FORMAL SAFETY ASSESSMENT, INCLUDING GENERAL CARGO SHIP SAFETY

Update on the safety level of bulk carriers and comparison with predictions in previous Formal Safety Assessment (FSA) studies

Submitted by France and Germany

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**Background**

1 The IMO developed Formal Safety Assessment as a structured and systematic process, helping in the identification and evaluation of new regulations (MSC-MEPC.2/Circ.12/Rev.1). In contrast to the traditional process of regulation development following a reactive approach, FSA introduced risk analysis and a cost-benefit assessment in the IMO decision-making process. As a consequence, FSA provides information on the current and future safety level that remains unknown in the traditional process.
Periodic reviews of the safety level allow the actual impact of the regulations to be kept track of, and is well in line with the Generic guidelines for developing IMO goal-based standards (MSC.1/Circ.1394/Rev.1, figure 1), to identify risks not addressed in the initial rules/regulations development and to verify that the risk is kept as low as reasonably practicable (ALARP).

In the context of FSA and the usage of risk analysis, concerns were raised regarding the accuracy of the methodology, in particular with respect to expert judgement, e.g. used to determine the impact of the new regulations. One of the first applications of the FSA methodology has been on bulk carriers and such predictions, based on expert judgements and analysis, have been made.

The main objective of the present study, jointly prepared by two classification societies (i.e. Bureau Veritas (BV) and DNV GL), is the identification and quantification of the main risks of bulk carriers and the comparison of this current safety level with forecast/prediction made in context of the FSA studies 15 years ago. Furthermore, current risk is re-evaluated by means of an updated FN-diagram.

**FSA studies on bulk carriers**

Following the publication of the report into the sinking of the bulk carrier **Derbyshire** (MSC 69/2/1/Add.5), MSC 69 initiated a further review of bulk carrier safety, involving the use of Formal Safety Assessment studies to help with assessing what further changes in regulations might be needed. MSC 70 endorsed, in general, the United Kingdom's proposal for a collaborative FSA study (MSC 70/23). In the following years many flag States and non-governmental organizations (NGOs) contributed to carrying out this study. Mainly, four FSA studies were submitted to MSC:

1. the international collaborative bulk carrier FSA study, managed by the United Kingdom (MSC 76/5/5 and related documents);
2. the FSA study on bulk carrier safety carried out by Japan (MSC 75/5/2 and related documents);
3. the FSA on Life-Saving Appliances by Norway and ICFTU (MSC 74/5/5 and related documents); and
4. the bulk carrier FSA on fore-end watertight integrity carried out by IACS (MSC 74/5/4 and related documents).

At MSC 75, the Working Group on Bulk Carrier Safety agreed the preliminary recommendations for decision-making, distinguishing recommendations for new and existing ships (MSC 75/WP.19, annex 2). Subsequently MSC 76 approved, in general, a list of 16 recommendations together with a draft schedule and responsible IMO bodies.

**Risk control options (RCOs)**

The main relating RCOs implemented by IMO and IACS are:

1. the Enhanced Survey Programme (ESP) (1993);
2. SOLAS chapter XII (including IACS UR, e.g. strength of bulkheads included) and strengthening of bulkheads on existing bulk carriers (Entered into force in 1999);
.3 hatch cover strength of IACS UR S21 (1998);
.4 resolution MSC.146(77) – Application of IACS UR S26, S27, S30 and S31 to bulk carriers (adopted in 2003);
.5 resolution MSC.144(77) amending A.744(18) Enhanced Survey Programme (2004);
.6 regulation 5 of SOLAS chapter XII – Structural strength of bulk carriers, (2006);
.7 regulation 6 of SOLAS chapter XII – Structural and other requirements for bulk carriers (2006);
.8 regulation 7 of SOLAS chapter XII – Survey and maintenance of bulk carriers, (2006);
.9 regulation 12 of SOLAS chapter XII – Hold, ballast and dry space water ingress alarms, (2006);
.10 regulation 14 of SOLAS chapter XII – Restrictions from sailing with any hold empty (2006); and

Monitoring of bulk carrier safety

8 In the following, the main parts of the study are summarized focusing on comparing the predicted and the monitored effect of RCOs recommended by the FSAs on bulk carrier safety.

Consistency of the fleet database and evolution of the fleet

9 In order to characterize and show the evolution of the fleet of bulk carriers, some basic analyses of fleet data are carried out using IHS databases and the same criteria as the IACS study for selecting the fleet (MSC 74/5/4), i.e. bulk carriers of 20,000 tonnes deadweight and upwards, intended to carry dry cargo (including ore/bulk/oil carriers).
In figure 1, the bulk carrier world fleet in terms of number of shipyears per year is plotted considering the data of IACS FSA (MSC 74/5/4, annex 2) for 1978 – 1998 (blue) and updated data for 1978 to 2014 (red). It is observed that the updated number of shipyears determined from the database and that for the IACS FSA does not differ by more than 2% for the period 1980-1996. Such small differences are well known from other studies and, typically, are caused by the continuous updating process by IHS. This proves the consistency of the today (current) database with the one used in 2001.

From 1978 to 2008, there is a slight increase in the fleet of bulk carrier in activity followed by an important fleet growth between 2009 and 2013. The number of shipyears has increased by more than a factor of three between 1978 and 2014 and doubled in the last decade. This has led to a rejuvenation of the fleet since 2009, from an average age of 14 years in 2008 to 9 years old in 2014.

Consistency of the casualty database and safety level of the fleet before 1998

For this fleet, the IHS casualty database contains 6612 casualties records for the period 1978 to 2014, of which 2509 are reported as 'Non-serious' and 4103 as "Serious" casualties. Fifteen Non-serious casualty reports were fatal and therefore reclassified as Serious casualties. Figure 2, shows the number of casualties per year and compares the results presented in the IACS FSA to the analysis of the 2015 database. The difference between both sources is less than 5% in each year. As was already the case in the IACS FSA study, only serious casualties have been considered because these are relevant for the risk level.
Accident frequencies and potential loss of life (PLL)

13 Taking into account the number of ‘Serious’ incidents and the number of shipyears for the fleet of interest, the average accident frequency for the period 1978-1998 is estimated to be 2.7E-2 acc./shipyear. From the above-mentioned data records, the PLL over the period from 1978 to 1998 is calculated as: 0.0167 fat. per shipyear (against 0.0170 fat. per shipyear in the FSA). This shows that the FSA results that were published 15 years ago can be retrieved from the available databases today, which allows them to be used for comparison and determination of societal risk.

Recorded safety level prediction based on FSA results (IACS)

14 Document MSC 77/5/4 (United Kingdom) also presented an estimation of risk reduction achieved with the introduction of the package of risk control measures agreed by MSC 76 (including double side skin), forecasting risk reduction by 74.9% in terms of PLL. This estimation was based on pure expert judgement. Document MSC 77/26 suggested that this figure could serve in the future as a benchmark when trying to ascertain the effect of any further safety measures.

Figure 2: Recorded Serious casualties extracted from the database (after reclassification) compared to MSC 74/5/4, annex 2

Figure 3: Prediction of development of PLL prepared in 2001 based on available FSA results
The project manager of the IACS FSA also estimated the future risk reduction based on the FSA studies (not including the double side skin). This had already been prepared in July 2001 and contained the timeline for the expected reduction in PLL (see figure 3), considering the phasing in of new ships complying with the new requirements and the phasing out of older ships. This figure indicates that the 74.9% reduction should be reached shortly after 2020.

Safety level of bulk carrier fleet in 2014

Updated FN Criterion

As the period upon which the casualty data is analysed has changed, the risk acceptance criteria also needed to be updated. The updated ‘FN Criterion’ has been calculated in accordance with the approach described in the FSA Guidelines and in the document MSC 72/16 (Norway) providing decision parameters including risk acceptance criteria.

In this study, the value of occupational fatality risk per unit GNP contribution has been updated based on the number of occupational fatalities and GNP in OECD countries and has been estimated at 0.29 fat. per $billion GNP. The most recent data for occupational fatalities and GNP have been retrieved from the ILO and World Bank databases respectively, both accessible online. The average annual turnover for bulk carriers has also been updated based on the Review of Maritime Transport 2014 (UNCTAD, 2015) and is of $2.82m per year. This leads to an average PLL of 8.2E-4 fat./shipyears in 2014. This has reduced to one third compared to the 2000-value and accordingly, boundaries of the ALARP area are much lower than before (figure 4).

FN Curves

The societal risk for the period 1978-98, based on historical data, has been given in the IACS FSA study and is presented in figure 4 (blue), along with the former and updated FN Criterion and FN curves for different periods of time. The figure shows that the FN curve is found in the upper ALARP region (with the criterion calculated in document MSC 72/16), especially in around N=20 fat, corresponding to the total loss of the ship and its crew, which reflects the concern for the bulk carriers in that period.

The FN curve calculated based on historical data for all operating ships and the period 1994-2014 (green), having the same length as the period of reference, is found to be partly in the intolerable area (with the updated FN Criterion). In the following, the time period considered is the 17-year period from 1998 to 2014. 1998 is considered as the starting point of the studied period because of the introduction of the RCOs. 1998-2014 corresponds, therefore, to the period where all new buildings complied with the introduced RCOs and for existing ships transition phase started. This sample is more representative of the world fleet in activity, and is regarded to be more representative of ships built in accordance with current SOLAS regulations. Therefore, it is considered that this period is representative of assessing the current situation. This landmark date is in line with the FSA Critical Review carried out by Greece (MSC 78/5/1):

"Risk level [after implementation of RCOs] corresponds to ships built after 1997, when ESP and SOLAS XII were fully implemented."

1 From a presentation prepared 14/6-2001.

https://edocs.imo.org/Final Documents/English/MSC 96-INF.6 (E).docx
Figure 4: FN curve for bulk carriers larger than 20,000 DWT. The blue curve has been extracted from MSC 74/5/4.

**Risk contributors**

Table 1 provides the PLL and fatal accident frequencies for the periods 1978-98 and 1998-2014 per casualty type which have been recalculated based on historical data for both periods. Figure 5 presents graphically the potential loss of life per accident category for both periods. The categories ‘Contact’, ‘Wrecked/Stranded’ and ‘Collision’ have been merged into one category entitled ‘Navigational Accidents’. ‘Hull/Machinery’ fatal incidents often involve loss of life during unloading (such as the collapse of cranes) or a man swept overboard. For the purpose of the study, liquefaction has been separated from the category ‘Foundering’.

![Figure 5](https://edocs.imo.org/Final Documents/English/MSC 96-INF.6 (E).docx)

![Table 1](https://edocs.imo.org/Final Documents/English/MSC 96-INF.6 (E).docx)

For a period of 17 years, from beginning 1998 to end of 2014, the total number of fatalities was 489. The number of accidents with fatalities was 67 yielding an average number of fatalities per accident of 7.3. The PLL for this period is calculated 5.0E-3 fat. per shipyears, which is about one third of the PLL estimated for 1978-1998.

https://edocs.imo.org/Final Documents/English/MSC 96-INF.6 (E).docx
Foundering is the main contributor in both periods, representing 55% of the total PLL and about 25% of the fatal accidents. This type of incident often involves the loss of most of the crew. For 1998-2014, liquefaction is the second main contributor to risk. As for the ‘Foundering’, liquefaction accidents have a high fatality rate.

Fire

For both periods, fire contributes to 35% of the fatal accidents. Although the 2000's RCOs introduced did not target fire risk reduction, both fatal accident frequency and PLL have been reduced by 50% between both periods which might be explained by the fact that the newly-built fleet may have benefited from SOLAS chapter II-2, and FSS Code, as well as the introduction of the ISM Code.

Liquefaction and Foundered

For the period 1998-2014, seven bulk carriers were identified as involved in liquefaction-related accidents. However, more accidents considered as 'Foundering' or 'Missing' for the 1978-98 period might have been caused by liquefaction of cargo. Four of these seven accidents occurred on ships younger than 10 years old and three of the accidents on ships older than 25 years old. Therefore, no relationship between the age of the ship and the risk of liquefaction is observed and, furthermore, liquefaction is also a significant risk for new ships. This observation is contrary to findings for Foundering accidents where the average age at time of incident is 24 years and the youngest ship 15 years old. It is worth mentioning that with the exception of one, all ships involved in liquefaction transported nickel ore, and that this issue had already been addressed by the IMO (MSC.1/Circ.1454/Rev.1).

Navigational accidents

Fatal navigational accidents represent around 13% of fatal accidents for both periods. Although the frequency of fatal navigational accidents has been reduced by a factor of two, the severity dramatically decreased with an average number of fatalities per accident dropping from 17 to 5. While the introduction of the series of RCOs have no direct effect on collisions, contacts, and groundings, for the period 1998-2014, the fleet of bulk carriers may have benefitted from the introduction of more stringent regulations, which entered into force during that period and became mandatory for all ships such as the ISM Code.

![Figure 5: Potential loss of life for periods 1978-1998 and 1998-2014](https://edocs.imo.org/Final Documents/English/MSC 96-INF.6 (E).docx)
Comparison of historical to estimated safety levels

In this section, the development of PLL predicted in 2001 based on available FSA results and the historical PLL are compared (figure 6). The historical values of PLL have been calculated for each year N, looking at the number of fatalities and shipyears for a 21-year interval, ending on the 31/12/N. For all values before 1998, shorter intervals were taken because the IHS casualty database contains only records starting from 1978. This is expected to cause higher oscillation in PLL values before 1998. Figure 6 shows a clear trend for the risk of bulk carrier and excellent agreement between the forecast based on expert judgment and calculation. The same global trend may be observed although some impacts may have been anticipated (phasing out of the built before 1998).

Conclusion

This study demonstrates by means of historical data an enhancement of bulk carrier safety in the past 20 years. For the period 1998-2014, corresponding to the period where RCOs were introduced:

1. FN curve is below that of the studies carried out about 20 years ago; and
2. FN curve is in the area of risk where the ALARP process can be applied considering updated evaluation criteria.

It should be pointed out that the observed improvement of bulk carrier safety cannot be traced back solemnly to the recommendations made by the FSAs, because risk reduction is also observed for accident categories not addressed by the RCOs, e.g. 'Fire'. Additionally, for some RCOs their effect is difficult to identify because of the small number of incidents and too short an observation period. Furthermore, the study also showed that there is room for improvement. The main area where improvement is required relates to liquefaction.

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3 Prediction by the IACS/FSA PM, made 29/5/2001.
In the context of the usage of FSA in the IMO decision process as well as the discussion on goal-based standards, safety-level approach often concerns had been raised regarding the adequacy and accuracy of risk-based methods. By this study for bulk carrier it has been demonstrated that:

1. the effectiveness of RCOs can be monitored; and
2. FSA methodology is able to accurately predict the effect of RCOs on safety level 15 years in advance.

It should be pointed out that the fleet of bulk carriers is well suited for such risk study, given the large fleet and, therefore, large experience that it is possible to gather, as well as the ship similarities throughout the fleet.

**Action requested by the Committee**

The Committee is invited to note the information provided.