REGULATORY APPROACHES LEADING TO HOLISTIC IMPLEMENTATION IN A FISHING VESSEL FLEET LESS THAN 24 M IN LENGTH

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SUMMARY

Fishing is a very dangerous sea activity with a high rate of fatalities that is difficult to deal with by Maritime and Fisheries Administrations around the world. Meanwhile the Ocean Governance requires a global approach to sustainability and safety, with overarching principles governing both of them. This paper deals for the first time with the implementation of a complete methodology to assess the safety at sea, by means of a bottom-up goal based standards with safety level approach, encompassing the national regulations and using formal safety assessment as the driver in a fishing vessel fleet below 24 m in length (L). It is concluded that such methodologies are applicable, goal based regulations can be established, flexibility in the design can be provided and have the potential to be later extrapolated to holistic approaches.

NOMENCLATURE

L	Length between perpendiculars
FSA	Formal Safety Assessment.
GBS	Goal Based Standards
SLA	Safety Level Approach
GBS-SLA	Goal Based Safety Level Approach
ALARP	As Low As Reasonably Practicable
VPF	Value of Preventing a Fatality
GCAF	Gross Cost of Averting a Fatality
NCAF	Net Cost of Averting a Fatality

1. INTRODUCTION

Fishing has been traditionally considered one of the most dangerous activities, with more than 4.5 million vessels below 24 m in length and millions of fishermen operating them worldwide.

The rates of fatalities per 100,000 fishermen in developed countries show a decline in the last 15 years, however the figures are still high. In the UK the rate of fatalities varies between 80 (highest) and 30 (lowest), in Norway between 50 and 40 and in Canada between 30 and 20, in a context of a declining number of fishermen and fish stocks. Meanwhile in Spain the rate is between 45 and 22, with a soft decline in frequencies in the last eight years. However in the national context, the Spanish rate is between 6 to 9 times above average and 3 times higher than popular sectors such as house building, as it can be seen in figure 1.

In some cases health and labor accidents in fishing vessels are mixed with safety at sea related accidents thus making difficult to separate incidents and isolate those strictly related to the lack of safety. In general, accidents in vessels below 12 m in length tend to be more related to safety whereas for the range from 15 m to 24 m in length are more related to occupational health.

It is not easy to find literature that can quantify the casualty risk of fishing vessels. The available data refer to the fatality rates or number of fatalities, but never in very detailed manner and even less taking into account the impact of these accidents in the national economies. This issue, among others, diverts the attention in maritime safety towards the more global international shipping in merchant ships.

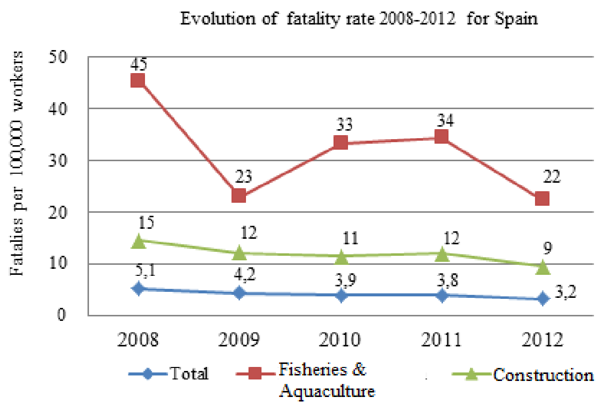

Figure 1. Rates of fatalities in Spain. Total working force, fisheries and aquaculture and construction

The achievement of high level goals in the fishing vessel industry is more cumbersome than in international shipping, due to the complexities of an activity that is mainly carried out at regional level and, in addition, the low level of commitment at international level to deal with these vessels.

This complexity requires a collaborative approach between the agencies involved and also a holistic approach. However, in order to be holistic, it is necessary to carry out an exercise to assess how safety at sea can be considered in isolation in such a broad manner that it later allows to combine it with other elements such as the management of the resource, pollution and labor conditions.

With all of the above challenges, fishing vessels below 24 m in length between perpendiculars (L) were chosen as a case study due to the following:

- the higher incidence in safety at sea versus. occupational safety in comparison to larger vessels;
- the frequency of fatalities that seems difficult to be further reduced;
- availability of statistical data in a single fishing vessel fleet;
- the need to be able to find a systematic approach to decide on the most adequate technical solutions to reduce the high fatality rates; and
- the future challenges, in particular related to Ocean Governance and life below the water management;

2. OBJECTIVES

To assess safety at sea in fishing vessels of less than 24 m in length in a quantifiable manner in order to be able to move to a more holistic approach that can be later connected with sustainability.

In this regard a research was carried out in the Spanish fishing vessel fleet with the following objectives.

- Quantify risk and find the safety level of the national fishing vessel fleet (excluding aquaculture) by analyzing its impact on the national economy, the regulatory framework and analyzing the accidents in a fleet that has changed in the last 17 year due to the pressure on the fishing stocks.
- Generate a structure and methodology to be able to change the reactive approach to accidents.
- Provide a certain degree of freedom in the design in a very heterogeneous fleet that can be later extrapolated to the worldwide fleet.

3. TOOLS FOR QUANTITATIVE ASSESSMENT, DECISION AND RULE MAKING

In order to identify and apply tools for a change towards a more quantifiable and holistic regime in maritime safety this research it is necessary to explain several IMO methodologies, some of which are still under development (Núñez, 2016).

3.1 FORMAL SAFETY ASSESSMENT

Formal safety assessment (FSA) (IMO, 2015), as outlined in figure 2 is a tool that evaluates new regulations in steps and helps to compare proposed changes with existing standards, enabling a balance to be drawn between the various technical and operational issues, including the human element, and between safety and costs. FSA uses risk models (step 2) that help to evaluate recommendations (step 3), known as risk control options, which should be presented to the decision-makers in an auditable and traceable manner (steps 4 and 5).

These recommendations are based upon:

- the comparison and ranking of all hazards and their underlying causes;
- the comparison and ranking of risk control options as a function of associated costs and benefits; and
- the identification of those risk control options which keep risks as low as reasonably practicable.

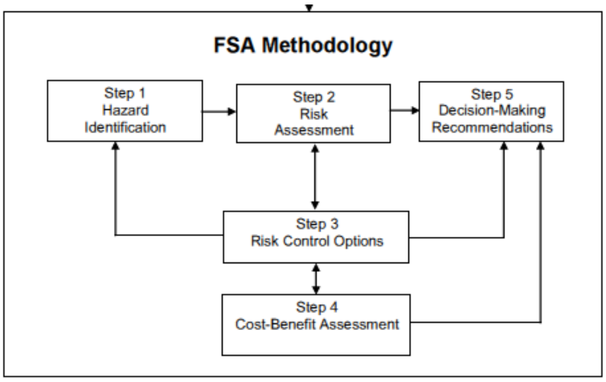

Figure 2. FSA step approach (IMO, 2015)

However, this risk-based approach technique has some challenges, such as:

- the quality and quantity of the data collected in order to support monitoring and development of safety regulations;
- the integration of risk-based methodologies and the latest analysis techniques into the safety regulatory framework to provide a sound scientific and practicable basis for the development of future safety regulations; and
- the know-how required to use these tools versus the traditional approach to propose new rules or amend existing rules, with justifications that do not require detailed documented rational, basis for assumptions, description of uncertainties or sensitivity analysis.

3.2 SAFETY LEVEL APPROACH (SLA)

SLA is the structured application of risk based methodologies to reach an explicit safety level or to verify compliance of rules. The aim is to have quantitative and rational safety levels to be able to be used and provide a way to measure safety in the ship concept and the human element in the IMO rule making process.

This approach needs the development of quantitative or qualitative safety levels and processes to be used for achieving a practicable safety level, or an implicit safety level such as that in the ALARP principle (IMO, 2000) with F-N curves (societal risk). By doing this the safety level may be revised and adjusted as needed when this is not sufficient or it is exceeded.

3.3 GOAL BASED STANDARDS (GBS)

GBS is a "top-bottom" concept that offers a tiered approach, "rules to develop rules", working with the following principles (IMO, 2015), also indicated in figure 3:

- Tier I- Goal, which is a high level objective to be met that should address an issue of concern;
- Tier II- Functional Requirements, which provide the criteria to be complied in order to meet the goals and are developed after the goals and considering the relevant hazards;
- Tier III- Verification of Conformity, which provides a transparent instrument necessary for monitoring and verifying that the associated rules and regulation for vessels conform the goals and functional requirements.
- Tier IV- Rules and regulations for vessels, which are the detailed requirements (developed by IMO, a National Administration, a Recognized Organization or a Classification Society) that need to meet the goals and functional requirements
- Tier V- Industry practices and standards, developed as a consequence that may be referenced in the rules and regulations.

These have the aim to provide more clarity and flexibility to comply with the functional requirements by means of risk management tools without a pre-established agreed criteria in their definition.

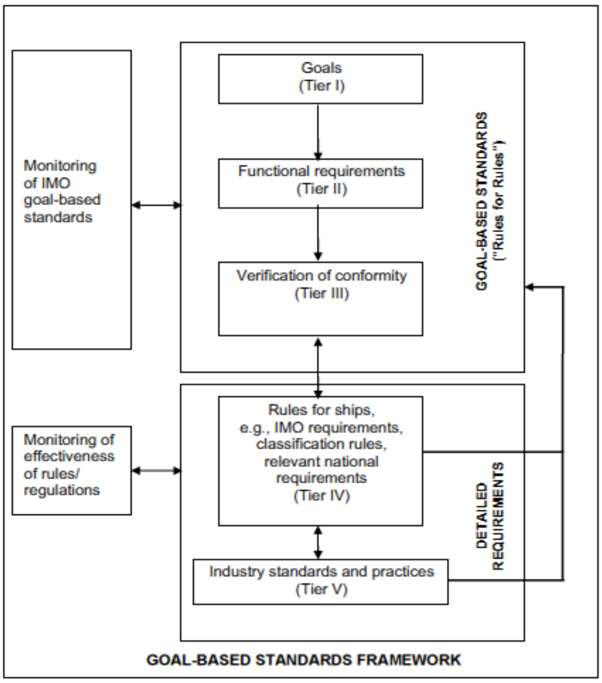

Figure 3. Goal Based Standard tiered structure (Data source: (IMO, 2015)

With the proper use of these tools there is a possibility to structure the rule development when interconnected as indicated in Figure 4, and therefore it was decided to proceed accordingly.

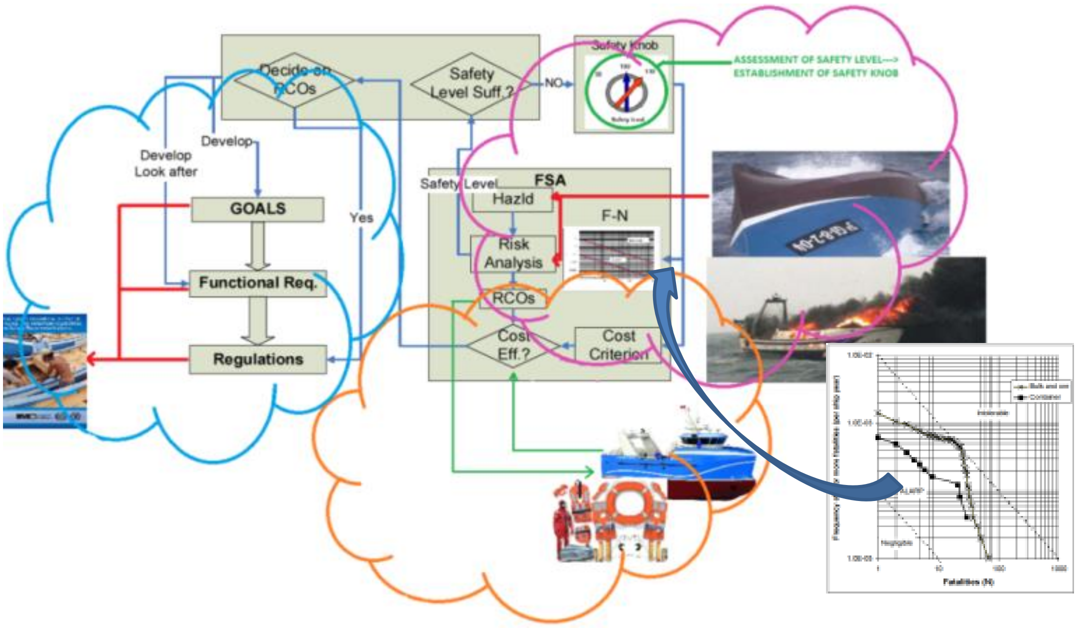

Figure 4. The combination of risk analysis, hazard identification, FSA, GBS and SLA (Núñez, 2016)

In this regard the following steps were taken:

- Analyze the fishing vessel fleet and the industry in terms of revenues, benefit and impact on the GDP;
- Analyze the fishing vessel fleet in terms of regulatory regime, fatalities and develop suitable high risk level models that can turn the frequencies into probabilities, to be able to analyze the impact of risk control measures. This is carried out in steps 1 and 2 of the FSA;
- Identify a safety level of the fishing vessel fleet using the previous two items based on cost analysis, considering some of the elements of step 3 of the FSA;
- Carry out a detailed formal safety assessment (FSA) of the fleet to determine the risk control options that can be implemented, taking into account the safety level as calculated; and
- Determine goals and quantifiable functional requirements for the national safety at sea regulations that can incorporate a safety level and be used as high level principles, to develop rules in a GBS-SLA environment inserting them in the high level risk models.

4. ANALYSIS OF THE FISHERIES ECONOMY

In order to be able to later consider in the national economy the costs and benefits of fishing vessel accidents an analysis was carried out.

Spain is traditionally considered one of the most important players in the world of fishing and one of the top 3 consumers in the world, with an important fishing vessel fleet below 24 m in length. The impact in the GDP by small scale fisheries with vessels less than 24 m in length constitutes approximately, 2,000 million € per year, approximately 0,1 % of the national economy, as indicated in figure 5.

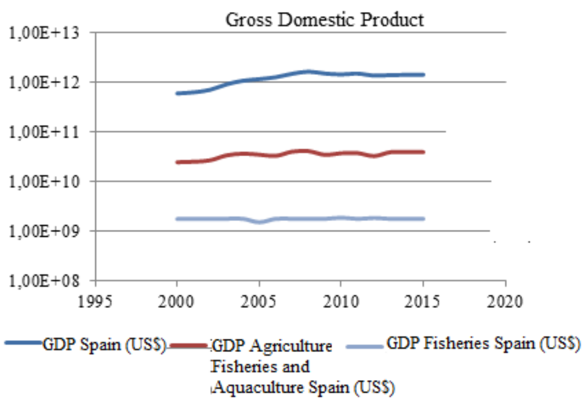

Figure 5. Evolution of the Spanish fisheries GDP

These revenues are heavily influenced by the size of the fleet that has been progressively decreasing due to the lack of stocks, but has been balanced with the increase in value of the captures. In order to assess how the fleet will evolve a forecast was carried out by means of a multi-regressive ARIMA (1,1,1) (Rodríguez-Aragón, 2015). The results are shown in figure 6, that indicated a continuous decline that will probably continue in the future.

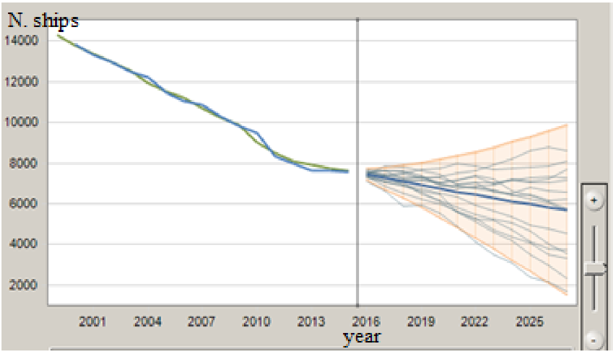

Figure 6. Evolution of the Spanish FV fleet below 24 m L and future forecasts by means of ARIMA (1,1,1)

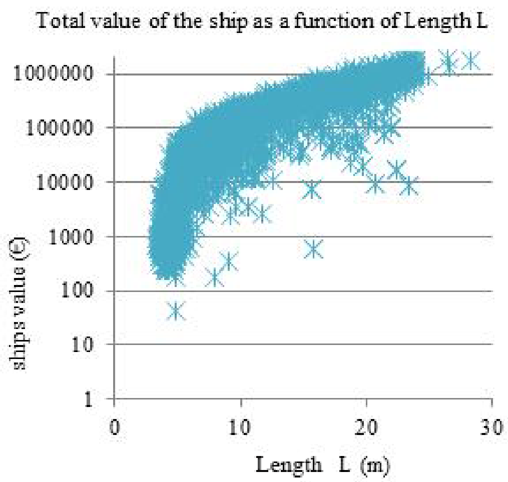

Figure 7. Vessels value (€) against length

The fisheries economy and the value of ships were quantitatively analyzed from 2000 to 2015, taking into account the evolution of the fleet, the economic value of the ship indicated in national certificates and the loss of the asset as the fishing vessel increases its age. Figure 7, shows the value of the fleet below 24 m in the year 2015.

The daily income per fishing vessel is heavily dependent upon its size and the type of fisheries. Taking into account the captures and its value, the revenue was calculated as indicated in figure 8. This data was then used to assess the loss of income per day in case of accident of a fishing vessel.

Finally the costs of repairs in case of accident were assessed taking into consideration the necessary hull and machinery repairs in the reported accidents, after consultations with shipyards and manufacturers. Due to the limited data, the values provided were adjusted to statistical distributions, such as the one indicated in figure 9, by means of Montecarlo simulations.

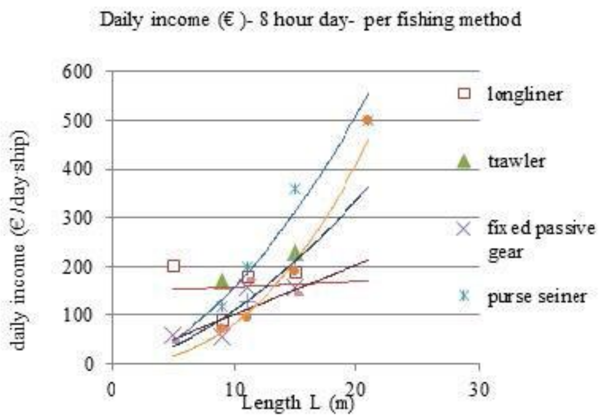

Figure 8. Daily income, fishing vessels below 24 m L depending on the ship´s method

The above three elements constitute the basic costs and loss of benefits of accidents in monetary terms, in case of accident.

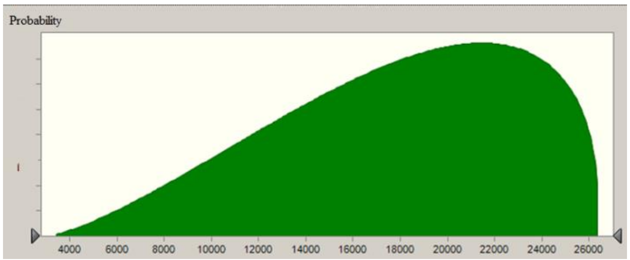

Figure 9. Beta distribution with costs of repairs to the structure for accidents in vessels between 15 and 24 m L

5. ANALYSIS OF THE SAFETY AT SEA REGIME TAKING INTO ACCOUNT ACCIDENTS

The fishing vessel safety regime depends on the ship size. The use of tonnage as per the International Convention on the Measurement of Ships, 1969 is well established in Europe, however the use of length in the 1930 or 1966 Load lines Convention (as transposed to fishing vessels) and the 1993 Torremolinos Protocol turns length (L) into the main parameter, whose main threshold is set at 24 m. For vessels below 24 m key figures such as 12 m, 15 m or 18 m are normally used. In the case of Spain the regulatory regime below 24 m sets a limit of 12 m, which is approximately 15 m length over all (LOA). This creates a division in the regulation which is similar to other countries like the UK (MCA, 2002).

A database of 975 accidents was analyzed in order to get valuable information, such as the monthly percentages, that remained approximately constant irrespective of the season, as indicated in figure 10. With these data, the individual risks (taking into account the exposure) and the potential loss of life per ship per year (PLL) per type of accident were also calculated.

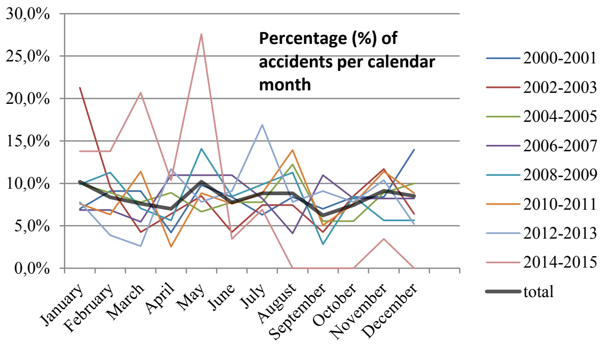

Figure 10. Percentage of bi-annual accidents in the fishing vessels fleet below 24 m L per calendar month

The rate of fatalities in Spain in the period 2000-2013 provide acceptable values of the potential loss of lives (PLL) in terms of fatalities per ship per year except for some types of incidents, such as foundering and shows a decline when comparing the periods 2000-2007 versus 2008-2013.

The societal risks by means of FN curves (Svein, 2005) were also calculated. These curves show the frequency of accidents with N or more fatalities in vessels of less than 12 m, as indicated in figure 11 and for vessels on or over 12 m in figure 12.

These FN curves were limited by an as low as reasonable possible "ALARP" region that allowed to assess the status of the fleet in terms of societal risk, whether unacceptable (above ALARP) and negligible (below ALARP), that is built taking into consideration the Potential loss of life of the activity (PLL_A), which refers to the potential number of fatalities in the fisheries activity by comparison to the economic value of the activity and the national GDP. Figures 11 and 12 show different bands for comparison of merchant vessels: IMO standard for general cargo ships as chain line, the 2000-2007 region as a dotted line and the 2000-2013 region as a dashed line.

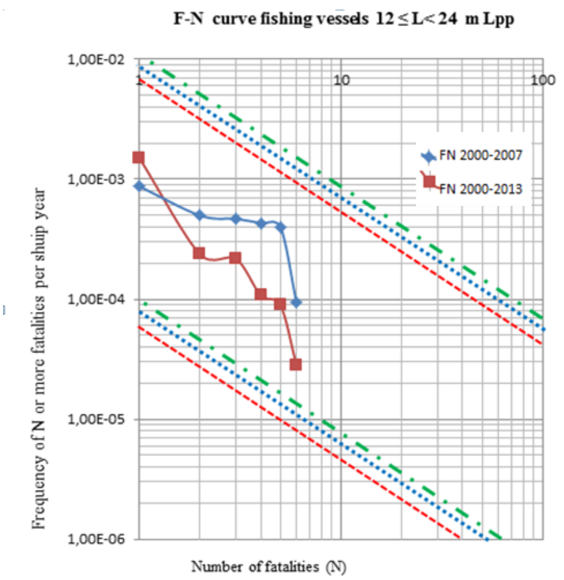

Figure 11. F-N curves fishing vessels from 12m to 24 m L

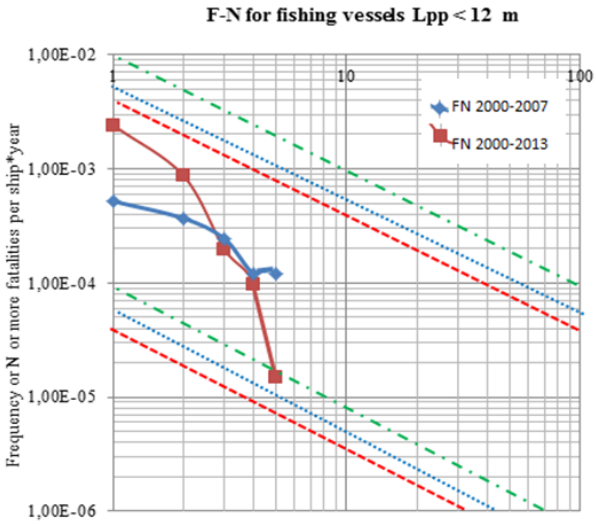

Figure 12. F-N curves fishing vessels of less than 12 m L

Taking the above into consideration, it was found that this fishing vessel fleet was performing within the ALARP zone and relatively well, if compared to the global merchant ship fleet in terms of individual risks and the value of the activity (Svein, 2005).

Finally, after considering the PLLs and the F-N curves it was decided to develop "bow- tie" high level risk models (Papanikolau *et al,* 2009), that would consider fault and event trees with the aim to capture the reasons why an accident was triggered and its consequences. These trees were made for the following types of accidents: collision, fire-explosion, grounding, foundering and list, as the example shown in figure 13. These models would take also into account; *inter alia,* the area of operation of the ship, the loading conditions and the consequences.

Not all the accidents could be included in the models, but only those with sufficient information. In order to compare the data in the model with historic data, the PLLs were benchmarked in the FN curves with satisfactory results. However, in terms of loss of benefits, a deviation of 15% was obtained. This error will be accumulated in the whole research whenever benefits had to be considered.

6. IDENTIFICATION OF THE SAFETY LEVEL

Taking into consideration the costs calculated above, it was decided to calculate a safety level for the Spanish vessel fleet by means of costs criterion for the years 2000 to 2013. In order to achieve it and considering the decline in frequencies, as indicated before, it was benchmarked how the implementations of new safety regulations in 2006 and 2007 had helped to reduce the fatalities taking into consideration the evolution of the fleet.

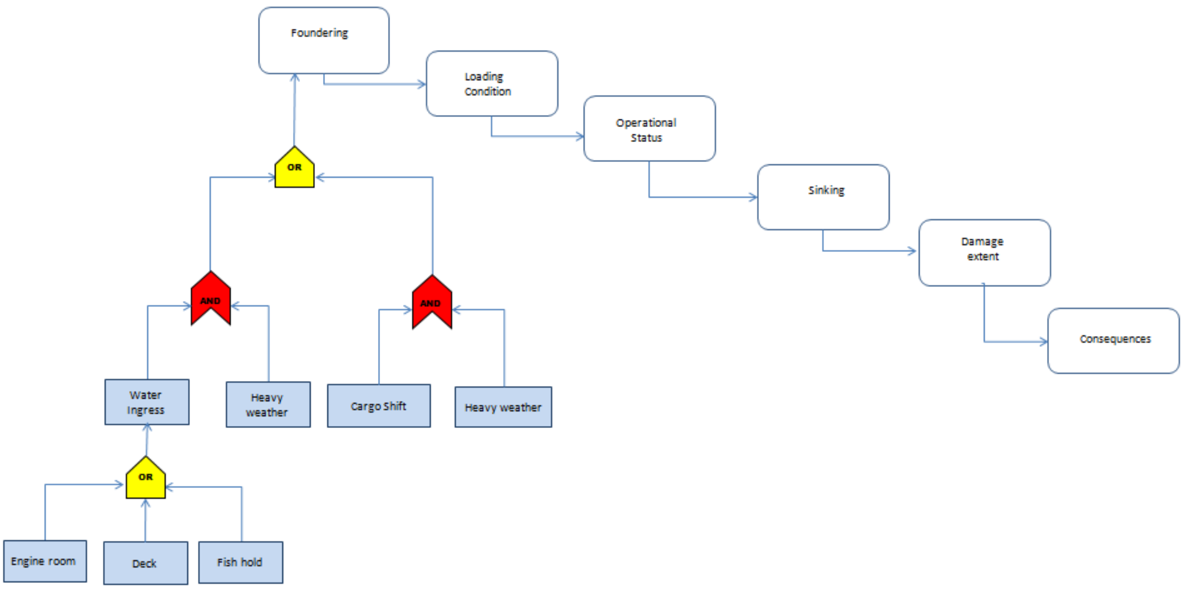

Figure 13. Foundering High level risk model

These measures included the implementation of the Code of Safety for fishing vessel below 24 m L (Ministry of Transport, 2007) that required additional safety and navigation equipment for all vessels, together with measures for new ships, such as new load-line assignment (see figure 14) and other measures implemented , such as GMDSS regulations and concentrated inspections.

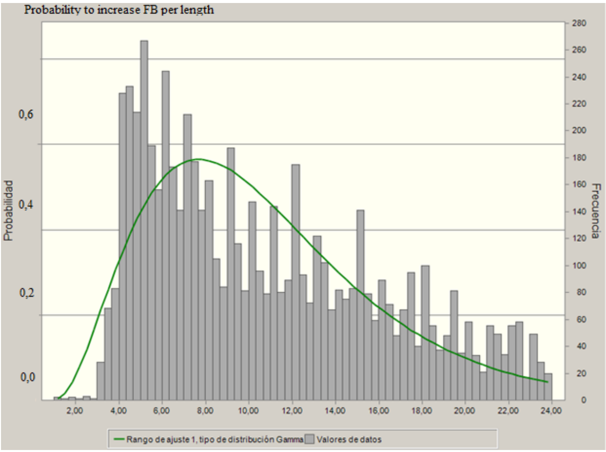

Figure 14. Probability (1/10) of necessity to increase freeboards depending on the ship length

In order to calculate this level the value of preventing a fatality (VPF) was also determined for Spain (4.5 M €) and this value compared with the Gross cost of averting a fatality (GCAF) and Net cost of averting a fatalities (NCAF) of the combined implemented measures as indicated in formulas 1 and 2.

$$GCAF = \frac{\Delta Cost}{\Delta Risk} \quad (1)$$

$$NCAF = \frac{\Delta Cost - \Delta Benefit}{\Delta Risk} = GCAF - \frac{\Delta Benefit}{\Delta Risk} \quad (2)$$

The costs of implementation of these new regulations (ΔCost) were determined in consultation with manufacturers and designers. The benefits (ΔBenefit) were taken from the historic data, and the calculations carried out as shown in section 4 of this paper. The risk reduction (ΔRisk), in terms of fatalities, were determined with the statistical values as shown in section 5. All of the above was calculated taking into consideration the forecasts of the fleet in the next 15 years.

The ratios obtained when dividing the parameters GCAF or NCAF by the VPF indicates the percentage of VPF to be used to determine safety measures. Therefore, considering the impact of the implemented regulations, this ratio is assumed to be the safety level of the current regime and the "lever" indicating, in terms of costs, which potential new regulations can be developed depending on the risk reduction, costs and benefits.

Using GCAF only and taking into account the fatalities in the years 2014 and 2015 the factor needed further readjustments as indicated in figure 15, showing how sensitive the parameter is to the change in frequencies. In terms of safety the calculation shows that vessels from 12 m to 24 m L have performed well and also shows that special attention is needed on those vessels below 12 m, which is coincident with the initial consideration that vessels below 12 m L are more prone to have safety at sea related incidents and the FN curve shown in figure 12.

It also shows that during the period 2014 and 2015 the reduction in the risk of fatalities was not sufficient and therefore the increase in costs triggered an increase in the safety level factor.

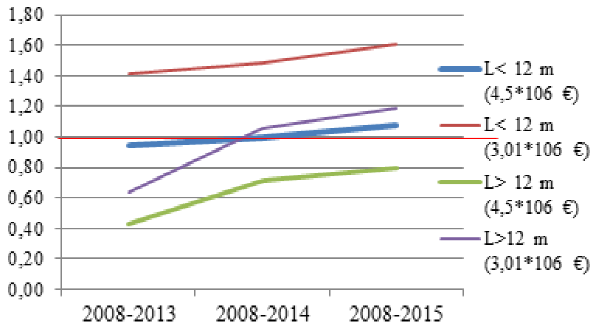

Figure 15. Safety level adjustment incorporating the accidents on the year 2014 and 2015

7. COMPLETION OF A FORMAL SAFETY ASSESSMENT

Once the safety level was determined, this was assessed by means of a complete FSA to determine potential risk control measures to be implemented. Twenty two (22) risk control options were proposed, as indicated in table 1. These were quantified in terms of costs and its effectiveness was assessed by a group of experts.

Taking into account the effectiveness of these risk control measures, as indicated in figure 16, and the reduction of risks provided by them, these risk control options were ranked by means of a cost and benefit analysis using the GCAF and NCAF formulation indicated above.

Due to the instability in the safety level as indicated in section 6 a cautious approach for rule development is recommended, with a safety level of 1,0 (100%).

A sensitivity analysis was carried out, taking into consideration different possible scenarios in terms of VPF value (the Spanish value of 4.50 M€ and the IMO standard value of 3.01 M€), the most extreme forecasts in the evolution of the fleet and the highest and lowest values of effectiveness. With all of these, some risk control measures have a solid potential to be implemented.

Table 1. Risk Control Options proposed to be implemented by a group of experts. (N means “new vessel” and E means “existing vessel”)

RCO 1	Improvement of safety culture with promotion campaigns (N&E)
RCO 2	Concentrated campaigns of inspection (N&E)
RCO 3	Improvement of Stability Training for skippers (N&E)
RCO 4	Improvement in Stability booklets (L≥15 m)
RCO 5	Lightweight control (N&E) (L≥15 m)/ Stability test (N&E) (L<15 m)
RCO 6	Marking and control of fishing gear (N&E) (7,5<L≤12 m and L≥12 m)
RCO 7	Allow for fish stowage on deck N&E (7,5<L≤12 m)
RCO 8	Draught marks (E) (L≥15 m)
RCO 9	General Arrangement and hull forms enhanced control (N) (7,5<L≤12 m and L≥12 m)
RCO 10	Increase door sills height (E)(L≥12 m)
RCO 11	Improved design of shipside valves (N) (L≥12 m)
RCO 12	Stability Software installation (N&E) (L≥15 m)
RCO 13	Shipyard Quality Control (N)
RCO 14	Engine room ventilation calculation with engine compartment (N)
RCO 15	Improvement of ventilation systems for existing ships(N&E) (L≥12 m)
RCO 16	Engine room machinery controls automated (E) (L≥12 m)
RCO 17	Smoke detectors in accommodation, fire detectors in engine room (N&E)
RCO 18	GMDSS radio communication information available on the bridge (N&E)
RCO 19	Safety Management System implementation (N&E)
RCO 20	Enhance monitoring of vessels (N&E) (L≥15 m)
RCO 21	Plan Approval by Classification Society (N)
RCO 22	Improvement of freeing ports (E)

The most relevant measures to be implemented are the development of a safety culture by means of a structured program, the need to consider fish on deck during stability calculations for decked vessels below 12 m in length, and the need to have available draught marks for vessels between 12 m and 24 m in length. Other measures such as the implementation of ISM or the approval of new constructions under the rules of a classification society did not pass the cost benefit analysis (FSA step 4) and therefore shouldn´t be considered as risk control measures to be made applicable (FSA step 5).

Taking into consideration the parallelisms with other fishing vessel fleets in Europe, the use of VPF values (both the Spanish and the OMI values) and the evolution of the fleets in other parts of the world these risk control options could be applied globally, although necessary studies should be carried out, including the model adjustments and the use of the fishing vessel accidents in the region of concern.

8. DEVELOPMENT OF GOALS AND FUNCTIONAL REQUIREMENTS

The FSA methodology had helped to develop the risk models and the safety level nevertheless, in order to further progress in a holistic approach; a GBS-SLA was decided at the next step. This could help to develop long lasting regulations in the future (IMO, 2015).

In this regard overarching goals and functional requirements for the safety of fishing vessels following tiers I and II of GBS as indicated in figure 17 could be developed. These could be quantifiable and able to incorporated the safety level approach.

Hence, it was necessary to develop text that would avoid the prescriptive nature of the current regulations encompassing the current applicable national safety regulations, in particular the above mentioned Code of Safety for fishing vessels adopted in 2007 (Ministry of Transport, 2007), therefore a bottom-up approach was decided.

The current works in IMO (IMO, 2017) and NATO (NATO, 2014) were used to develop functional requirements with the three following elements: a description, performance requirements/rationale and justification following the example indicated in table 2.

The rationale and description were based on the analysis of the current regulations that could also address the hazards. The justification was developed to address the risks and risk factors, thus making the functional requirements quantifiable.

The 50 functional requirements developed were connected to the high level models developed during the risk assessment in step 2 of the FSA as shown in figure 18. Quantitative/qualitative goals were subsequently developed, but the quantification rests in the functional requirements themselves.

These functional requirements are not only the basis to develop new regulations and therefore considered “rules for rules”, applicable to a very heterogeneous fleet, but also the means to start developing risk based design (Papanikolau *et al*, 2009). In order to do so the high level models developed could be used by the sector (mainly shipyards and designers in this particular world of fisheries) combined with low level risk models.

Following this approach safety would not only be in the hands of the regulatory bodies but also in the hands of the whole sector and would allow consistency and alternative design (IMO, 2006), providing flexibility and allowing the whole sector to build and use the methodology.

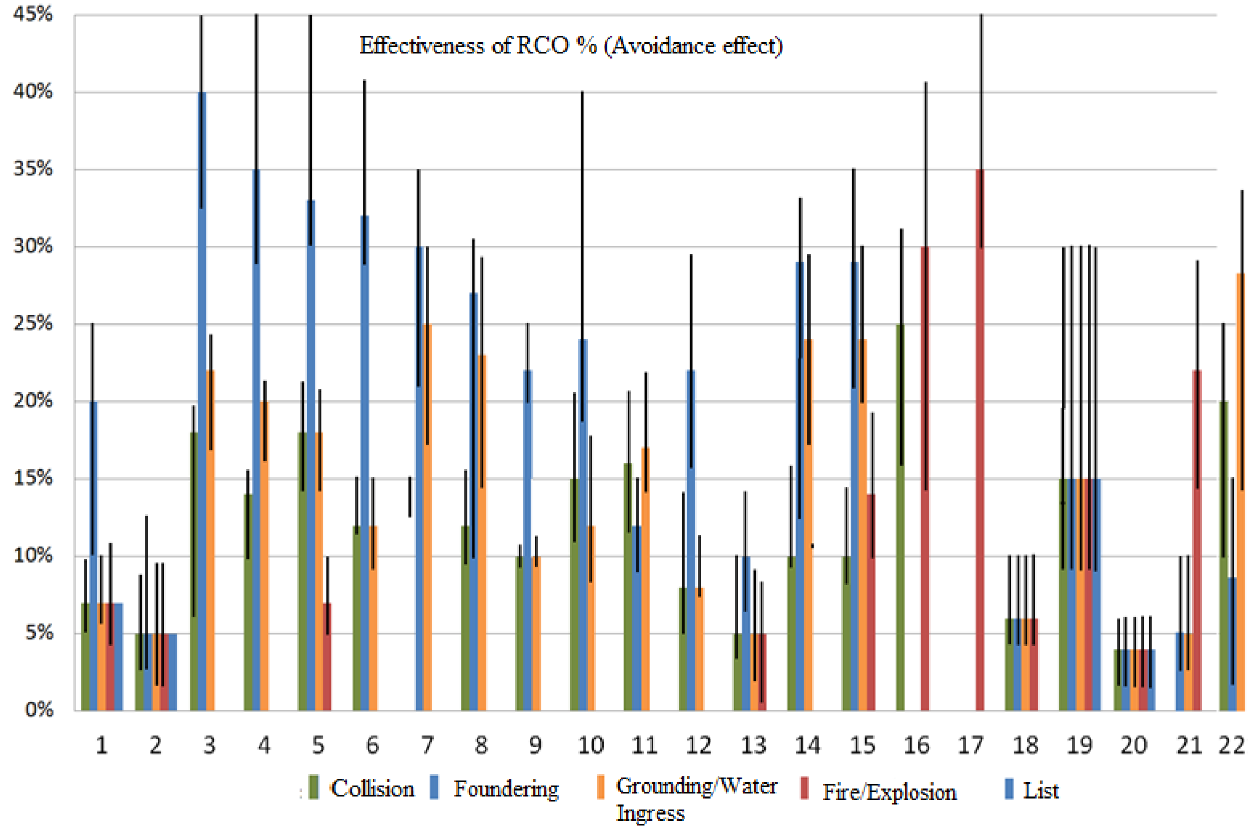

Figure 16. Effectiveness of proposed risk control options for each type of accidents and bands showing maximum and minimum values

Table 2. Example of functional requirement as developed

	Description	Performance requirement/Rationale	Justification
What it is	a specific and short explanation of the required function.	description of the necessary function in quantitative terms. this description should cover all aspect necessary for verifying compliance and the conditions under which these have to be reached	assignment of hazards to be mitigated by the function under consideration
What was developed (example)	Provide ready access to survival systems for all persons	• quantity, distribution and arrangement of life saving appliances on board • spare capacity • signage for life-saving appliances • reflect the physical characteristics and capabilities of the embarked persons	Collision, grounding, fire/explosion, foundering, list in case of total loss of the ship and abandonment.

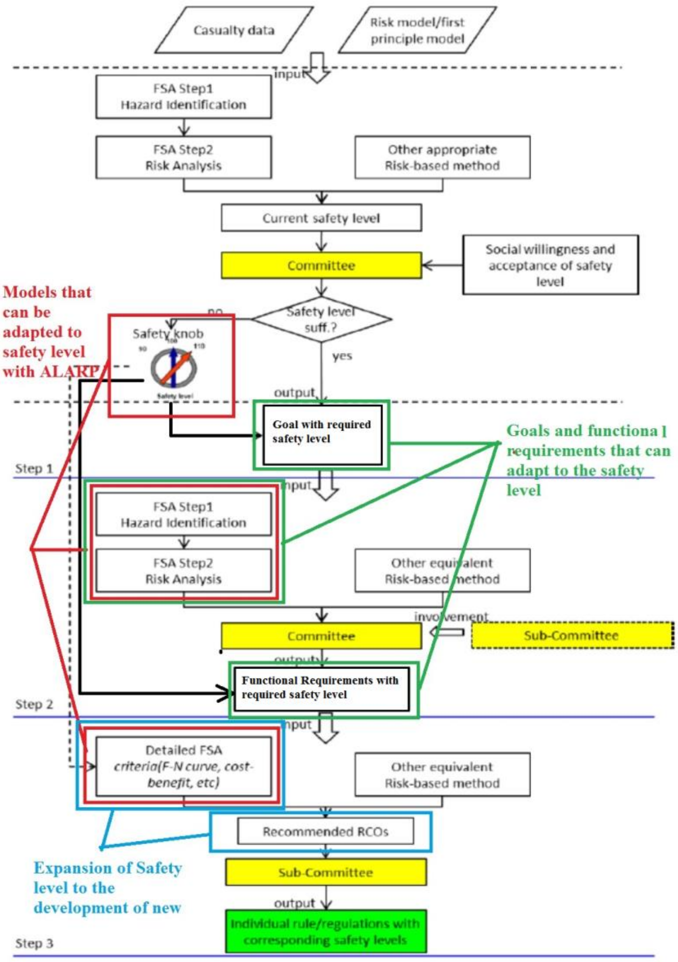

Figure 17. Development of Goals and functional requirements in a GBS-SLA approach (IMO, 2015)

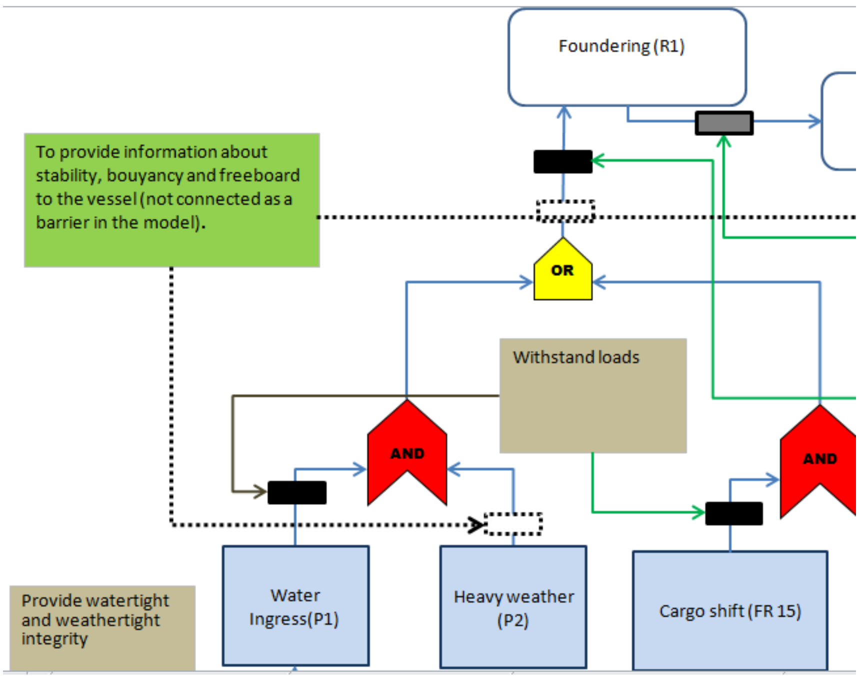

Figure 18. One Section of the foundering high level model incorporating functional requirements

The developed GBS-SLA goals and functional requirements allow to develop rules and also to go into a holistic approach, introducing later matters of pollution, responsible fisheries, sustainable development and others. In this regard a fishing vessel owner with high safety standards would be more likely to be involved in responsible fisheries.

All this process constitutes an application of the GBS-SLA approach using FSA techniques, that will assist to develop holistic regulations and also to address very heterogeneous fishing vessel fleets. A further refinement by the Administration would remain pending.

The developed goals and functional requirements could also be considered by Maritime Administrations, provided suitable models were adjusted and populated with accidents.

9. CONCLUSIONS

The above research in combination with the assessment of the current situation leads to the following conclusions:

- Fishing activity is dangerous due to its complexity and the substantial risks involved. It is difficult to quantify its risk and therefore to legislate.
- The implementation of overarching principles such as sustainability requires the regulations to be more holistic. In order to do this it is necessary to put the safety legislation into context to be able to move into the future.
- The safety level can be measured and applied taking into consideration the needs of reduction of risk in terms of fatalities, taking into consideration cost and benefits.
- Suitable measures for fishing vessels and small craft can be analysed taking into consideration costs, benefits and risks reduction with sensitivity analysis in an FSA environment that has been restricted for the moment to merchant vessels.
- Safety culture is an issue in this activity. Fishermen assume certain risks even consciously while these can be avoided by means of cost-effective measures. In order to improve this it is necessary to raise awareness by means of training courses, enhance knowledge of stability and create safety culture by means of explanatory concentrated campaigns of inspection.
- Safety of fishing vessels is seen as a regional activity but requires overarching policies. A GBS-SLA approach may help to develop consistent Maritime Policies at national, regional and international levels
- The GBS-SLA approach will help to develop risk based design regulations for fishing vessels in the future and overcome the difficult exemption regime.

10. REFERENCES

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