limitations of the current GBS system and estimate the future tasks regarding the application of SLA and the generalization of GBS regime; and finally provide feasible recommendations addressing these issues.

This dissertation will commence from the research of the current progress on GBS made by IMO, including the new SOLAS amendment and relevant standards and guidelines, so an overview of the current GBS system can be presented by synthesizing and constructing relevant information. Based on the analysis of the framework of the current GBS system, potential problems, limitations and disadvantages of the current system can be identified and assessed, taking into account the related research and opinions from experts. Then the necessity of promotion or future development of associated aspects can be confirmed and potential choices of solutions addressing the problems can be approached. By comparing and analyzing the advantages and disadvantages of alternative solutions, feasible proposals and recommendations will be concluded.

1.3 Structure of the dissertation

To start with, chapter 1 will provide a general idea about the current development of GBS in the Maritime world raising the issues in question regarding relevant future work, and then introduce the framework of this dissertation.

In the second chapter, the key progress in different periods during the development of GBS will be presented, emphasizing the initiative, methodology and basic principles of GBS, the five-tier structure of the GBS system, and the latest approved IMO instruments. Then an overview of the current GBS system will be summarized as a basis for further analysis.

In the third chapter, the effects of GBS on the maritime regulatory system and the industry will be evaluated taking account of both positive and negative aspects. Advantages in respect of the role of IMO in structural standards, technical transparency and technical renovation and challenges in achieving functional requirements and verification criteria are discussed.

Chapter 4 will identify the controversial issues and practical problems in the implementation of GBS, during which the workload and resources in the verification audit scheme and the response of classification societies will be analyzed in detail. Practical recommendations will be proposed to aid the implementation work.

Chapter 5 will elaborate the SLA as a method to develop the GBS system, during which associated concepts such as risk-based approach and formal safety assessment are introduced and the function of SLA in controlling maritime safety is analyzed. By discussing the progress of SLA, problems in the use of SLA are disclosed and corresponding solutions are suggested. The coverage of the current GBS system will be analyzed and the process to expand GBS application will be discussed. A recommended scheme on GBS generalization will be suggested considering the necessity and feasibility of the expansion process.

In the last chapter, a holistic conclusion will be drawn in regards to the current GBS system covering all aspects including the current progress, potential effects, implementation scheme and future development. Recommendations will be summarized to form a systematic scheme of the future work on GBS.

CHAPTER II DEVELOPMENT OF GBS SYSTEM IN MARITIME FIELD AND ITS LATEST PROGRESS

2.1 Difference between a goal-based standard and a prescriptive standard

The traditional standards, which have become familiar to people over the historical development of standards, are mostly prescriptive ones. Prescriptive standards tell people what to do and/or what to avoid doing. Specific means of achieving compliance are usually clearly stipulated in prescriptive standards. For instance, "You shall install a 1 meter high rail at the edge of the cliff" is a typical prescriptive regulation. It specifies the explicit and exclusive means of "a 1 meter rail" in order to prevent people from falling over the edge of a cliff (Penny & Eaton, 2001, p. 35).

Goal based standards (GBS) came after prescriptive ones and were developed only in the last 10 years. A goal based standard differs from a prescriptive standard in its methodology. It tells people what to achieve rather than what to do. It does not specify the means of achieving compliance but sets goals that allow alternative ways of achieving compliance (Kelly, McDermid & Weaver, 2005). For the same example, a goal based standard will require that "people shall be prevented from falling over the edge of a cliff" (Penny & Eaton, 2001, p. 35). All kinds of measures other than a rail can be permitted if only they can achieve the same function. Although GBS have only been developed for a few years, the tendency of their adoption is increasing nowadays and they are believed to be preferable to more prescriptive regulations (Penny & Eaton, 2001).

2.2 Introduction of GBS into Maritime field

The concept of "goal-based ship construction standards" was introduced in IMO in November 2002 at the 89th session of the Council, when Bahamas and Greece submitted such a proposal together. The proposal suggested that "IMO should develop initial standards that would permit innovation in design but ensure that ships are constructed in such a manner that, if properly maintained, they remain safe for their entire economic life", and "the standards must also ensure all parts of a ship can be easily accessed to permit proper inspection and ease of maintenance" (International Maritime Organization, 2002b, p. 1).

The introduction of GBS to IMO has its reasonable technical background. Around 2000, 3 accidents which led to serious casualties occurred. They were NAHODKA in 1997, ERIKA in 1999 and PRESTIGE in 2002, and each of the involved ships was more than 25 years old. So considerations were raised by administrations on whether there were some deficiencies in the present regime of ship construction in which ships were designed, constructed and maintained according to the rules of classification societies. At that time there was no international legislation or guidance addressing these matters (Nakajima, 2006).

The proposal necessitated the enhancement of structural safety by IMO, and aimed to suggest that IMO play a more important role in determining ship construction standards, which is traditionally the responsibility of classifications and shipyards. Following the 89th Council, a proposal for developing goal based standards was submitted by Greece and Bahamas in MSC 77. Over the next two years' intensive discussion, the 23rd session of IMO Assembly decided to include the "Goal-based new ship construction standards" into IMO's strategic plan and long-term work plan ("Goal-based construction", 2011).

GBS are not a completely new concept in the work of IMO. They were employed by the IMO in some specific subjects although it was not in a systematic manner, such as the 2000 amendments of SOLAS Chapter II-2 on fire protection, fire detection and fire extinction, as well as the 2006 amendments of SOLAS Chapter II-1 and II-2 on the Safety of large passenger ships. In the revised SOLAS Chapter II-2, regulation 2 sets up the fire safety objectives and the functional requirements. Sections of "Purpose" were added from regulation 4 to regulation 20 containing the objectives and functional requirements in order to assist administrations to resolve matters which are not fully addressed by the prescriptive requirements. In the revised Chapters on safety of large passenger ships, a guiding philosophy, strategic goals and objectives are included in the new approach for the revision. The new regulatory approach set up the goal that "a ship should be designed for improved survivability so that, in the event of a casualty, persons can stay safely on board (in a safe haven) as the ship proceeds to port" (Hoppe, 2005, p. 3). This approach was recognized as holistic in nature and tended to be an ideal method to develop a future regulatory framework for passenger ships.

2.3 Methodology of the development of GBS

The MSC commenced detailed technical work on the development of GBS at its 78th session in May 2004, and a working group on GBS was established at MSC 79 and MSC 80 to address the research. From the initiation of the issue there were diverging views in the Committee on how to approach the development of GBS for new ship construction. Some IMO Members advocated applying a risk-based approach which would establish a procedure to evaluate the current safety level of existing mandatory regulations related to ship safety, and furthermore consider setting up future risk acceptance criteria using the Formal Safety Assessment (FSA) approach. This methodology is known as Safety Level Approach (SLA). Other Members supported a more deterministic approach, which emphasizes the necessity of clearly quantified functional requirements, which should be achieved based on the vast practical experience of oil tankers and bulk carriers over the years. This methodology is usually called Deterministic Approach (Hoppe, 2005).

The SLA is recognized as a holistic approach which is supposed to be an ideal basis for the future development of GBS system. It can provide a quantitive analysis of safety level and address the problem with cost-effective means employing the FSA process, so the safety level of ships can be clearly defined and controlled with this approach. However, SLA needs much research work to assess the risk of a variety of elements and is regarded as a long range work. For pragmatic reasons, many states supported proceeding with the Deterministic Approach in order to make it more practical. An agreement was made that the SLA should be further explored over the next few sessions while proceeding with the deterministic approach at the same time. That means both of the approaches were planned to be carried out on a parallel track (International Maritime Organization, 2005).

As far as the deterministic approach is mentioned, one important activity of its application is the Pilot Project on the trial application of verification process using the International Association of Classification Societies (IACS) Common Structure Rules (CSR). "The objective of the pilot project was to conduct a trial application of Tier III of the GBS for oil tankers and bulk carriers with the intention of validating the Tier III verification framework, identifying shortcomings and making proposals for improvement and implementation" (International Maritime Organization, 2006g, p. 61). The Verification process and standards were tested and promoted in a practical sense when the project was finished, and further amendment of the verification of compliance was achieved together with a new revision of functional requirements. The usage of the pilot project can be regarded as an application of the deterministic approach because it employs the existing experiences of the development of CSR to pursue the new verification standards. It was proven that the deterministic approach contributed a lot to make the new standards more practical and applicable.

2.4 Basic principles of goal-based standards

In order to provide a direction and objective for the development of the GBS system, it is necessary to define the basic principles of GBS. The basic principles of IMO GBS was considered and developed by the working group at MSC 79 and agreed at MSC 80, as shown below.

> IMO goal-based standards are:
>
> 1. broad, over-arching safety, environmental and/or security standards that ships are required to meet during their lifecycle;
> 2. the required level to be achieved by the requirements applied by classification societies and other recognized organizations, Administrations and IMO;
> 3. clear, demonstrable, verifiable, long-standing, implementable and achievable, irrespective of ship design and technology; and
> 4. specific enough in order not to be open to differing interpretations.
>
> (International Maritime Organization, 2004c, p. 9)

These principles specified the scope and basic features of GBS. It should be noted that these basic principles "were developed to be applicable to all goal-based standards developed by IMO and not only goal-based new ship construction standards" (International Maritime Organization, 2004c, p. 3). All goal-based standards developed by IMO should follow the same principles even if GBS are further expanded to other areas.

2.5 The five-tier framework of the GBS system

Since the proposal for a framework of GBS was submitted on MSC 78 by Bahamas, Greece and IACS, broad discussions concerning the GBS structure were held among the member states, international organizations and working groups through the next few sessions. After a general debate of the issues, the Committee agreed to utilize a five-tier system proposed in MSC 78/6/2, which consists of a five-tier structure as shown in Figure 1.

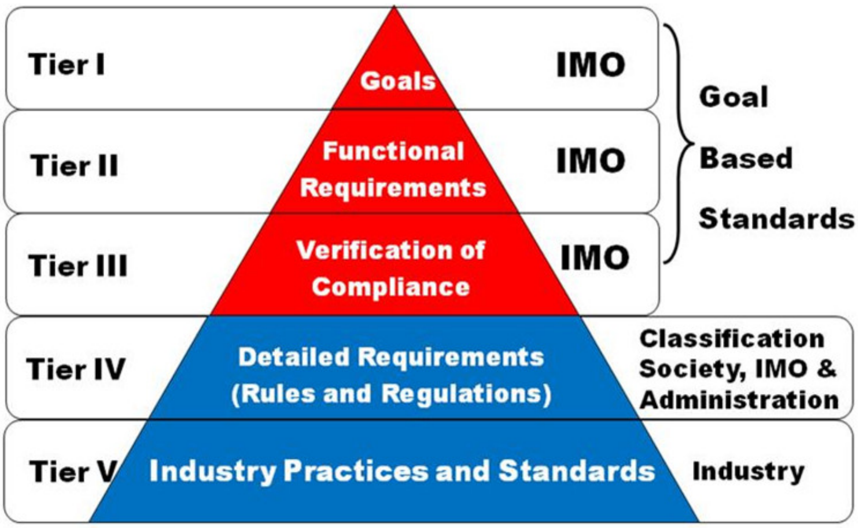

Figure 1- Goal-based standards framework

Source: Nakajima, Y. (2006, Sep 15). *IMO Goal-based Standards- A shipbuilders' point of view.* Japan.

In such a GBS framework, Tier I stipulates a set of goals to be achieved in ships construction and operation so as to ensure safety and environmental friendliness. Tier II develops a set of requirements to be complied with regarding the functions of the ship structures, which support the above-mentioned goals. Then Tier III provides the procedures and instruments necessary to demonstrate that the detailed requirements (mainly rules in terms of ship construction) in Tier IV comply with the Tier I goals and Tier II functional requirements. As it goes down, Tier IV refers to the detailed requirements developed or applied by IMO, national Administrations and/or classification societies acting as Recognized Organizations to the design and construction of a ship in order to meet the Tier I goals and Tier II functional requirements. At last, Tier V refers to industry standards and shipbuilding and design practices that are applied during the design and construction of a ship (Hoppe, 2005).

In the 5-tier structure of the framework, higher level tiers govern the lower level ones and lower tiers serve and support the upper ones in general. The GBS of new ship construction consist of Tiers 1, 2 and 3, which are goal-based without prescriptive requirements, and should be developed by IMO and under the charge of IMO. Tiers 4 and 5 can be prescriptive, providing detailed requirements to support the Tiers 2 and 1, and make the goal based standards applicable and practical. Tier 3 builds up a link between goal-based standards and prescriptive requirements, forming the two parts as an integrated standard system. One more point should be emphasized that Tier 2 should fully cover Tier 1, which means when all the functional requirements are met, the achievement of Tier 1 goals is ensured, and therefore the verification of application can just focus on the conformation of the functional requirements.

The establishment of GBS framework can be seen as a basis of the GBS development because it set up the Goal-based structure in the international maritime field. It describes the logical relationship between different levels of IMO instruments and provides an instruction for the future development of IMO in a goal-based structure. The future regulatory system of IMO will be based on this essential structure.

2.6 The latest progress in IMO with regard to GBS

Since the 5-tier GBS framework was established, IMO continued to work on the specific regulations in Tier I and Tier II, and the draft guidelines for Tier III by establishing working groups and correspondence groups. IMO also planned to develop new amendment to the SOLAS convention in order to make GBS for bulk carriers and oil tankers mandatory. After great efforts and deliberations in the next few years, 3 important final drafts regarding the GBS system were achieved last year. On 20 May 2010, MSC of IMO formally adopted International Goal Based Ship Construction Standards for Bulk Carriers and Oil Tankers at its 87th session, along with amendments to SOLAS Chapter II-1, making their application mandatory, with an entry into force date of 1 January 2012. The Committee also adopted the Guidelines for the Verification of Compliance with GBS, which give the Organization a role in verifying compliance with the aforementioned SOLAS requirements (International Maritime Organization, 2010d).

2.6.1 New amendment of SOLAS Chapter II-1

The amendment of SOLAS Chapter II-1 on GBS for bulk carriers and oil tankers started in MSC 83 with the purpose to incorporate the GBS requirement into the ship safety convention system and make it mandatory. It was also agreed that this work should be done after the GBS for bulk carriers and oil tankers were finalized.

In the new adopted amendment of SOLAS Chapter II-1, a new "Regulation 3-10 Goal-based ship construction standards for bulk carriers and oil tankers" is added after the existing regulation 3-9. This new regulation stipulates the application of the requirement as shown below:

1 This regulation shall apply to oil tankers of 150 m in length and above

and to bulk carriers of 150 m in length and above, constructed with single deck, top-side tanks and hopper side tanks in cargo spaces, excluding ore carriers and combination carriers:

.1 for which the building contract is placed on or after 1 July 2016;

.2 in the absence of a building contract, the keels of which are laid or which are at a similar stage of construction on or after 1 July 2017; or

.3 the delivery of which is on or after 1 July 2020. (International Maritime Organization, 2010g, pp. 5-6)

This new regulation also sets up a set of general goals, which are also stipulated in Tier I of the GBS system, for the new construction of ships:

2 Ships shall be designed and constructed for a specified design life to be safe and environmentally friendly, when properly operated and maintained under the specified operating and environmental conditions, in intact and specified damage conditions, throughout their life. (International Maritime Organization, 2010g, pp. 5-6)

Following the above statement regarding the goals to be achieved, more specific interpretations including the meaning of “safety”, “environmental friendly” and “design life” were clarified. The amendment also stipulates that the requirements above shall be achieved through satisfying applicable structural requirements of a recognized organization, conforming to the functional requirements of the Goal-based Ship Construction Standards for Bulk Carriers and

Oil Tankers. The amendment also requires a Ship Construction File conforming to the guidelines developed by IMO to be provided upon delivery of a new ship and maintained during its operation (International Maritime Organization, 2010g).

The SOLAS amendment provides a strong legal base for the application of the GBS, and addresses new ship construction on a goal-based level. The application of the requirements covers the two mainstream ship types of large scale in which most experiences are accumulated in the practice of main classification societies.

2.6.2 International Goal-Based Ship Construction Standards for Bulk Carriers and Oil Tankers

The task to develop GBS for bulk carriers and oil tankers started originally when GBS was included into the IMO work plan. A working group was established in MSC 79 to address this issue *inter alia*, as a main task in the prescriptive approach. In order to focus the discussion, the consideration was restricted to these two main ship types for the time being, based on experience gained from the development of IACS Common Structure Rules.

In the new "International Goal-Based Ship Construction Standards for Bulk Carriers and Oil Tankers", the Tier I-Goals are stipulated in the same words as in the new amendment of SOLAS Chapter II-1. In Tier II, the functional requirements (applicable to bulk carriers and oil tankers in unrestricted navigation) are provided in fifteen aspects which consist of the following structure and cover the whole lifespan of a ship including design, construction, in-service operation and recycling.

DESIGN

II.1 Design life

II.2 Environmental conditions

II.3 Structural strength

II.4 Fatigue life

II.5 Residual strength

II.6 Protection against corrosion

II.7 Structural redundancy

II.8 Watertight and weathertight integrity

II.9 Human element considerations

II.10 Design transparency

CONSTRUCTION

II.11 Construction quality procedures

II.12 Survey during construction

IN-SERVICE CONSIDERATIONS

II.13 Survey and maintenance

II.14 Structural accessibility

RECYCLING CONSIDERATIONS

II.15 Recycling (International Maritime Organization, 2010h, pp. 6-9)

From this outline it can be seen that the functional requirements have been extended from the original scope of construction to other important aspects, covering all the lifespan of a ship, thus a “from cradle to grave” regime was incorporated in the GBS Tier 2.

Detailed functional requirement are provided for each aspect in the Standards. For instance, as the design life is mentioned, it is demanded that “The specified design life shall not be less than 25 years”, and as far as the environmental conditions are concerned, it is required that “Ships shall be designed in accordance with North Atlantic environmental conditions and relevant long-term sea state scatter diagrams” (International Maritime Organization, 2010h, p. 6).

In Tier III of the Standards, it is clarified that the term “verification” means “the rules for the design and construction of bulk carriers and oil tankers as described above have been compared to the Standards and have been found to be in conformity with or are consistent with the goals and functional requirements as set out in the Standards” (International Maritime Organization, 2010h, p. 10).

2.6.3 Guidelines for the Verification of Compliance with GBS

In the new Guidelines for the Verification of Compliance with GBS there are two parts of requirements. Part A specifies that “the verification process consists of two main elements: self-assessment of the rules by the Submitter and an audit of the rules, the self-assessment and the supporting documentation by the Organization” (International Maritime Organization, 2009e, p. 5). It also describes how the verification should be carried out and how the responsibilities and tasks are distributed, as shown in Figure 2. Part B plays a key role in the verification implementation and consists of three steps in a verification practice for each functional requirement in the GBS system, which includes statement of intent, information and documentation requirements and evaluation criteria (International Maritime Organization, 2009e).

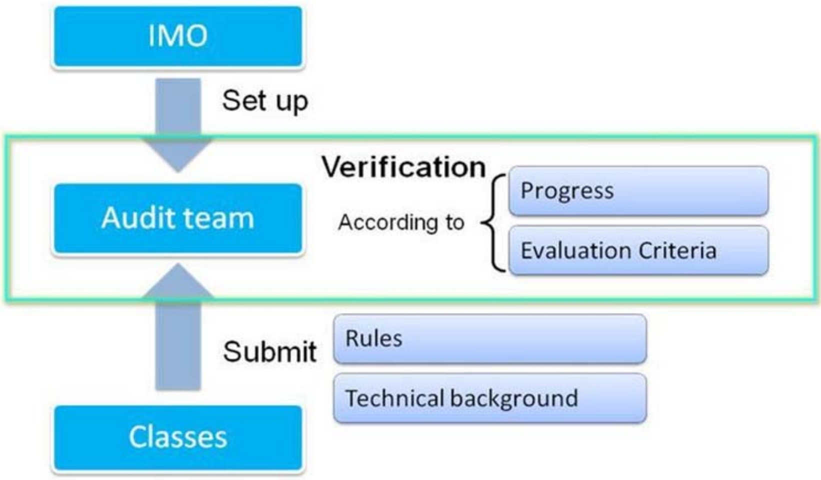

Figure 2- Mechanism of rules' verification

For example, in order to demonstrate the conformity to the functional requirement of Design Life, it is to confirm that the specified design life is at least 25 years and this life span is incorporated in the rules. Regarding the information and documentation, there should be a statement of design life in years used in developing the rules, and a description of the assumptions and methods should be used to incorporate design life into the rules including consideration of extreme loads, design loads, fatigue and corrosion. Regarding the evaluation criteria, design parameters including structural strength, fatigue and corrosion additions should be used in the rules based upon the specified design life, and at the same time the design life should be properly applied in sections of the rules where specified (International Maritime Organization, 2009e).

With respect to the implementation of verification, practical consideration besides these guidelines such as the timetable and schedule of activities for the implementation of the GBS verification scheme, and the funding of the verification scheme were also addressed and discussed. Up to now all the goals, functional requirements and verification approach are decided and there is detailed practical consideration, so it can be assumed that the GBS for bulk carriers and oil tankers are basically ready for implementation. Then the future work for the classification societies is to submit their rules for classification and develop their rules continually complying with the GBS.

2.6.4 Generic Guidelines for Developing Goal-based Standards

The task of developing a generic GBS framework was proposed at MSC 84 in the report of the GBS correspondence group. It was deemed necessary to develop such a framework for all new or revised IMO regulations, class rules and other mandatory standards to be followed in an agreed mode (International Maritime Organization, 2008). Draft of the guidelines were made in MSC 84 and amended in following sessions, and the final version was approved at MSC 89 in May 2011 with the instrument of MSC.1/Circ.1394.

Generic Guidelines for Developing Goal-based Standards were developed based on the experiences obtained from the establishment process of the International Goal-Based Ship Construction Standards for Bulk Carriers and Oil Tankers. The purpose of developing the Generic Guidelines is to provide a standardized process to develop, verify, implement and monitor GBS so that the future regulatory development of IMO GBS can be guided. It should be noted that the guidelines are both applicable to the deterministic approach and the safety level approach. In such a sense, the guidelines give a systematic instruction to carry out the GBS regime in a holistic view, and can be regarded as a base for IMO to extend the GBS system to all ship types and ship aspects.

Regarding the GBS Tier 1 of Goals, the guidelines require that goals which are high-level objectives to be met should "reflect the required level of safety", so the principle of taking risk-based approach into account is provided. Regarding the Tier 2 of functional requirements, it is instructed that "functional requirements provide the criteria to be satisfied in order to meet the goals", and "once a goal has been set, functional requirements are defined". The guidelines also require the functional requirements to be developed according to experiences, assessment of existing regulations or systematic analysis of relevant hazards, covering all functions and areas necessary to meet the goals. Concerning Tier 4, it is specified that the rules and regulations refer to detailed requirements which form a part of GBS framework after verification as conforming to the GBS. Concerning Tier 5, it is clarified that the suitability of industry practice and standards incorporated into or referenced in rules/regulations should be justified by the rules/regulations' submitter and should be provided during verification of conformity (International Maritime Organization, 2011b).

Besides the development of GBS instruments, the guidelines also set up the fundamental key points in regard to monitoring including the basic process, main consideration and responsibility of each tier. At last an example of a goal-based regulation structure was provided which can be a model format for new developing GBS (International Maritime Organization, 2011b).

It can be concluded that the guidelines provide requirements in principle regarding the development of GBS. In order to make it broad, generic and applicable to all ship types and aspects, the guidelines do not contain technical criteria within specific ship types. Nevertheless, the guidelines are a preparation document for further development and the holistic expansion of the GBS regime throughout the whole maritime regulatory system.

2.6.5 The Progress of Safety Level Approach

After the MSC 80 agreed on two parallel tracks with both the deterministic approach and the safety level approach, two correspondence groups on SLA were established to address this issue between MSC 81 and MSC 83. The main considerations identified included the evaluation of current safety level, relationship between GBS and FSA, development of risk models and common terminology of FSA. Other tasks such as Tier structure for use in the safety level approach, and examination of Tier 2 and Tier 3 for the GBS for bulk carriers and oil tankers was also conducted within the correspondence group as well as the session (International Maritime Organization, 2007). Some tasks proceeded but did not reach an applicable stage. For example, statistical data referring to different ship types and risk categories were collected but they were difficult to interpret at the IMO level (International Maritime Organization, 2006f). Due to difficulties such as lack of sufficient experience and data, it was believed the SLA should be a long term project with further research work. As the deterministic approach reached a substantial stage, SLA was placed as a high-priority issue for future study at the MSC 89 in 2011 (International Maritime Organization, 2011a).

2.7 Summary of the current GBS system

The establishment of GBS is based on the concept of “rules for rules”. GBS defines standards which determine the goals to be achieved without specifying the specific solutions, which means the focus of GBS is what to achieve, not how to achieve it. The application of GBS in the maritime field means an important change of methodology for the development of the regulation system: from an empirical regime to a goal-based regime.

With the adoption of the amendment to SOLAS Chapter II-1 together with “International Goal-Based Ship Construction Standards for Bulk Carriers and Oil Tankers” and guidelines for the Verification of Conformity with GBS, IMO has accomplished the main paper work for the GBS system for bulk carriers and oil tankers. The SOLAS amendment provides a legal basis for the application of GBS. The goal-based construction standards set up the goals and functional requirements which are the first 2 tiers in the GBS framework, and the guidelines for verification specify the criteria and procedure for verification process which belongs to GBS Tier 3. Along with other practical considerations, the GBS regime is ready to be implemented, which means the GBS has come to the implementation stage. Furthermore, these instruments are developed mainly based on the experiences obtained from long term practice, so it also means the deterministic approach has made substantial progress.

The current GBS regime is accomplished only in a limited domain, *i.e.* the structure of bulk carriers and oil tankers. However, the implementation of GBS in this domain will act as a trial and will obtain more experience, which is very helpful for further development and expansion of the GBS application. The application scope of the current GBS regime (shown in Figure 3), *i.e.*, the structure of oil tanker and bulk carriers (in red), only covers a small part of the whole maritime safety and environmental protection system. There are other ship types including container ships and passenger ships in the structure aspects which are not covered, and there are also other aspects besides structure such as machinery and electrical installations which are not covered yet. As agreed in MSC, the GBS regime, in the long term perspective, should cover all other aspects relevant to new buildings, including safety, environmental protection and quality assurance.

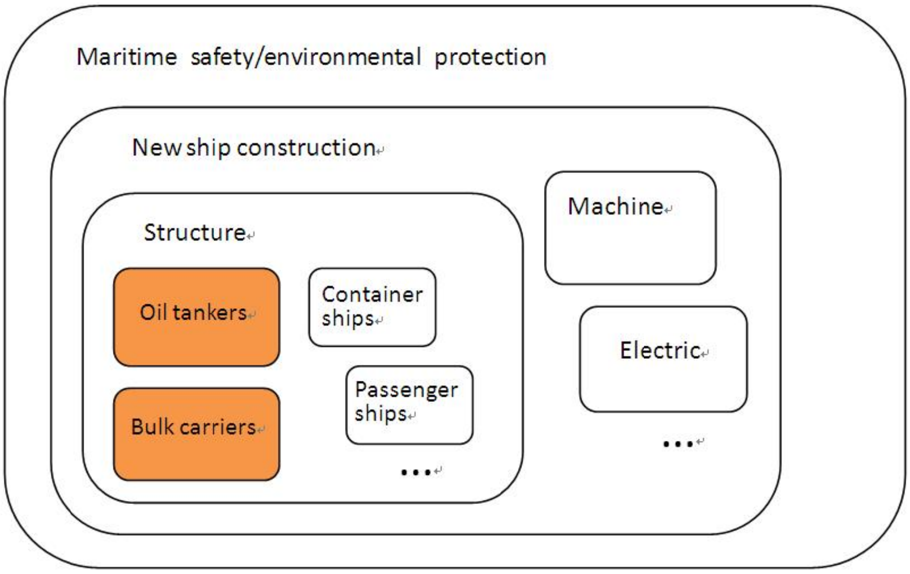

Figure 3- The coverage of GBS in the maritime field

In the domain which is covered by the GBS regime, the Amendment of SOLAS Chapter II-1 serves as the legal basis for implementation, supported by the goal-based ship construction standards and the guidelines for verification; in the domain of other ship types and aspects, the generic guidelines for developing GBS can be employed to expand the application, as shown in Figure 4.

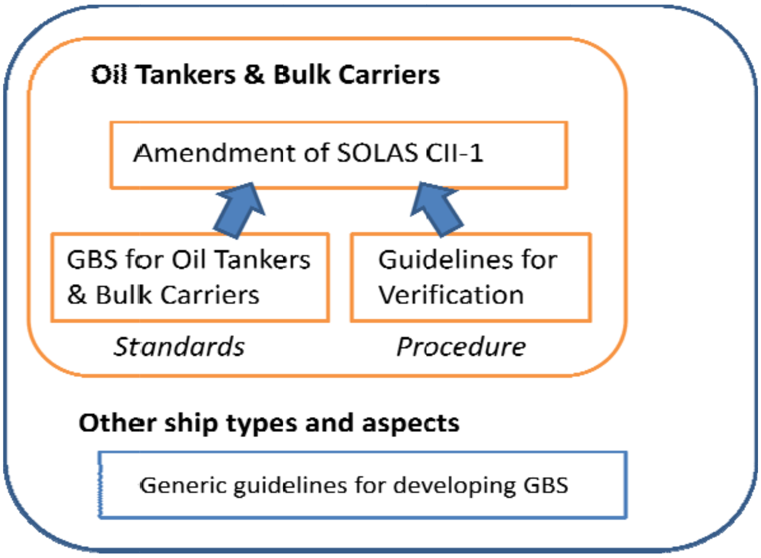

Figure 4- The application of GBS in the maritime field

Another point should also be noted that the GBS for oil tankers and bulk carriers are not currently examined with the safety level approach. They are still mainly based on historical experiences under the deterministic approach. The risk of ships has not been analyzed and the safety level has not been confirmed. These tasks would be carried out during the further development of SLA. As agreed in the latest MSC session (MSC 89), the further development of SLA was arranged as a high-priority issue. At the same time, the current prescriptive method should also proceed due to the difficulties in the development of the SLA (International Maritime Organization, 2011a).

CHAPTER III EFFECTS OF GBS ON SHIP CONSTRUCTION

Since the first SOLAS convention was developed nearly 100 years ago, traditional standards, which are prescriptive, have been applied by the maritime field. We are familiar with such kind of regulations and recognize that they help the industry a lot. After each major maritime accident, relative requirements were complemented to the existing conventions or codes, so the safety level was constantly promoted with the lessons learned. Presently, the GBS, which regulate the industry by a different new method, are introduced to the maritime field and are becoming a governing system for ship construction. With the application of the system, new concerns are arising in the maritime world.

Traditional standards are generally clear about what needs to be done, but can become difficult to apply in changing circumstances. Goal-based standards offer more flexibility, but raise a number of concerns. Most notably they introduce ambiguity about what is required to achieve compliance. As a result, questions may arise as to whether the new standards system will work better than the old one. In the following section an analysis is carried out on the challenges and opportunities posed by goal-based standards.

3.1 Advantages of GBS regime

3.1.1 A more important role of IMO on the development of ship construction standard

As far as the opportunities and advantages are concerned, the first point is that the standards of ship structure will be controlled and supervised by IMO to a further degree. It was widely recognized that "the premise behind the development of goal-based standards is that IMO should play a larger role in determining the fundamental standards to which new ships are built" ("Goal-based construction", 2011). In the unrevised SOLAS convention, there are no substantial requirements for ship structure to ensure the strength of ships. The only statement with regards to the construction of ship structure is that ship structure "shall be designed, constructed and maintained in compliance with the structural, mechanical and electrical requirements of a classification society" ("International Convention for the Safety of Life at Sea", 2009, p.36).

It is widely accepted that the structure of ships is a basic element in ship safety. Because of the technical characteristic and the historical practice, this important issue was addressed by the classification societies all along. It is difficult for the IMO to incorporate into its own conventions or codes, so there is insufficient control of ship construction at the convention level. As a result, ship structure can be seen as a gap of safety in the SOLAS system.

It should also be noted that there is no intention for IMO to take over the detailed work of the classification societies, but IMO would state what has to be achieved, leaving classification societies, ship designers and naval architects, marine engineers and ship builders the freedom to decide on how to employ their professional skills in the best way to meet the required standards. With the new amendment based on GBS, goals and functional requirements are added into SOLAS with a footnote referring to the goal-based standards, and then a holistic requirement for ship structure which can act as a basis for ship safety is provided in the convention, which means the GBS application helps to supplement the gap in SOLAS (“Goal-based construction”, 2011).

As far as the role of IMO in ship safety is mentioned, another point which should not be neglected is that GBS would help the regulatory system to be proactive. The current regulatory system in IMO is based on a reactive approach. Many regulations were “adopted *ad hoc* in the aftermath of catastrophic accidents”, such as Exxon Valdez, Estonia, Erika and Prestige, which means the regulations were solely a response to accidents and were always one step behind. Therefore, it is necessary to identify the main factors that affect safety on board at an early stage, so that regulatory actions can be developed before undesirable events occur (Psaraftis, 2006). With the safety level approach of GBS, a risk-based proactive approach would be employed to identify conceivable hazards before they lead to accidents. It has the potential to look beyond the limitation of existing lessons, conduct a before-event analysis, and provide corresponding solutions (Lee, 2009).

3.1.2 Uniform goals and functional requirements for rules

The GBS for bulk carriers and oil tankers establish uniform goals and functional requirements for all the rules from different classification societies. As agreed in the research work on SLA, the safety level of ships lies in and is determined by the goals and functional requirements. Since the goals and functional requirements were united, the safety level is decided as the same. The unification of goals and functional requirements would facilitate control of the safety level. For example, before the GBS were developed, ships’ design life differed among different classification societies. Ships were designed according to a lifespan of 20 years in the previous rules of ship construction from ClassNK, while at the same time a 30 years' service life was demanded in the rules of Lloyds. Based on different design lives, there are different dimensions for plates and beams even in the same location on ships of the same size. In such a case, the safety level of ships designed with different rules differs very much. With the new GBS requirement, ship design life is stipulated to be no less than 25 years, and the main classification societies all adopted a 25 year life span (International Maritime Organization, 2010 g). Even though classification societies can achieve the uniform goal in multiform methods, it is easy to compare the safety level with a certain design life.

According to economic laws, a lighter ship with smaller scantling will be more attractive to new ship buyers. The competition of the market tends to drive classification societies to cut down the ship costs by reducing the required scantling as much as possible. Such competition in the standards domain will bring hazards to the ship safety. The unification of standards at a goal-based level is helpful to "remove the possibility of competition between classification societies in the quality", which will contribute to the safety of ships from the construction period (International Maritime Organization, 2002b, p. 2).

3.1.3 Promotion of rule development

As the 5-tier GBS framework was established, a governing law was formed to direct the development of the rules of classification societies. All the rules developed by different societies must comply with Tier 1 and Tier 2 through the verification process. Classification Societies have the responsibility to demonstrate the conformity with enough technical background information behind the text and formulas, which is a positive process for the development of the rules.

During the Pilot Project on the trial application of verification process using the IACS Common Structure Rules, a series of gaps, where relevant functional requirements cannot be fully covered by the rules items, were found in the CSR for oil tankers. Even though the purpose of the Pilot Project is to validate the guidelines for verification, not to verify the rules themselves, IACS endeavored to find evidence to illustrate CSR’s conformity with GBS when preparing the documentation package. These gaps include the areas of residual strength, structural redundancy, human element considerations, design transparency, survey and maintenance and recycling (International Association of Classification Societies, 2008). In order to fill these gaps, IACS took measures such as revising rule items or seeking technical support according to the requirements in the verification guidelines. Furthermore, in the proceeding CSR Harmonization project, which is to incorporate CSR for oil tankers and bulk carriers into one harmonized version, the guidelines of verification are deemed as new criteria for the further development of IACS rules (Tikka, 2010).

3.1.4 Technical transparency

While the application of GBS urges the promotion of rules, it also helps to ensure the transparency and justification of rules. Regarding the standards, transparency means “being clear and justified of the safety level that is achieved”; therefore, it is helpful for the whole industry to evaluate and assess the safety level of the standards (Penny & Eaton, 2001). In the history of maritime operation, classification societies had the full authority to develop their own rules for ship construction according to experiences in their business. They decided their scantling and formulations without the necessity to explain why these standards were valid. On the contrary, the technical background behind the requirements of rules was kept secret as a method to protect their technical authority. According to GBS Tier III, rules of classification societies are required to be verified to conform to the goals and functional requirements; therefore, classification societies have to provide the evidence with which the rules achieve the goals and functional requirements.

During this process classification societies must show the reasons for each specific regulation and formula in their rules to both IMO and the industry, and then the transparency and justification can be presented (Kelly, McDermid, & Weaver, 2005).

3.1.5 Open standards system for technical innovation

The GBS system is an open standards system ready for technical innovation. Technologies always run faster than standards. As technologies change, standards also change, but generally, they change relatively slowly – for example, IEC (International Electrotechnical Commission) 61508 [4] took more than ten years to be produced; nevertheless, after six years of issue, it was already being updated. Prescriptive requirements stipulate the specific methods, so if there are novel technologies applied in different methods, prescriptive standards are not capable of regulating them properly; therefore, they run the risk of always being "behind the curve" of technology. Prescriptive standards may not properly regulate new technologies; on the contrary, they may result in unnecessary expense or hazards because inefficient assessment techniques are used when there are better technologies. So prescriptive regulations encode the best engineering practice at the time they were written and rapidly become deficient when best practice is changing with evolving technologies (Kelly, McDermid, & Weaver, 2005).

Unlike the prescriptive standards, goal-based standards are flexible and open to new technologies by permitting various approaches to the same goal and functional requirement. Without the restriction of specific solutions, all the novel technologies are welcome and the most cost-effective and safest ones tend to be employed based on market mechanism. Nowadays, new technologies are developed at a rather high speed. The Green Ship technologies such as fuel cell and wind power are spurred to be provided by human beings as environmental problems prove to be more and more serious. The GBS system leaves a broad space for more technical innovation without restrictions for the usage of modern technologies.

3.1.6 Sustainability of standards

The application of GBS can improve the sustainability of standards. Historical practice indicated a trend wherein there were more and more revisions to SOLAS over the years as well as other international maritime conventions, and such a situation will continue. These amendments and revisions impose a huge amount of endless work to IMO and its committees. As the president of the Polish Register of Shipping said, “the number of exceptions appearing with time leads to the proliferation of regulations, which are difficult to absorb by the maritime industry” (Polish Register, 2009). Facing such a situation, GBS can give a solution to let the standards keep up with the time. The GBS regime in the future will apply not only to the rules of classification societies, but also to conventions and regulations developed by IMO, so it provides an option to leave some technical parts of the regulatory system regarding detailed prescriptive requirements to professional organizations. The GBS regime separates the functional requirements and prescriptive regulations in different tiers, thus the functional requirements lying in a higher level are more stable. When time changes and the detailed prescriptive regulations are proved to be insufficient, the functional requirements may still be applicable. Subsequently the organizations that issued the regulations do not have to revise the standards so frequently, so this can help to maintain the sustainability and continuity of standards and liberate the time and labor of IMO to more strategic issues.

3.2 Challenges and limitation of GBS regime

Everything has two sides. While the GBS system provides many opportunities for the management and development of standards, there are also challenges brought to the system itself. Two major problems are raised by the new standard system. One is the question of how to achieve acceptable functional requirements because it is difficult to find functional requirements which are both consistent with the goal and viable for the temporary technical condition. The other is the question of how to verify the rules' conformity to goals and functional requirements (Kelly, McDermid, & Weaver, 2005).

3.2.1 Problems in achieving acceptable functional requirements

From the risk based point of view, safety is not absolute. "A system is deemed safe when the level of risk it poses is acceptable, or tolerable", and "the level of risk which is judged acceptable, or tolerable, depends on many factors" including "who is put into risk", "the dread of the risk" and "whether or not the risk is taken on voluntarily" (Kelly, McDermid, & Weaver, 2005, p. 2). In order to achieve the general goal which is on the top of the GBS system, analysis must be made to break the general goal into sub-goals and functional requirements. How is it possible to find the proper functional requirements and verify that they comply with the goals? When a new standards system is framed, it tends to be necessary to seek answers or aid from the existing standards. The method conducted in IMO involved mobilizing professional experts to extract the major factors and aspects from the vast elements in practice.

However, the current functional requirements are mainly based on the experiences of practice, and they have not been tested by a risk based approach due to practical and technical difficulties. The risk based approach, which is defined as SLA in GBS research, also depends on former experience. The risk analysis including the identification of risk model and safety level assessment depends a lot on the statistical data and accident information. The result of analysis, which will further decide the risk based functional requirements, should also be achieved through a comprehensive and accurate distillation according to former experience. Therefore, even if in the future the SLA is established to an applicable level, it still cannot make GBS absolutely proactive, and these functional requirements will still be open to amendment with the development of new practice.

3.2.2 Problems in verifying the conformity

The prescriptive regulations are usually clear and explicit. While the criteria are stipulated in those standards, the specific measures are also provided. Dissimilarly, GBS are vague and implicit in terms of valid measures. The verification process builds up a bridge between what is to be achieved and what is to be done, linking the functional requirements and prescriptive regulations. To build such a linkage, it must be found "how to decide on what constitutes sufficient evidence" (Kelly, McDermid, & Weaver, 2005, p. 5). Solutions could also be sought based on existing applicable standards.

During the development of GBS for oil tankers and bulk carriers, a pilot project on the trial application of the verification process was conducted using the IACS CSR. Comparing the rules provisions with the functional requirements, IMO developed a 3-step verification mode within the Guidelines for the Verification of Compliance with GBS. This approach is a reverse application during which existing rules were used to find suitable verification process and criteria. It should be recognized that it is a necessary process to employ previous experience to instruct the establishment of standards. However, this approach has an obvious limitation, because its validity depends on the conformity level of the existing rules. That is to say, if the CSR cannot fully cover all the functional requirements and this is not realized by the experts, then the verification developed through the trial application may be deficient, which means there still might be gaps between Tier 2 and Tier 4. As a result, there is always probability of deficiency when the verification criteria are developed from standards whose conformity level is unsure.

CHAPTER IV PROBLEMS IN GBS IMPLEMENTATION

4.1 Timetable for GBS implementation

As the GBS regime has proceeded to an implementation stage, detailed considerations in respect to the implementation have been discussed and a specific plan has been scheduled. At the MSC 86th session, the Committee approved the timetable and schedule of activities for the implementation of the GBS verification scheme, which provides a framework for GBS implementation, as shown in Figure 5 (International Maritime Organization, 2010d).

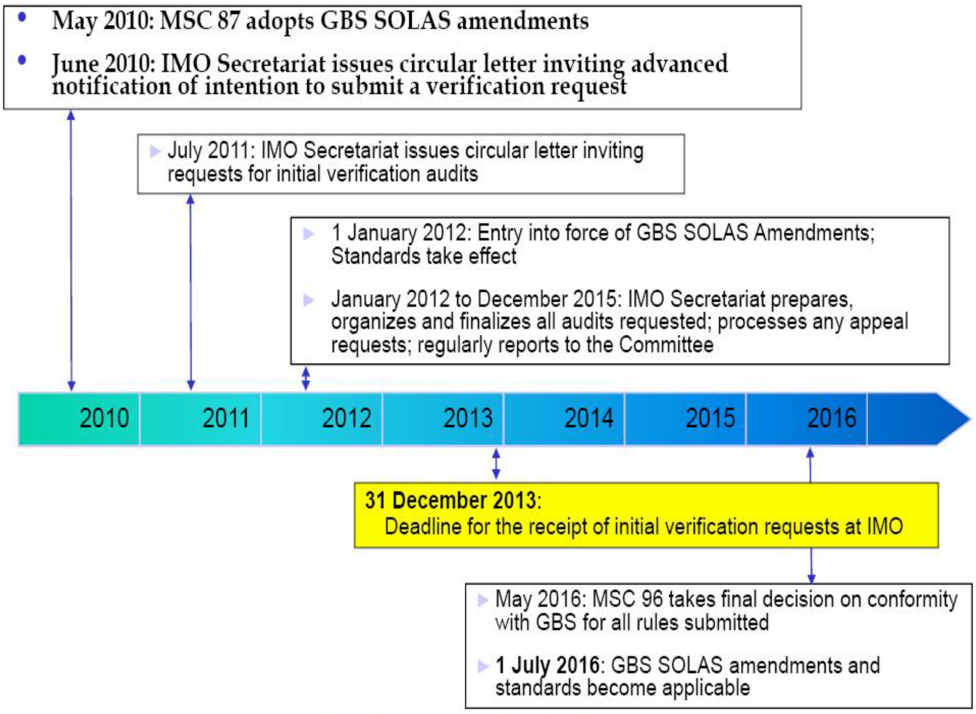

Figure 5- Timetable for GBS implementation

Source: Philippe Baumans & Åge Bøe. (2010, Oct 6-8). *Goal Based Standards for Harmonized CSR.*

London, United Kingdom.

It can be seen from the timetable that the period from July 2011 to 31 December 2013 is the window for all the classification societies to submit their audit requests for initial verification to IMO. During the same period, IMO will prepare the verification process including specifying the audit team and organizing the audit plan, but no substantial audit action will be conducted. During the period from 1 January 2014 to May 2016, IMO will commence to carry out the GBS verification process to all rules submitted, but the results of the verification will only be released in May 2016 at the MSC 96th session, in order to avoid giving a competitive advantage to particular submitters (International Maritime Organization, 2009d). According to the newly amended SOLAS Chapter II-1, the GBS regime applies to bulk carriers and oil tankers of 150 m in length and above for which the building contract is placed on or after 1 July 2016 (International Maritime Organization, 2010c). Therefore, before the applicable date of the GBS requirements, the final decisions on conformity with GBS for all rules submitted would be taken and the results of the verification would be announced to the public.

4.2 Controversial issues regarding the GBS implementation

As far as the implementation is concerned, the guidelines for verification of conformity with GBS including the procedure and the criteria will play a key role during the conduct of rule verification. During the development of the guidelines, several considerations addressing the practical issues were discussed and finally agreed in the adopted guidelines.

4.2.1 Self-assessment process for verification

The first controversial issue is whether to adopt a self-assessment-based verification process. Some delegations proposed a self-assessment and documented rule development process instead of a full assessment by the IMO Group of Experts, in order to "ensure the transparent technological and state-of-the-art development of classification rules and the efficient use of resources". On the contrary, some delegations disagreed with the self-assessment based concept and insisted that the Group of Experts should verify the rules through their own independent review so as to ensure a reliable and effective verification (International Maritime Organization, 2009d).

The self-assessment approach can be considered reasonable for some practical concerns. Firstly, the cost of a full assessment by the IMO Expert Group is very high. The estimate indicates the external cost for one Group of Experts verifying one set of structural rules would be in the order of US$300,000, and the total initial cost will probably be ten times higher only for the first very limited scope covered by IACS CSR. As the scope of GBS expands to all structure rules, the cost will be 100 times or more, so that the huge cost of rule development will be prohibitive. Secondly, it is almost impossible to "scrutinize the work of hundreds of experts done over several years with a handful of other experts in just a few weeks", and "the availability, number and quality of such independent experts is most likely not sufficient to manage the verification in a reasonable time frame" (International Maritime Organization, 2009b, p. 5). Thirdly, regarding the legal aspects, it is the rule developer's responsibility to ensure that their rules comply with the GBS requirement, and "an expert verification by IMO may be taken as justification for classification societies to waive their responsibility" (International Maritime Organization, 2009b, p. 5).

The MSC finally adopted the self-assessment approach taking into account these aforementioned considerations, reducing the cost from $900,000 per rule set to $50,000 (Bockmann, 2009). The decision can be regarded as a wise choice because the key point of initiating such an implementation is practicability. Since one significant step has been taken with the mandatory regime on rule verification, it is quite meaningful to make the implementation easy and practical at the beginning. Then if the current control scheme is later found not strong enough, more measures can be supplemented and the process can be promoted with more experience from the practice.

4.2.2 Funding mechanism

The second controversial issue is the funding mechanism for GBS verification. As far as the cost of the Expert Group for the rule verification is mentioned, there were options regarding who should cover the cost, IMO, rule submitters or nominating governments. According to the estimate by IACS, an initial verification of one rule set would cost approximately US$50,000, presuming a team of five auditors working within 15 days (International Maritime Organization, 2010a). The MSC 87 reached an agreement that "the submitter of a request for verification should pay an audit fee of US$50,000 into a GBS Trust Fund to be established at IMO", which was approved by the 104th session of IMO Council. Besides the Expert Group, it is also agreed that "a P.4 professional officer and a G.4 administrative assistant should be made available in the Secretariat for the implementation of the verification scheme". There are 2 options to cover the cost of the two additional posts: one is the regular budget of the IMO Secretariat and the other is extra payment from the rule submitters. Delegations supporting option 1 stressed in an ethical dimension that IMO is "obliged to bear the cost of its staff and should not rely on outside sources of financing"; delegations supporting option 2 stressed that there had been practice in existing arrangement funded outside IMO such as GESAMP-Ballast Water Working Group (International Maritime Organization, 2010d). Noting the assessment of the Secretary General, the Council approved that the task of the two posts could be undertaken by the existing staff so there was no need for new recruitment (International Maritime Organization, 2010e).

With such a decision, the cost of the Expert Group will be paid by the rule submitters and the cost of IMO staff will be covered within the Secretariat budget, which can be assumed as a balance between the stakeholders. Classification societies will pay a reduced fee while the IMO will undertake extra work and cost. It should be noted that a proper funding regime is essential for the successful conduct of the verification scheme since it would affect the long run in the economic aspect. The adopted funding regime can be regarded as a feasible regime for the time being, and it can be open to adjustment with the progress of practice.

4.2.3 Certification during the verification process

Another issue is whether the Cargo Ship Safety Construction Certificate can be issued when a ship's construction is under an amended rule during the verification process. The United Kingdom pointed out in its proposal that based on the revised SOLAS II-1/3-10, a ship designed and built to a rule amendment which is at the time going through the verification process, should not be issued a valid Cargo Ship Safety Construction Certificate. Furthermore, if rule amendments are reviewed based on a five-year collecting period, this will result in a serious negative effect on the development of rules (International Maritime Organization, 2009c). The MSC considered this concern and finally agreed on an annual verification regime, in which an aim of 10% of the rule change will be selected for verification by IMO audit team every year.

The annual verification scheme instead of the 5-year basis can avoid conflicts between the SOLAS requirements on the certificate and the development of rules. Based on the annual verification scheme, the period during which rules are revised by classification societies but waiting for the outcome of verification by IMO has been reduced to an acceptable span which is estimated at around 1 or 2 months, so that the rule development will not be obstructed by waiting for a time-consuming process.

However, the annual verification aimed at a 10% of total rule change introduces another problem. The verification regime for maintenance of conformity is based on a selective examination, which means only a small portion among the rule changes will be audited in order to give a result on whether the amendment conforms to the GBS requirements. Even though another mechanism is available which permits the administrations to request IMO to conduct a review when they realize there may be non-conformity in the rule change, it tends to be insufficient to ensure the integrated conformity of rules, and there may be liability issues involved in the decision-making method.

Taking into account the workload and the resources with regard to GBS implementation, the foregoing solution is also based on a practical consideration. The development of rules involves a huge amount of expertise, which is usually the business of classification societies through their long term technical experience. The verification process will be a long term task for IMO to arrange, including not only the initial verification but also maintenance verification which would last forever. Furthermore, the regime will be expanded to all aspects related to ship safety, security and environmental protection. The future workload will increase to a vast level. Therefore how to conduct the verification in a cost-effective and resource-effective way is a key point to achieve successful implementation. It is recognized that it is difficult for IMO to find enough well qualified experts in GBS auditing, so the selective regime would help a lot to reduce the total workload for maintenance verification in the long perspective. As far as the liability issue is concerned, it is clear that it should be the rule submitter's responsibility to guarantee the conformity to GBS of their rules. Considering the practical aspects, the selective regime, as employed in the Port State Control regime, might be the only acceptable mode to carry out a long term operation. It was also agreed during discussion that the Organization would retain the flexibility to vary the actual percentage over time.

4.3 Work load and resource analysis of GBS verification scheme

According to the adopted verification guidelines and relative time schedule, detailed solutions regarding the GBS implementation have been addressed. It is of great significance to have an analysis of the workload and the resources needed in conducting such a scheme. Comparing with the resources available, potential problems could be found and addressed.

The overall workload regarding the verification should be estimated in two periods: initial verification and the maintenance verification. It was noted in MSC 86 that "an initial verification of one rule set would cost approximately US$50,000, presuming a team of five auditors, a well-documented submission that can be audited within 15 days" (International Maritime Organization, 2010a, p. 3). It should be expected that all ten IACS members who participated in the development of CSR would apply for the verification audits, and then there would be 20 rule sets to be audited. It can also be assumed that another 3 to 4 recognized organizations outside IACS may request verification audits. Supposing there may be appeals against the findings of a GBS Audit Team, appeal audits should be carried out. Thus the Secretariat would have to organize at least 25 GBS audits before the application date of the SOLAS amendment on GBS (1 July 2016). Assuming 5 auditors for one audit, up to 125 person-times would be needed, and the total cost paid by submitters would be around US$1,250,000. As far as the need for auditors is concerned, the MSC agreed to establish an auditor pool, from which auditors can be selected to form audit teams. Considering that 25 audits can be conducted by 5 teams (5 auditors in each team) during 5 different periods (approximately within 3 months), then at least

25 auditors can be regarded as a sufficient number needed by the initial verification, and the total period to conduct all audits will be around 15 months (International Maritime Organization, 2010a).

In respect of the maintenance verification, "presuming a total of 20 rule sets and in each rule approximately 5% of the content is changed annually, the workload of maintenance verification for each year will be equivalent to conducting a single initial verification" (International Maritime Organization, 2010a, p. 3). In the light of the adopted guidelines, only 10% of the rule changes will be selected for audit, so the total workload will be further reduced by a substantial degree. Since the workload for maintenance verification will be much less than that in the initial period, the auditors available will be enough.

Compared to the number of auditors needed (at least 25), the auditor resources available are still far from sufficient. Up to the 89th session of MSC, the number of GBS auditors nominated by Member Governments is 13, which is "not sufficient to allow for the proper selection and establishment of GBS Audit Teams" and "may endanger the timely implementation of the GBS verification scheme". Consequently, "the Committee urged Member Governments and, in particular, international organizations to submit further nominations for GBS auditors to the Secretariat as a matter of priority" (International Maritime Organization, 2011a).

There are technical reasons for the lack of nominations from Member States. According to the verification guidelines Part A, GBS auditors "should have adequate knowledge of, and experience in, ship structural design and construction, the standards and classification society rules and rule development", and there are also other specific requirements for nominees listed. It is also required that audit team members should not have any conflict of interest relating the rules being verified, which means the experts working for classification societies should not be involved (International Maritime Organization, 2010a). It can be seen that the knowledge and experience demanded for auditors is very specialized. As we know, most experts with scientific or engineering knowledge of technical subjects addressed in ship structural standards are mainly working for classification societies. It is not easy to select experts with such specialized qualifications from Member Governments or other related Organizations. The lack of well qualified auditors was taken into account when the scope of the verification regime was discussed. The self-assessment-based verification scheme and the 10% annual review scheme were also probably affected by this resource factor.

The aforementioned workload estimation is solely based on the current application of GBS, which only covers the structure of bulk carriers and oil tankers of 150m or more. As the GBS regime expands to other ship types and aspects, the overall workload will be increased tremendously. As estimated in the proposal MSC 86/5/4, the workload and cost will be multiplied by a factor of 100 or more. At that stage, many more auditor nominees will be needed in order to undertake both the initial and the maintenance verification audits. In spite of the auditor resource, it will be very difficult for the Secretariat to organize so many audit activities, and there should be a huge database to maintain the information associated with the conformity of all kinds of rules. Through the perspective of the workload of the future, it is obvious that the importance of establishing a convenient and cost-effective scheme should be emphasized for the GBS implementation.

4.4 Response of classification societies to the verification regime

The verification of conformity with GBS is a significant issue for the main classification societies over the world and brings them both opportunities and challenges. As the GBS requirements become mandatory, if the rules of some classification societies are verified as non-conforming with GBS, they will lose the right to employ their own rules for the construction of bulk carriers and oil tankers of

150m or longer. On the other hand, if some classification societies' rules get through the audit while some others do not, they will gain a competitive advantage in the ship-building market. The verification audit can be regarded as an opportunity for some advanced classification societies to demonstrate their technical competence and eliminate their opponents. Therefore, the implementation of GBS would probably establish a new order in the classification market. Facing the verification audit, most classification societies, especially the IACS members, are taking measures to prepare for the forthcoming rule verification.

In the current ship building market, most large ships are under the class of IACS members, and among these ships most bulk carriers and oil tankers of 150m or longer are designed and constructed in conformity to the IACS CSR. The CSR were developed by IACS members and the copyright of CSR is owned by IACS members at that time, which include 10 classification Societies. The CSR apply to tankers of 150m or above and bulk carriers of 90m or above, so they fully cover the scope regarding the application of the current GBS requirement (International Association of Classification Societies, 2011). The CSR were incorporated into the IACS members' rule system after development, and all IACS members use this uniform standard for their classification.

During the development of the guidelines for verification of conformity with GBS, the CSR was used as a trial application in the Pilot Project to examine and validate the draft guidelines. Even though the purpose of the Pilot Project was not to verify the conformity of CSR, many potential gaps between the CSR and GBS were found. After the trial application, IACS endeavored to conduct correlative research in order to fill these gaps by seeking technical evidence as well as rule amendments. The Harmonized Common Structural Rules (HSR) project is one of the main activities aiming at the verification regime, which is ongoing and planned to be finished in 2013. The HSR will be developed based on the current two separate sets of CSR and achieve a harmonized rule set with consistent methodology, taking into account the GBS requirements (Baumans & Bøe, 2010).

There may be particular requirements besides CSR added into the rule system of individual members, but it was estimated that over 90% of the rules requirements among the IACS members would be the same. Therefore there was a proposal "to combine rule reviews in an efficient manner, *e.g.,* by assigning multiple rule sets to a single Audit Team in view of the general utilization of IACS CSR" (International Maritime Organization, 2010a).

Regarding such a proposal, IACS pointed out that the CSR is owned by individual societies, not IACS, so individual societies should present their individual Rules. IACS also noted that each Recognized Organization should "be treated individually from both a technical and financial viewpoint", but the combined audit can "be undertaken with the content of all the submitters involved" (International Maritime Organization, 2010b). It was agreed in MSC 87 that the Secretariat has the flexibility to combine rule reviews to improve efficiency, and submitters are encouraged to identify sections of their rules which are common with other rule sets (International Maritime Organization, 2010d).

As mentioned above, 90% of rules among the IACS members would be the same, so the remaining 10% will be the key portion which will lead to different audit results. Since gaps of conformity exist in the former CSR, individual IACS members also strive to improve their own rule system in order to fill the gaps. It can be assumed that if the maintenance work of CSR and the HSR project cannot fill all the gaps, then individual actions including rules amendment and additional regulations would be helpful to achieve conformity with GBS. As a result, efforts in response to GBS verification were made, for the time being, both in IACS group level and in individual classification societies.

As far as the recognized organizations outside IACS are concerned, those who use the IACS CSR for their construction would not have to request verification audits. Some organizations may request verification providing they have their own rules or regulations for ships covered by GBS requirements in SOLAS, then similar work to prove conformity with GBS should be carried out as well.

4.5 Practical recommendations on the GBS implementation

Based on the aforementioned analysis in respect to GBS verification, some practical recommendations are provided in order to achieve a successful implementation.

First, a combination of rule review could be conducted to promote efficiency. Since about 90% of the rule content would be the same, it would be quite cost-effective to select the 90% out of each rule set for a combined review by a single Audit Team. The remaining 10% of content would be left to the Audit Team in charge of individual rules, and then the workload would be reduced to one tenth. Furthermore, the HSR project would be finished before the audits are carried out, thus the common part which is from the uniform HSR could be more than 90%, because more content will be unified through the research process of HSR. Considering the lack of auditors, this measure could be a compensation for the scarcity of auditor resources.

Second, a harmonized scheme should be established to have a smooth link between rule revision and rule verification. Formerly, classification societies amended their own rules and issued new versions freely, so rule revisions could soon become applicable after approval by classification societies. With the GBS regime, one more control process is added and the rule revisions must be verified through maintenance audits, which require extra time. In order to hasten rule application and facilitate rule development, a harmonized scheme should be established to connect maintenance verification and rule revision. For instance, a fixed date in every year can be specified for the classification societies to submit their new amendments, and audits will be scheduled soon after the submission. This measure would not only shorten the waiting time for audits, but also facilitate the management of verification.

Third, Member States and international organizations should try to submit further nominations for GBS auditors. The qualification of GBS auditors requires a very high level of expertise and background, so sufficient auditors are a key element for the timely implementation of the GBS verification scheme. Nominees could be further considered and selected from the ship design or ship building industry, research institutes or universities. In case that there are not enough qualified auditors by the time of verification, 2 mitigating measures could be considered. One is to use an appropriate grouping scheme to ensure the required expertise of audit teams, which means to select auditors with different backgrounds and cover the technical scope needed in a team, focusing on the integrity of expertise of an audit team rather than an individual nominee. The other is to conduct a combination of rule reviews in order to reduce the workload and labor resource, as mentioned in the first point.

Last but not least, specialized GBS group or section could be established for GBS implementation in the future. It was estimated that for the time being, the workload for GBS verification could be undertaken by existing staff. However, as the GBS expands to other ship types and aspects, the overall workload would not be able to be absorbed within the Secretariat, so it would be necessary to establish a new specialized group or section for GBS, in charge of management and coordination of the initial and maintenance verifications. Furthermore, a GBS database should be developed and maintained by IMO as a long term task. As the GBS scheme expands its scope in the future, historical information regarding rules verification including each verification date of a new revision would become vast and complicated, so a computer-based management would be essential for successful implementation.

CHAPTER V TASKS FOR FURTHER DEVELOPMENT OF THE GBS SYSTEM

In Chapter 4, the implementation of GBS for bulk carriers and oil tankers was discussed based on the GBS system which is established currently. It should be noted that this is only part of the task regarding the whole application of GBS in IMO. While the current GBS scheme is conducted in practice, there are further tasks to be carried out at the same time, which mainly include two aspects, *i.e.,* the application of the safety level approach to the GBS system and the generalization of the GBS scheme.

5.1 Application of safety level approach to GBS

5.1.1 The safety level approach for the development of GBS

As discussed in Chapter 2, the current GBS for oil tankers and bulk carriers have an important limitation, *i.e.,* the safety level is not specified in the system. This is because the current GBS regime for bulk carriers and oil tankers is developed mainly through the deterministic approach, so the risk in the system is not assessed with the risk-based approach and the safety level is not integrated into the safety goals yet. As the deterministic approach achieved a significant progress and the GBS regime is ready for implementation, the core of the GBS work tends to be transferred to the SLA. As a result, the SLA research was made a high-priority issue in the MSC work plan at its 89th session (International Maritime Organization, 2011 May 27).

SLA is a risk-based approach for the development of IMO GBS. It is based on the quantification of safety, which means to develop a uniform safety level for ships that "facilitates development of envisaged rules or regulations in a consistent, transparent and reliable manner" (International Maritime Organization, 2006a). Since SLA is a risk-based approach (RBA), this chapter will first introduce the RBA in order to have a better understanding of the SLA.

5.1.1.1 Risk-based Approach

For the time being, the regulatory framework in the maritime field is mainly developed through a traditional approach, which means the development of standards is based on the experiences obtained in practice and triggered by accidents (International Maritime Organization, 2006a). Regulations were usually produced as a response to maritime accidents, so this approach is regarded as a reactive process. Limited by the existing accidents, it is difficult to foresee the potential hazards before the accidents happen. As a result, there is a need to adopt a proactive approach which can anticipate the hazards rather than wait for accidents to reveal them (Kontovas, Psaraftis, & Zachariadis, 2007).

It is believed that the risk level of the current standards is agreed depending on what is acceptable for the shipping industry. However, the actual risk level behind the current standard is unknown, and this is regarded as an important disadvantage of the re-active approach. In order to address this problem, it is necessary to adopt a risk based approach to identify the potential hazards in the standards and quantify the risk level for ships. This approach will help to anticipate hazards before accidents and provide measures in a proactive method.

The risk based approach, as defined in the IEC guide 51, is "a systematic, logical, and comprehensive tool to assess risks for the purpose of increasing safety in the life-cycle of a system(s)". The risk in the RBA is defined in the following formulation:

$$\text{Risk (R)} = \text{probability (P)} \times \text{consequence (C)}$$

where the risk of a system consists of two elements, namely, how often the hazard happens and how serious the consequence is (Lee, 2009, p. 6).

With the risk analysis and assessment process, risk can be identified and quantified and the safety level can be controlled to an acceptable degree. Compared to the traditional approach, RBA can analyze safety issues in a systematic and comprehensive manner rather than seek solutions on a case-by-case base, so it has the potential to provide a proactive development of standards. The differences between the two approaches are presented in Table 1, which can further illustrate the advantages of employing the risk-based approach. It should be noted that RBA focuses on the safety level rather than specific technical measures when it sets up requirements and the same safety level should be achieved when justifying alternative solutions. Furthermore, with the application of RBA, human factors and organizational aspects can be better integrated into the regulatory system.

Table 1- Comparison of the traditional approach and RBA

Traditional approach	Risk-based approach
➢ **reactive, responding to accidents** ➢ **continuous amendment of regulations**	➢ **proactive, trying to identify all conceivable hazards** -before they lead to accidents
➢ **prescriptive regulations**	➢ **regulations, consistent with safety objectives**
➢ **principle of technical equivalency**	➢ **principle of safety equivalency**

➢ **contains mainly technical requirements**	➢ **encompasses technical, human and organizational aspects**

Source: Lee, J.-K. (2009, Dec 4). *Shipbuilder's Views Shipbuilder s on Risk-Based Regulatory Framework (SLA-based GBS)*. Shanghai, China.

5.1.1.2 Important tool: Formal Safety Assessment

The implementation of SLA needs suitable tools, among which the Formal Safety Assessment (FSA) will be helpful for GBS initiative. FSA is used to disclose implicit safety levels in current regulations and the effectiveness of risk control measures, and then safety goals can be stated in terms of the risk evaluation criteria (International Maritime Organization, 2006d). So it is of great significance to introduce the FSA before further discussion of SLA.

FSA was introduced by the IMO as "a rational and systematic process for assessing the risk related to maritime safety and the protection of the marine environment and for evaluating the costs and benefits of IMO's options for reducing these risks" (International Maritime Organization, 2002a, p. 1). It is agreed that FSA is helpful to evaluate the new regulations for maritime safety and environmental protection and to make a comparison between existing and possibly improved regulations in the IMO rule-making process.

The FSA should be conducted with a five-step procedure, which is presented in Figure 6. The first step is to identify all potential hazardous scenarios which could lead to significant consequences and prioritize them by risk level. Then the risk level should be analyzed by quantifying the frequency and the consequence of each hazard. Subsequently, the risk control options (RCOs) should be found to decrease frequencies or mitigate consequences in order to reduce the risk to an acceptable degree. After that the RCOs should be assessed by comparing their cost and the corresponding benefit, so that the recommendation would be made in a cost effective way.

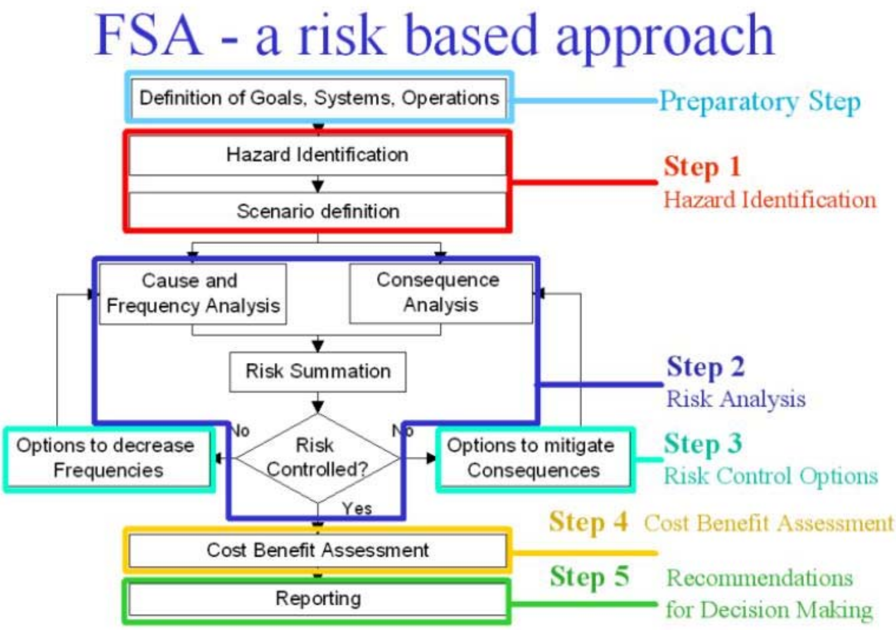

Figure 6- The procedure of formal safety assessment

Source: Psaraftis, H. N. (2006, May 10). *GBS vs "Safety Level Approach": contributing to the debate*. Athen, Greece.

It is accepted that the formulation of the risk matrix is a crucial process in risk analysis as well as in FSA, and in this process there are many aspects which can affect the accuracy of the result such as data resource and related indexes. It should also be noted that the risk acceptance criteria play a very important role in decision making. It was suggested in the IMO FSA guidelines that both the individual risk and the societal types of risk should be considered to decide the risk acceptance criteria. The individual risk is defined as the risk to an individual person while the social risk is recognized as the risk to the society of a major accident which involves and affects more than one person. According to the Health and Safety Executive's (United Kingdom) Framework for the tolerance of risk, the region where the risk will fall can be divided into three parts, which is shown in Figure 7. In the unacceptable region, where a high accident frequency and high number of fatalities exist, risk should be reduced at any cost, while in the broadly acceptable region, no action is needed. Between these two regions, the ALARP (as low as reasonably practical) region is defined, where risk should be reduced in an economically effective manner until it is no longer reasonable. That means acceptance of an activity whose risk falls in the ALARP region depends on cost-benefit analysis, which can be recognized as an important principle in current risk assessment (Kontovas, Psaraftis, & Zachariadis, 2007).

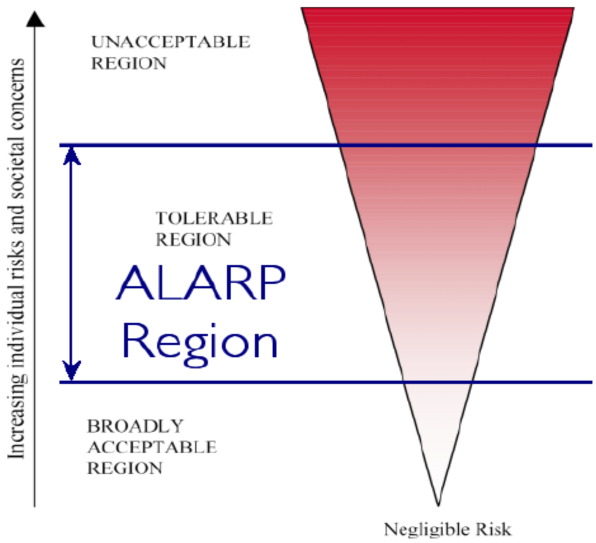

Figure 7- The ALARP concept

Source: Kontovas, C.A., Psaraftis, H.N. & Zachariadis, P. (2007). The Two C's of the Risk-Based Approach to Goal based Standards: Challenges and Caveats. *International Symposium on Maritime Safety, Security and Environmental Protection.* Athen, Greece.

Nowadays, the FSA is widely used in the development of ship design and the maritime regulations. The European Union's project SAFEDOR carried out high-level research on FSA aiming to make explicit the current risk level for specific ship types and to develop generic risk models and cost-effective risk-control options. Six reports on FSA studies were submitted to IMO including the mainstream ship types such as oil tankers, container ships and cruise ships (Lee, 2009). Besides that, the International Ship and Offshore Structure Congress (ISSC) also conducted risk assessments through FSA method, and the results are available for IMO (International Maritime Organization, 2006b). These assessments provided strong technical support for IMO to develop the SLA for GBS.

5.1.1.3 The safety knob to control maritime safety

The SLA can provide IMO a safety knob by which the safety level can be adjusted, when necessary, in a consistent, verifiable, transparent and reliable way in order to rectify the observed deficiencies (International Maritime Organization, 2006c).

The SLA should provide appropriate levels for several safety aspects such as safety of the ship, safety of passengers, safety of cargo and safety of the environment which are in Tier 1 of GBS, then each of the safety levels in Tier 1 should be divided into several sub-elements related to the specific functions or systems or operation belonging to Tier 2. As mentioned before, the FSA should use risk evaluation criteria to conduct risk assessments, among which the ALARP principle is the widely accepted one. "The ALARP boundaries related to individual risk, and societal risk and acceptance criteria for safety measures are the parameters of the formal safety assessment", and "the safety knob controls these parameters" (International Maritime Organization, 2006d, p. 3). Safety can be enhanced by decreasing the intolerable limit; therefore, the essential element of the safety knob is to control the ALARP boundaries. Another element of the safety knob is to control the cost effectiveness criteria, among which the Cost of Averting a Fatality (CAF) is an important criterion to evaluate the economic benefit of the risk control options. FSA will deliver the basis of rules and regulations which affect the safety level of ships by controlling these parameters. If the safety knob is turned, some of the basic parameters will be affected. Such a relationship is shown in Figure 8 (International Maritime Organization, 2006d).

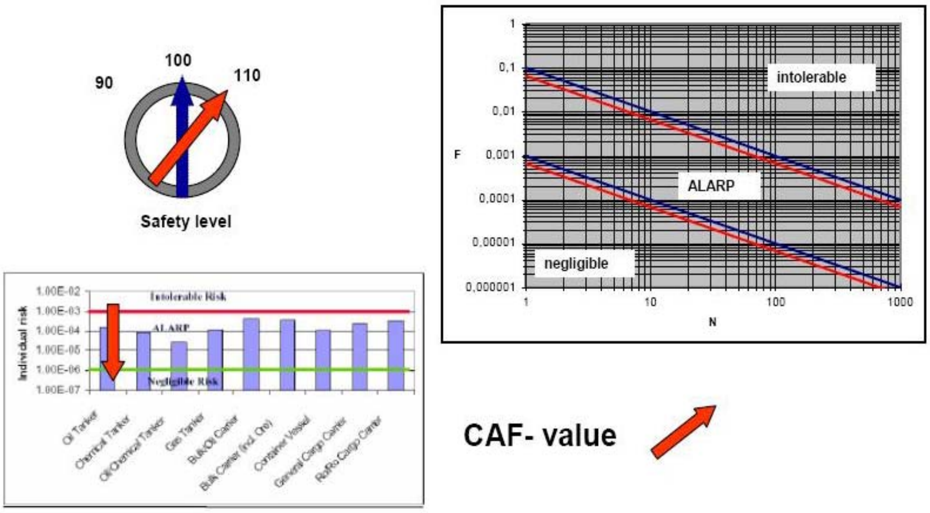

Figure 8- The maritime regulator's safety knob

Source: International Maritime Organization. (2006, Mar 7). *Goal-based new ship construction standards. The safety level approach – introducing the safety knob to control maritime safety. Submitted by Denmark and Germany* (MSC 81/6/8). London: Author.

5.1.2 The progress of SLA for the development of GBS

Since the MSC agreed at the 81st session to continue the work of GBS applying both the deterministic approach and the safety level approach in a parallel track, research and consideration on the safety level approach were continuously carried out by working groups and correspondence groups in and between the following sessions, taking into account the proposals on SLA by member states. Among the work undertaken, there are several tasks of great significance to be emphasized to provide a general picture of the research.

5.1.2.1 Determination of current safety level

The safety level of current regulatory system provides IMO a foundation for judging and improving the safety of shipping. The target safety level in the GBS system should be developed based on the current safety level, so that the continuity of the safety policy can be guaranteed. As a result, one of the important tasks regarding SLA is to determine the safety level of the current regulatory system by analyzing the historical data in the industry. The scope of this task includes the determination of an overall goal of acceptable risk level and, if required, the determination of individual risk levels for individual casualty types (sub-categories) (International Maritime Organization, 2008).

Information on safety levels referring to different ship types and to different risk categories were collected based on statistical data from different sources by the correspondence group established at MSC 81. Large amount of statistical data including accident frequency, fatality frequency, individual risk and oil spill risk frequency ordered by different ship types were presented for discussion. However, it was recognized that the existing data on risk levels for ship types needed to be consolidated based on a unified systematic process before they were interpreted at IMO level, and clear definitions of risk terminology and ship types were necessary to facilitate this consolidation (International Maritime Organization, 2006f). Subsequently, work in respect of definition of generic ship types and time windows for historical data was carried out, nevertheless, no general agreement was reached and further consideration was deemed necessary.

In order to evaluate the current safety level, an assessment of the current safety level for Bulk Carriers was presented by MSC 83/5/3 referring to ship type categories of Lloyds Register Fairplay. In this assessment historical data were analyzed to evaluate risks for ship, cargo and seafarers as well as risks for a number of functional requirements (International Maritime Organization, 2007). There were also other available assessment data on current safety level applying the FSA method, for example, the FSAs in the SAFEDOR project as mentioned before. However, the data used in these assessments cannot be verified by the IMO Experts Group, taking into account the fact that different data resources could lead to different results and there were no generally validated data resource. So these results regarding the current safety level of ships are not regarded as generally accepted ones, which means the current safety level is not explicit yet for the time being. Nevertheless, even though the validity of data was questioned, there was no doubt that the FSA can be used to evaluate the safety level for ship types. These high-level investigations provided a lot of experience and information to employ the safety level approach to quantify the risk level of specific ship types (International Maritime Organization, 2010f).

As far as the validation of the available data is mentioned, there are two main factors which may affect the valid use of statistical data. On one hand, the available statistical data are not large and wide enough to demonstrate the safety level. There are always unreported cases which are not recorded in statistics and the recorded fleet is only part of the actual fleet all over the world, so the accidents recorded in statistics usually represent only part of the actual accidents. On the other hand, the data are arranged in different methods by different resources. The categorization of ships, fleet size and record period differ very much in different statistical sources, so assessment according to different sources may lead to different results (International Maritime Organization, 2010f).

In order to address the lack of valid data, long term information collection is supposed to be necessary. According to the statistical theory, the frequency calculated from statistics can only be equal to actual probability when the historical data sample is large enough, which is also a principle for the correct application of FSA. As the sample size reaches a substantial level, the result of assessment will tend to be convergent and then accuracy will be achieved. Furthermore, a uniform mode for accident data records including a generic definition distinguishing ship types in a clear manner should be achieved so as to facilitate a valid historical record regarding safety level. Thus the determination of current safety level should be carried out as a long term work involving a large amount of effort.

5.1.2.2 Identification of the linkage between FSA and GBS

As FSA plays an important role in the conduct of safety level approach, the linkage between FSA and GBS was discussed after MSC 80. It was concluded by the correspondence group report of MSC 83/5/3 that the FSA in general could be used to:

1. conduct holistic assessments (e.g. ship types, whole system reviews, etc.) with a view to establishing the level of risk and set goals accordingly;
2. identify and/or formulate high level goals and functional requirements;
3. support high level goals to determine associated hazards and develop appropriate risk control options;
4. assess specific issues (e.g. focus on diesel engine fires) to determine associated hazards and associated risks and develop appropriate risk control options;
5. identify inherent safety levels in existing standards and from that make explicit the inherent risk acceptance criteria;
6. verify compliance of regulations (e.g. classification society rules) with high level goals and functional requirements; and
7. find gaps in functional requirements. (International Maritime Organization, 2007, pp. 3-4)

After further consideration, it was recognized that "FSA is the process that helps to determine the current safety level because each FSA contains a quantification of the current risk level but not the safety objectives". FSA process is needed to put functional requirements into GBS structure and to identify gaps, as well as to aid the development of detailed requirements, as shown in Figure 9 (International Maritime Organization, 2008).

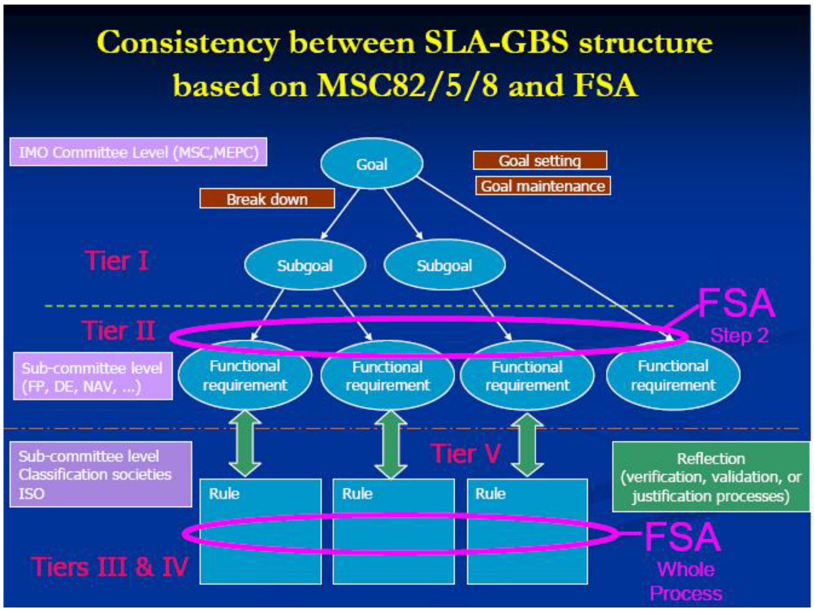

Figure 9- Use of FSA in SLA-GBS

Source: International Maritime Organization. (2008, Feb 5). *Goal-based new ship construction standards. Report of the GBS correspondence group: Submitted by Germany* (MSC 84/5/3). London: Author.

Furthermore, the FSAs performed in SAFEDOR provided examples to apply the risk-based method to determine and evaluate the risk levels of ship types in high-level analysis, through which the function of FSA to determine and, if deemed necessary, to adjust the safety level of regulation is confirmed by researchers. The reports of FSAs' review provided comprehensive information which can serve the further development of safety-level based standards.

However, for the sake of the important role of FSA in GBS, the limitation of the FSA method should be sufficiently considered in practice. A variety of identified weaknesses of FSA and RBA were elaborated by Kontovas and Psaraftis, and they further cautioned that the eagerness to drop all prescriptive rule formulations and adopt risk based formulations from other industry could be dangerous (Kontovas, 2005; Kontovas & Psaraftis, 2006). So the FSA needs further research in order to be applied properly and the current prescriptive standards should be referred to as much as possible. As a result, the development of SLA should follow and take advantage of the future improvement of FSA.

5.1.2.3 Progress on other issues

There are also other important developments made on SLA of GBS with the efforts of working groups, correspondence groups and delegations. For instance, the tier structure of SLA for GBS was formed and a worked example was provided in MSC 81/6/14, which was used as a basis for future development (International Maritime Organization, 2006e). The process to monitor the effectiveness of GBS was considered during several sessions, and it was agreed that the effectiveness of both the rules/regulations and the goals and functional requirements should be addressed according to information resources, where the under-reporting issue should be addressed (International Maritime Organization, 2009a). The aforementioned efforts provided preparation for further research and will serve for the application of SLA to GBS development.

5.1.3 Future work and recommendation on SLA

The work on SLA for GBS has achieved much progress in many associated areas. However, due to the lack of long-term data support and the limitation of current technique reserve, much of the work has not reached a conclusion yet and there are many loose ends left; therefore, SLA would be a long term work and much more efforts are need (International Maritime Organization, 2010f).

For the time being, SLA should be first developed for the new-building construction standards for oil tankers and bulk carriers where the SLA results can be calibrated with the prescriptive approach. Then it could be used for other ship types or areas where there is not so much prescriptive experience available (International Maritime Organization, 2008). Based on the current work accomplished, a method to specify the acceptable safety level should be clarified; the model to determine the safety level should be verified; and the availability of statistical data should be addressed.

As far as the determination of current safety level is concerned, an efficient data collecting scheme will be helpful for the safety level evaluation. One possible measure is to develop a standardized and structured method of data arrangement including categorization of ship types, risk categories and time window of data, and introduce it to the organizations that conduct the statistics. The unification of the accident data statistics will be beneficial for not only the implementation of SLA but also for other research on ship safety such as casualty investigation. With a proper data support scheme and a long period effort, sufficient historical data are supposed to be obtained and the safety level in the existing rule and regulation system could be evaluated. Then the safety level in the GBS tier system can be established with the calibration of the current safety level.

In order to make effective use of "state-of-the-art techniques", new technologies adopted by the industry such as Risk-based Design (RBD) and Structural Reliability Assessment (SRA) should be closely followed by IMO. These technologies are closely related to SLA as well as rule development, and may have great influence on the development of SLA. Actually, these ship design techniques reach the GBS Tier 4, and in order to achieve a suitable safety level, the first 3 tiers are also covered. So their scope is wider and deeper than SLA, and the significance of using them for reference is obvious. Collaboration with industries regarding this research including jointly funded projects can be considered in order to pursue breakthrough of these key technologies.

5.2 Generalization of GBS system

5.2.1 The intent to expand GBS application

As discussed in Chapter 2, the current GBS regime is accomplished only in the domain of the structure for bulk carriers and oil tankers above 150m. It should be noted that the region covered by the GBS regime is only a small part of the whole maritime safety, security and environmental protection system. As showed in Figure 3 of Chapter 2, a much wider region including other ship types, other ship aspects such as machinery and electrical installations and other areas covered by IMO regulations regarding safety and environment, is not currently dominated by GBS.

From the start of the development of GBS, it was agreed that "in the long term, GBS should be extended to cover all main functions of the ship, but only after experience has been gained with GBS for ship construction" (International Maritime Organization, 2004b, p. 62). It was also reflected in the basic principle of GBS that GBS is a "broad, over-arching safety, environmental and/or security standards" with further comment "IMO may develop goal-based standards for other areas, *e.g.* machinery, equipment, fire-protection, *etc.*", which showed the intent to extend the scope of GBS (International Maritime Organization, 2004c, p. 3). It can be seen that the GBS tends to be applied to the entire maritime regulatory system in order to develop the system in a high-level manner. Since the GBS will bring many advantages such as technical transparency and openness for technical innovation, the tendency to expand GBS application in IMO is obvious.

The Generic Guidelines for Developing Goal-based Standards approved at

MSC 89 in May 2011 provide a basic mode and a uniform format to development a goal-based standard. It can be regarded as preparation work for further expansion of GBS in other maritime fields.

5.2.2 Analysis on the process of GBS expansion

As far as the GBS expansion is concerned, the areas which are not covered by GBS should be clearly identified first. First, within the area of ship structure, there are other ship types including container ships, passenger ships, general cargo ships, LNG/LPG carriers and so on. There are also bulk carriers and oil tankers of smaller size which are not covered by GBS. Second, outside the structure aspects but within the ship construction area which is dominated by rules, there are machinery installations and electrical installations to be covered. Third, outside the rule related construction area, there are many regulations in regard to maritime safety such as stability/floatability, fire safety, life-saving and navigation safety, where GBS can be further developed. At last, besides maritime safety and in the same level, there are maritime security and environmental protection, and then the whole maritime field can be addressed by the GBS regime. These regions are mentioned from smaller scopes to larger ones, containing all the potential areas wherein GBS could be applied.

Necessity and feasibility are two important elements to be considered for the expansion process of GBS. GBS should first be applied to ship areas where GBS are most necessary and most helpful. At the same time, the feasibility to develop GBS in such areas should be evaluated. Regarding necessity, the original motivation to develop GBS in IMO was to have better control over the rules for ship construction, especially rules for hull structure, which are developed by different classification societies and is not sufficiently addressed by the IMO convention system. For other areas that are covered by IMO conventions or regulations, such as stability, fire safety and life saving, the importance might be comparatively less. Regarding feasibility, due to the lack of statistical data and some technical limitations, SLA cannot, at the present time, be effectively used to develop the GBS system temporarily, so the deterministic approach will be the main tool for GBS expansion in the next few years. Therefore, the ship areas where there is rich technical reserve and vast practical experience should be first considered for GBS application.

Among the different ship types, bulk carrier, oil tanker and container ship are regarded as the three main ship types in terms of transport capacity. As the maximization of container ships develops, the structure of container ships tends to gain more attention of the shipping industry. There is also a trend that CSR will extend to container ships (Li, 2006). Rules for container ships have been practiced for a long time and there is plenty of experience available. With the experience obtained from GBS for bulk carriers and oil tankers, the time needed to set up GBS for container ships could be estimated as relatively short. Therefore, it is quite meaningful and feasible to develop GBS for container ships, so container ships can be assumed as the first area to apply GBS in the earliest period.

Besides the ship structure, machinery and electrical installations are also dominated by rules and are strongly controlled by statutory regulations, so they can also be objects for the next step of GBS expansion, together with the structure of other ship types.

In other safety-related areas such as stability, fire safety and life saving, environment-related areas such as oil pollution, air pollution and CO_2 emission, and even security issues, many regulations and codes have been developed by IMO during its long term maritime practice. It should be noted that these regulations and codes are also prescriptive standards and belong to Tier 4 of the GBS structure. Even though in some areas such as fire protection and large passenger ship safety, some high level safety objectives and functional requirements have been distilled, but they are not yet in a systematically organized. There is also a need to develop GBS in these areas to promote the structure of the existing regulatory system. Actions may include using a tier structure for the development of new regulations and distilling the first 3 tiers from the existing regulations.

5.2.3 Recommendation on the expansion scheme of GBS

According to the aforementioned analysis, a 3-step scheme is recommended for the future expansion of the GBS system, as shown in Figure 10. The process of the scheme consists of three steps:

Step 1: apply the GBS system to ship structure of the most important ship types. As analyzed previously, structure of container ships is assumed to be first addressed.

Step 2: expand the GBS system to other rule related areas where IMO does not have strong control, including structure standards for other ship types and standards for machinery and electrical installations, if deemed necessary.

Step 3: apply GBS to other statutory areas regarding maritime safety, security and environmental protection, in order to promote the structure of the existing regulatory system.

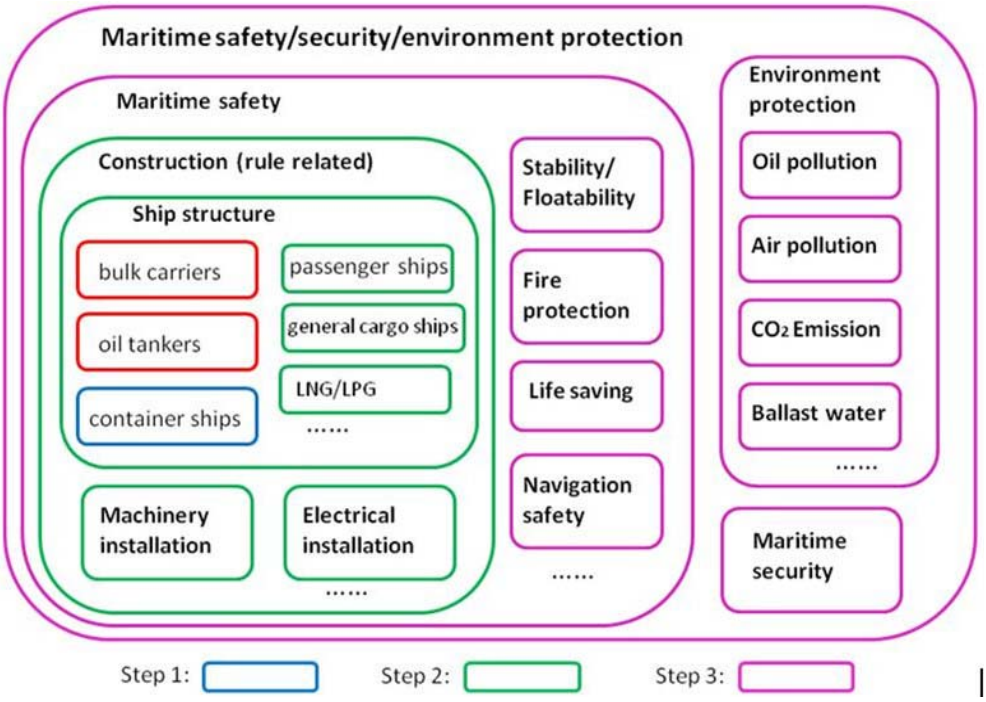

Figure 10- 3-step scheme for GBS expansion

CHAPTER VI CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

With the adoption of the amendment of SOLAS Chapter II-1 on GBS and the related "International Goal-Based Ship Construction Standards for Bulk Carriers and Oil Tankers" and guidelines for the GBS Verification, IMO has established the GBS system on the hull structure region of main ship types, where most concerns are attracted for maritime safety. This significant step can be regarded as a milestone in the development of GBS because the first 3 tiers have been accomplished in the relevant ship area, and GBS have been brought into the implementation stage. More experience will be achieved through the practice of GBS and this experience will contribute to further development and promotion of the GBS system in the maritime world.

The application of GBS is first accomplished mainly through the deterministic approach in the ship area where most experience was obtained during the long term maritime practice. Even though the GBS system is only partially developed partially within a limited area, it is an open system for further development and expansion. Implementation in the current area will serve as a trial which can accumulate experience to carry out the generalization process, and at the same time the current system will be further promoted with the development of the safety level approach.

With the implementation of GBS, IMO will play a more important role in the ship construction, especially the construction of hull structure, which has traditionally been dominated by the rules of classification societies and not substantially controlled by the IMO convention system. As the application of GBS covers this area, uniform goals and functional requirements were developed as "rule of rules" to direct the rules of different classification societies, so IMO's control over ship construction standards will be enhanced and the foundation of the ship safety regulatory system will be strengthened. At the same time, freedom is left to the ship designers to employ the best techniques in ship design.

The application of GBS is a significant change on the mode of the development of standards which will strongly influence the maritime standards system. This will bring many great advantages such as technical transparency and freedom of technical innovation, so more space for the further development of standards and techniques is provided by the GBS regime.

It is of great significance to solve the practical problems in the implementation of GBS because the effectiveness of the GBS regime can only be achieved by successful implementation operation. Measures should be figured out taking into account the workload in the expansion process as well as the availability of auditors with sufficient expertise. A proper mechanism is supposed to be established to address these elements so that the smooth implementation can be guaranteed.

The SLA is a holistic and systematic method to develop the GBS system in a high level manner using the risk-based technique. It can be applied to adjust the safety level and serve as a "safety knob" in light of practical demands and development of the technology and society. Due to the limitation of the current FSA process and the lack of available statistical data, the safety levels of the current regulatory system are not yet determined and SLA still needs a long time for further development.

The application of GBS should be generalized step by step according to the necessity and the feasibility to apply GBS to certain areas. GBS should be expanded from the ship types and aspects for which there have been long practice and sufficient experience, to other types and aspects where not much experience is available currently. All the areas regarding maritime safety, security and environmental protection are potential space for the expansion of GBS.

6.2 Recommendations

As far as the problems in GBS implementation are concerned, this dissertation suggests four main recommendatory measures through the analysis which can aid to facilitate its effective implementation.

1. Combination of rule review should be conducted in order to promote the efficiency of the verification audit. Taking into account that the common part of CSR is estimated to be more than 90% among different rules of IACS members after the HSR project is finished, the combination of reviews would be a highly cost-effective measure to save limited resources.
2. A harmonized scheme for maintenance verification of rules should be established so as to facilitate the rule revision. Measures such as specifying a fixed timetable for the submission of revised rules as well as for the verification process could be considered so that a smooth connection between the rule revision and verification on an annual basis could be guaranteed.
3. Appropriate grouping of the verification auditors could be considered to ensure the necessary expertise of each audit team in case that the number of qualified auditors is not enough to finish the audits before the applicable time of GBS requirements.
4. A new section or team would become necessary to manage the GBS

implementation, especially verification, as the GBS system expands its scope and the current personnel become insufficient to deal with the increasing workload.

As far as the future development of GBS system is concerned, three main recommendations are provided regarding the application of SLA and the generalization of the GBS system.

1. An efficient data collecting scheme should be established to support the analysis of the safety level of the current regulatory system. A standardized format for data collecting could be developed by IMO and recommended to organizations doing relevant statistical work, so that the development of SLA can be accelerated with sufficient data support.
2. Risk-based technology applied in industry such as Risk-Based Design and Structural Reliability Assessment should be closely followed by IMO. Collaboration with industries on these "state-of-the-art techniques" which are closely related to SLA will be quite beneficial to SLA research.
3. A 3-step scheme is recommended for the future expansion of the GBS system, which means first to expand the GBS system to the structure of containerships, second to other rule-related areas including the structure of other ship types as well as the machinery/electrical installations, third to other statutory areas regarding maritime safety, security and environmental protection.

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