Flooding Risk Assessment of Motor Bancas Operating in the Philippines

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ABSTRACT

This paper focuses on describing the process of assessing the flooding risk, as well as identifying and implementing cost-effective solutions, for designing new or for retrofitting existing motor bancas, representative of some 10,000 of these boats, serving most of the domestic trade in the Philippines. To this end, the selected design has been subjected to a systematic process of damage stability and flooding risk analysis in order to identify design vulnerabilities, leading to risk estimation in the form of PLL. A number of risk control options have then been identified, enabling a thorough risk assessment and identification of cost-effective RCOs, as well as impact assessment, using IMO risk acceptance criteria as the basis and the metric of Potential Loss of Life, facilitating estimation. The process of risk analysis and risk assessment is then detailed, the latter providing a cost-benefit assessment to aid decision-making in the RCOs selection, practical implementation, and impact.

Keywords: *Motor bancas, Philippines, Damage stability, Time to capsize, Flooding Risk Assessment, RCOs, Recommendations*

1. INTRODUCTION

One way of ensuring that action is taken before a disaster occurred is to use a process known as a formal safety assessment (FSA, MSC-MEPC.2/Circ.12/Rev.2.). This has been described as "a rational and systematic process for assessing the risks associated with shipping activity and for evaluating the costs and benefits of IMO's options for reducing these risks.". Such options have invariably been extended to other stakeholders (Flags, Administrations, Class, Shipyards and Ship operators), aiming at identifying cost-effective solutions to improve the safety standards of existing ships and new buildings. As the nature of this undertaking is highly technical, it is vitally important that the proposed solutions in the form of recommendations are properly communicated to ensure that all stakeholders gain sufficient information at a level that is readily understood to support effective decision-making (Vassalos et al., 2022a). One way to achieve this is by comparing proposed changes with existing standards, targeting life-cycle implications (design, operation, emergencies) to enable a balance to be drawn between technical and operational issues, including the human element as well as between safety (Delta Risk) and cost (Delta cost) in the implementation of the proposed recommendations (Goerlandt, F. & Montewka, J., 2015, Puisa et al., 2021).

This paper focuses on describing the process of assessing the risk (Aven, 2012, 2022), as well as identifying and implementing cost-effective solutions for the design of new ships or for retrofitting existing ships (Vassalos et al., 2021,2022b) to achieve higher safety standards with a focus on the highest risk contributor, as previously identified, namely inadequate damage stability and the ensuing risk to human life (Vassalos et al., 2019).

To this end, following a ship selection process of representative ships from the whole fleet currently engaged in domestic voyages in the Philippines, three ships have been selected, namely (a) a small motor banca; (b) a medium-sized modern RoPax and (c) a large older design RoPax. In this paper, only the first category is being addressed. The process of risk analysis and risk assessment is detailed, the latter providing a cost-benefit assessment to aid decision-making in the Risk Control Options (RCOs) selection, practical implementation, and impact.

2. ADOPTED METHODOLOGY FOR FLOODING RISK ESTIMATION

2.1 Survivability Assessment

The methodology adopted in the FSA Philippines project, has been tailored to cater for flooding risk estimation (using different risk metrics), pertinent to static assessment and statutory requirements, leading to risk-informed performance in relevant conditions and environments. This, in turn, facilitates the design and implementation of pertinent RCOs to prevent, mitigate and control flooding risk in domestic passenger ships and is comprised of eight distinct phases, as elaborated in the following and shown in Figure 1. The process begins by addressing damage stability assessment based upon conventional hydrostatic techniques (Bulian et al., 2016, Ruponen et al., 2018, Mauro & Vassalos, 2022). Such assessment is conducted in accordance with applicable IMO statutory instruments, which vary depending on vessel age, type, and size. When assessing new build vessels engaged in international voyage, this relates to the requirements of either SOLAS 2009 (IMO, 2009) or SOLAS 2020 (IMO, 2020), as applicable. This form of assessment enables a quantifiable baseline risk level to be established from which the impact of RCOs can then be measured and compared (Vassalos et al., 2022b). Unfortunately, a great deal of existing ships and domestic vessels are regulated based on older prescriptive regimes, with an implicit but not explicitly quantifiable safety level. This is by using the Index of Subdivision (A-Index) as the risk metric to facilitate comparisons in the attained “risk” level and for evaluation of various design options to enhance ship damage stability. This means that the choice of risk control options is somewhat shaped by the elements of assumption, generalisation and simplification that are commonplace within technical standards.

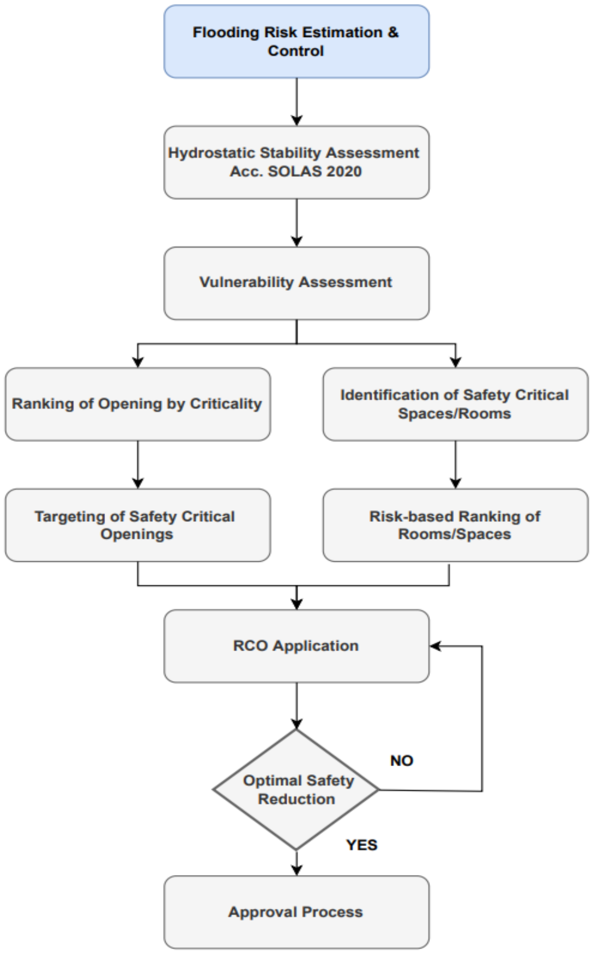

Figure 1: Methodology Adopted

3. RISK ASSESSMENT

3.1 General Considerations

Building upon the developments in risk models over the past 30 years, a generic risk quantification process and modelling is presented in this section, geared towards domestic passenger ships operating in the Philippines. In this respect, a generalised way of considering flooding risk in the form of PLL_A (Attained Potential Loss of Life) is given in equations (1) (Vassalos et al. 2023) with a detailed description in Figure 2.

$$PLL = Probability \ x \ Consequences \quad (1)$$

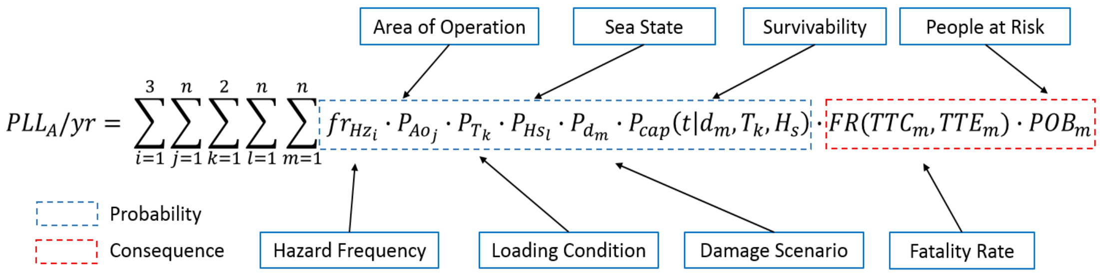

Figure 2: Description of Risk Estimation (PLL) Components

3.2 Flooding Risk Quantification – Input Data and Parameters

3.2.1 Sample ships – Initial ship data and preliminary analysis

The first item considered in analysing domestic passenger fleet data pertaining to the Philippines, has been to observe the fleet demographics in terms of ship type and age, as shown in Figure 3.

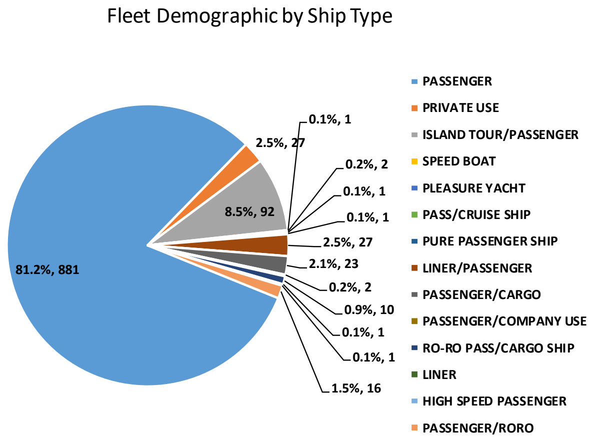

Figure 3: Ship Demographics by Ship Type and Ship Age

Here, the following key observations can be made:

- 93% of the fleet is less than 100 GT;
- 98% of the fleet is less than 1,000 GT;
- 37% of the fleet is less than 10 m length;
- 83% of the fleet is less than 20 m length.

In addition, the domestic passenger vessel fleet has also been analysed in terms of PAX capacity, Gross Tonnage and Length, as shown in Figure 4, Figure 5 and Figure 6.

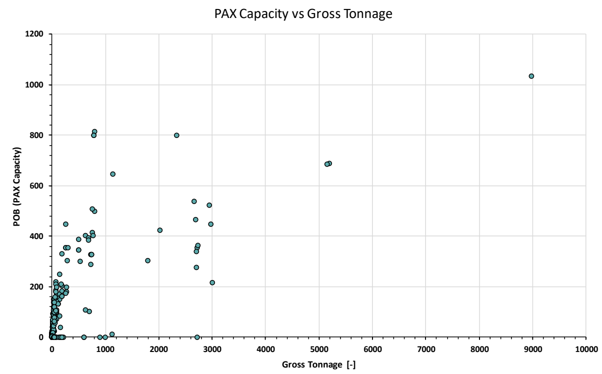

Figure 4: Fleet at Risk – PAX capacity Vs Gross Tonnage

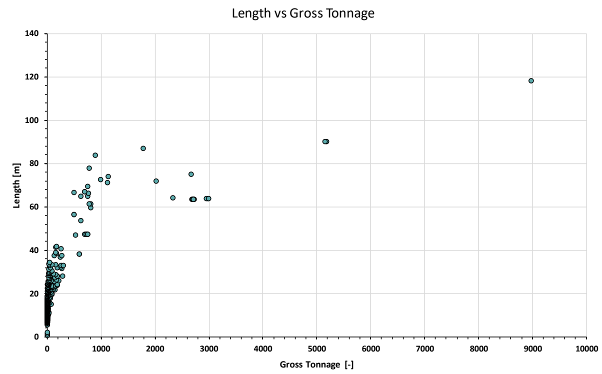

Figure 5: Fleet at Risk – Length Vs Gross Tonnage

3.2.2 Sample ships selection

Figure 6 (Pax Capacity Vs Length) outlines the vessels selected for the FSA study, representing the full size-range, on the basis of which quantitative risk assessment has been undertaken, in particular damage stability calculations and risk analysis in the FSA study. The red markers in the figure are the ships selected in order to provide a representative picture of the whole range of vessels comprising the fleet at risk. This, in turn, supports the argument that a weighted (based on the number of ships in each of the four selected bands) risk evaluation will suitably represent the whole fleet at risk.

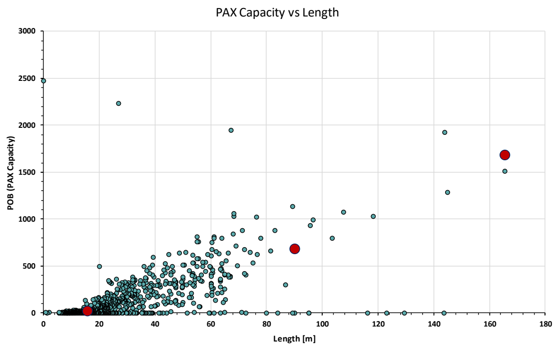

Figure 6: Vessel selection for the FSA study

Table 1: Representative ships and associated characteristics selected for the FSA study.

Name	Service	Homeport	Registry	Build Yr.	Rig	Hull	Length	Breadth	GRT	
Kate Alleson	Passenger	Surigao City	Surigao City	2019	MBCA	WOOD	15.75	1.24	3.86	2
Starlite Venus	Passenger	Batangas	Batangas	2020	MV	STEEL	90.11	16.3	1616	6
ST. POPE JOHN PAUL II	PASSENGER/CARGO	MANILA	CEBU	1984	MV	STEEL	165.31	26.8	19317	1

3.3 Frequency estimation of a loss scenario

1. Hazard frequency: This needs to be ship and area specific as well as hazard specific. In the absence of all the requisite information, we take frequencies from the database pertaining to each hazard in question (collision, bottom grounding, side grounding).

Table 2: Hazard frequencies for the domestic ferries in the Philippines

Hazard type	Domestic Ferries in the Philippines Frequency 1/ship year	
	Motor Banca	RoPax
Collision	4.55E-04	1.68E-03

2. Scenario frequency: This is the frequency of a given scenario occurring, conditional on the hazard being addressed, as defined by the p-factor. The product of 1 and 2 gives the frequency of the loss scenario being considered.
3. PLL calculation: Ship level PLL can be calculated by substituting scenario specific 1-s values, with the compliment of the Attained Index as an estimation of capsize probability.

3.4 PLL_A Quantification

3.4.1 Consequence estimation of a loss scenario

As the expected number of fatalities depends on the time to capsize and static analysis does not account for time, some approximation is called for to estimate the fatality rate. This is conditional on fast or slow capsize and assumptions relating to the percentage of passengers lost. To simplify the methodology and to account for the dependencies between survivability and fatality rate, the following simplifying assumptions are made (based on work performed in Project FLARE), Eq. (3) and Eq. (4):

If 0 < s-factor <1 → Fatality rate = 5% (3)

If s-factor = 0 → Fatality rate= 80% (4)

This simple and conservative approach is in line with the method used in the EMSA III Project and for the development of SOLAS2020. Moreover, research in Project FLARE (Cardinale, 2022) indicated that collated information from time-domain simulations on cruise and RoPax vessels that the majority of damage scenarios in a survivability assessment are transient capsize cases, in which case no time for evacuation is available (on average 5 minutes for RoPax). In the absence of other evidence, it is assumed that for domestic ferries this value also applies (potentially even less time will be available).

3.4.2 Main assumptions and considerations

Drawing from Eq. (1), the following main assumptions are made for risk estimation:

i	Only collision is considered (1=collision)
j	Area of operation is considered with Hs=4 m, as per SOLAS
k	Three loading conditions are accounted for
$FR(s)$	Fatality Rate as a function of s-factor according to eq. (4) and eq. (5)
POB	Persons on board (people at risk) according for the operational profile of each selected vessel
$PLL_{A/yr}$	Attained Potential Loss of Life per year of exposure.

On the basis of the above, Eq. (1), with all the variables set to unit values, i.e., PLL for collision, per loading condition and scenario, becomes:

$$\frac{PLL_A}{yr} = hazardfequency\ x\ scenario\ frequency\ x\ capzize\ probability\ x\ fatality\ rate\ x\ PoB \quad (2)$$

Where,

- Hazard frequency for domestic ferries in the Philippines (Table 2).

- Scenario frequency is the p-factor corresponding to the breach being examined (damage scenario)
- Capsize probability is the complement of the scenario s-factor, i.e., (1-s)
- SOLAS breach distribution for collision
- Calculations by software NAPA rel.2020.2

4. CASE STUDY NO.2 – SMALL MOTOR BANCA VESSEL

4.1 Vessel Principal Particulars

The vessel principal particulars are outlined in Table 3. Here, it can be observed that the vessel is a small traditional Motor Banca, with a length of approximately 16 m and a capacity of 24 persons.

Table 3: Vessel Particulars

Property	Value
Length O.A. [m]	15.75
Length B.P. [m]	15.75
Breadth Mld. [m]	1.94
Depth Mld. [m]	1.8
GT [-]	15.89
NT [-]	6.89
Pax Capacity	24

4.2 Coordinate System

A right-handed coordinate system has been used in defining the vessel stability model. The origin is located at frame #0, and locations in the ship are designated in accordance with a Cartesian coordinate system, where the axes are placed as follows:

- X-axis: longitudinal coordinate, positive in the direction of the bow, zero at frame #0,
- Y-axis: transverse coordinate, positive direction to port side, zero at the centre line,
- Z-axis: vertical coordinate, positive upwards, zero at the baseline.

In addition, trim is positive to stern and negative to bow. The heeling angle is positive when the vessel heels to the port side.

4.3 Stability Model

The ship model used in the damage stability calculations has been defined from the baseline to the upper extremity of the primary hull. The resultant calculation sections of the model are shown in Figure 7 below, with the profile and body plan illustrated in Figure 8, and the General Arrangement plan in Figure 9.

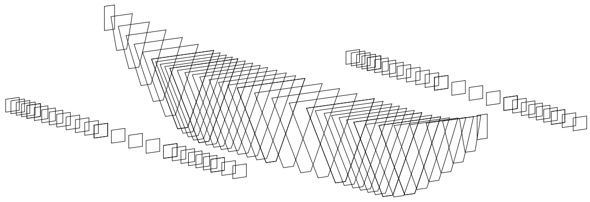

Figure 7: Vessel Calculation Sections

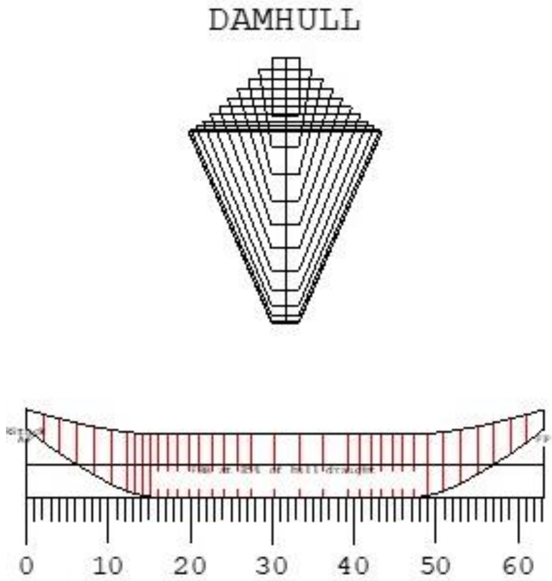

Figure 8: Vessel Body Plan & Profile

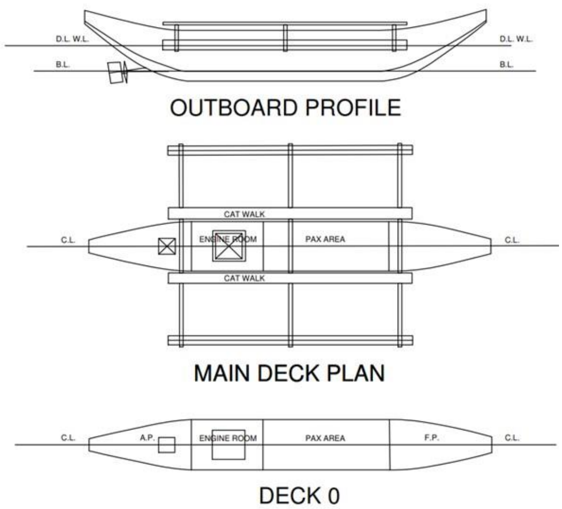

Figure 9: Vessel General Arrangement Plan

4.4 Relevant Openings

A list of all relevant openings considered within the damage stability calculations is presented in Table 4, indicating:

- **ID**: identification code used within NAPA model,
- **Description**: outline of opening purpose,
- **Type**: opening watertight rating,
- **Frame**: opening location relative to frame scale,
- **X**: x-coordinate of opening from frame zero (m),
- **Y**: y-coordinate of opening from vessel centreline (m),
- **Z**: z-coordinate of opening from vessel baseline (m),
- **Connection**: spaces linked by respective openings.

Table 4: Relevant Openings

ID	Type [-]	FR + Dist.	X [m]	Y [m]	Z [m]	Connected Rooms
OPE1	Hatch	#11-0.010	2.74	0.31	2.05	R001 SEA
OPE2	Hatch	#11-0.040	2.71	-0.31	2.05	R001 SEA
OPE3	Hatch	#20-0.120	4.88	0.6	1.94	R002 SEA
OPE4	Hatch	#20-0.120	4.88	-0.6	1.94	R002 SEA
OPE5	Unprotected Opening	#27+0.100	6.85	0.37	1.94	R003 SEA
OPE6	Unprotected Opening	#47+0.050	11.8	0.37	1.94	R003 SEA
OPE7	Unprotected Opening	#27+0.100	6.85	-0.37	1.94	R003 SEA
OPE8	Unprotected Opening	#47+0.050	11.8	-0.37	1.94	R003 SEA

4.5 Subdivision Arrangement

In the calculation of the Attained Subdivision Index, the vessel subdivision has been discretised into 6 zones as illustrated in Figure 10.

Note: Though not apparent within the diagram, the vessel outriggers have been considered within the zonal discretisation.

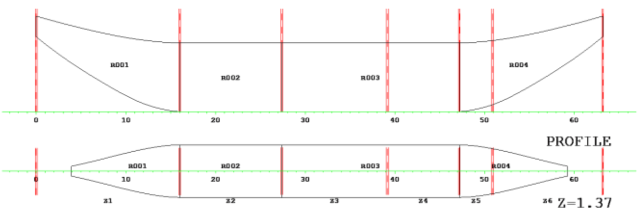

Figure10: Subdivision Arrangement Plan

4.6 Permeabilities

The permeabilities used in the damage stability calculations are summarised in the tables below, in accordance with the SOLAS 2020 prescribed values:

Table 5: Category-specific Compartment Permeabilities

Space Category	Permeability
Appropriated to stores	0.60
Occupied by accommodation	0.95
Occupied by machinery	0.85
Intended for liquids	0.95
Void spaces	0.95

4.7 Compartment and Tank Volumes

The following table outlines the vessel compartment/tank volumes, permeabilities, and centres of gravity, in accordance with space category.

Table 6: Compartment and Tank Properties

Purpose	Description	Volume	Perm	CGX	CGY	CGZ
		m3	[-]	m	m	m
VOID	Void Sp.	22.6	0.95	8.58	0	1.342
MMA	Machinery Sp.	6.2	0.8	5.425	0	1.21
TOTAL		28.7	[-]	7.901	0	1.313
Name	**Description**	**Volume**	**Perm**	**CGX**	**CGY**	**CGZ**
		m3	[-]	m	m	m
Void Space						
R001	Aft Peak	4.8	0.35	2.616	0	1.484
R003	Pax Space	10.7	0.95	9.325	0	1.21
R004	Fore Peak	4.8	0.35	13.184	0	1.484
ORS2	Void	0.3	0.95	5.425	-5	1.36
ORS3	Void	0.3	0.95	8.32	-5	1.36
ORS4	Void	0.2	0.95	10.795	-5	1.36
ORS5	Void	0.1	0.95	12.265	-5	1.36
ORP1	Void	0.1	0.95	3.55	5	1.36
ORP2	Void	0.3	0.95	5.425	5	1.36
ORP3	Void	0.3	0.95	8.32	5	1.36
ORP4	Void	0.2	0.95	10.795	5	1.36
ORP5	Void	0.1	0.95	12.265	5	1.36
ORS1	Void	0.1	0.95	3.55	-5	1.36
Machinery Sp.						
R002	Engine Space	6.2	0.85	5.425	0	1.21

4.8 Moments Due to Wind and Passenger Crowding

4.8.1 Wind Induced Moment

The projected windage area of the vessel and corresponding moment lever are shown in Figure 10. The wind induced heeling moment regarded in the damage stability calculations is calculated with the following formula:

$$M_{wind} = (P \cdot A \cdot Z)/9.806\ (tm)$$

Where,

P = 120 (N/m^2)

A = Windage area (m^2), measured in accordance with the projected lateral area relating to each calculation draft.

Z = Distance from T/2 to the centroid of windage area (m)

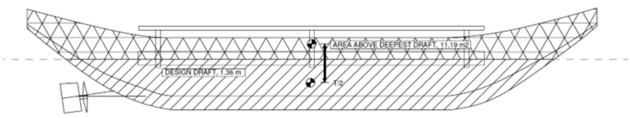

Figure 11: Wind Profile

4.8.2 Moment Resulting from Passenger Crowding

The moment resulting from passenger crowding has been calculated in accordance with the maximum passenger capacity of the vessel (24 persons). A conservative transverse lever of B/2 (0.97 m) from the centreline has been assumed and the weight attributed to each passenger is 75 Kg.

Moment by crowding of passengers = 1.746 tm

4.9 Required Subdivision Index R

The vessel's Required Subdivision Index has been calculated as 0.722.

4.10 Attained Subdivision Index Calculation under Operational GM Conditions

An initial damage stability assessment has been conducted on the vessel in the as-built condition. The results of this analysis are presented in the tables below, indicating an Attained Index of 0.6741, or in other terms, a survival probability of 67.41%. Based on current SOLAS standards, the vessel fails to comply by some margin, demonstrating a less than 1-compartment damage standard. Clearly some measures need to be taken if such vessels were to be operated safely.

Table 6: Attained Subdivision Index Calculation – As-Built Operational GM Conditions

Initial Condition	T [m]	TR [m]	GM [m]	A/R	COEF	A*COEF
DL	1.345	-0.100	12.242	0.997	0.200	0.144
DP	1.354	0.000	12.024	0.944	0.400	0.273
DS	1.360	0.000	11.857	0.892	0.400	0.257
Attained Subdivision Index A						0.6741
Required Subdivision Index R						0.722

Following this, the Risk Profile has been calculated with the aim to identify areas of heightened vulnerability within the vessel, as shown in Figure12. Here it can be observed that there is a concentration of vulnerable areas towards amidships, where larger compartment volumes are present. Furthermore, the predominant risk can be seen as resulting predominantly from 2-compartment damage scenarios.

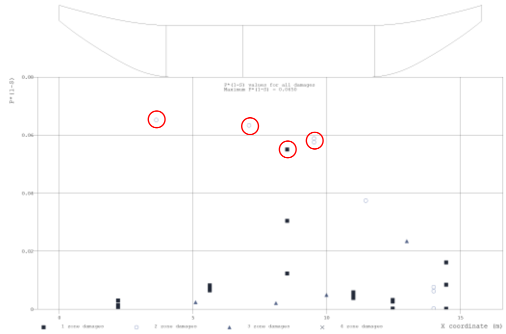

Figure 12: Vessel Risk Profile Under Operational GM Conditions (High risk shown in red)

4.11 RCO 1 – Increased Outrigger Volume

4.11.1 Description of RCO

The first RCO considered, has been to examine the potential benefit of increasing the volume of the vessel outriggers. The impetus behind exploring this RCO has been to provide the vessel with both a larger GM (intact and damaged), whilst at the same time offering additional reserve buoyancy in the damaged condition. In order to ascertain the optimal configuration, a form of sensitivity analysis has been undertaken, in which varying degrees of increased outrigger volume have been assessed. When scaling the outriggers, a ratio of 1:2 in beam to height has been adhered to and the lower extremity of the outrigger has been fixed, i.e., the draft of the outrigger has been kept constant. In relation to the former, a greater degree of vertical scaling has been favoured in order to provide reserve buoyancy, that will come into effect when the vessel is inclined. Furthermore, having vertically distributed reserve buoyancy will work to prevent the vessel from being too stiff, and thus uncomfortable to passengers. However, some degree of transverse scaling has also been considered as this increases the waterplane inertia and thus GM. The lower extremity of the outriggers has been kept constant again as a means of enhancing reserve buoyancy, with the majority of the added volume lying above the waterline. This also reduces the degree to which the resistance properties of the vessel will be impacted, as the immersed hull form is only marginally affected. Figure 13 below, provides an illustration of the scaling process that has been employed.

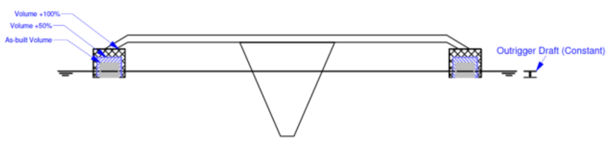

Figure 13: Outrigger volumetric increase diagram

4.11.2 RCO Impact on Intact GM & Attained Subdivision Index

The impact of RCO 1 has first been measured in terms of increased initial GM. The results of this analysis are presented in Figure 14, where a linear relationship between increased initial GM and outrigger volume can be observed. The reason for this primarily comes as a result of increased volume within the outriggers, which increases waterplane area inertia and also results in a greater transverse shift in the centre of buoyancy outwards (increased metacentric radius), both of which act to increase GM.

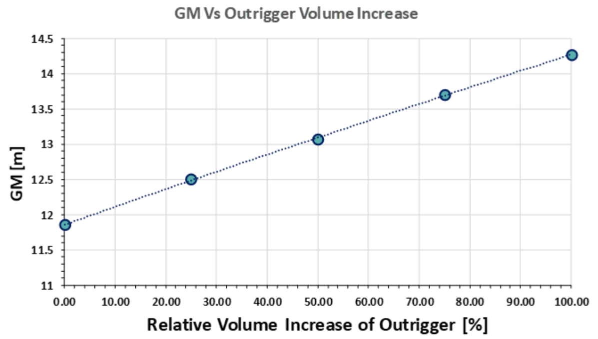

Figure 14: Impact of Outrigger Volume Increase on Vessel Intact GM

In addition to alterations in GM, and perhaps more importantly, variations in the vessel Attained Subdivision Index have also been evaluated. The aim here has been to identify the optimal increase in volume relative to enhanced survivability. This is identified as the point of diminishing returns in the relationship between the Attained Subdivision Index and outrigger volume, as shown in Figure 15. Here, an optimum volume increase of approximately 75% can be identified, leading to an Attained Index of 0.7988, which is SOLAS 2020 compliant.

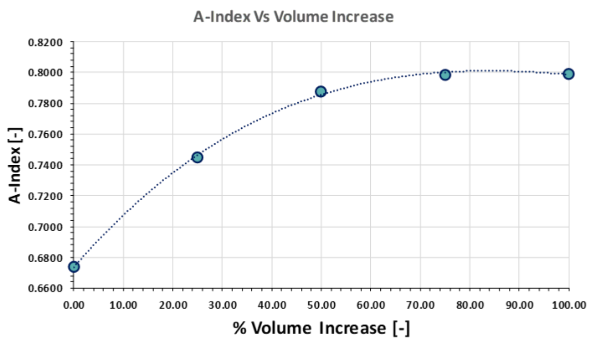

Figure 15: Impact of Outrigger Volume on Attained Subdivision Index

Table 7: Optimum Outrigger Volume

Outrigger Volume Increase (%)	A
0.00	0.6741
25.00	0.7450
50.00	0.7876
75.00	0.7988
100.00	0.7990

4.12 RCO 2 – Reduction in Outrigger Beam

4.12.1 Description of RCO

A further assessment has been conducted examining the potential to reduce the outrigger beam offset. The motivation behind such an assessment relates to reducing vessel susceptibility to damage, whilst also improving the operability of the vessel in relation to its size. To this end, a further sensitivity analysis has been conducted in which varying degrees of outrigger offset have been explored and the impact on Attained Index measured. The results of this process are presented in Figure 16 and Table 7, where an outrigger beam reduction of at least 0.75m is achievable, without significantly impacting the Attained Index.

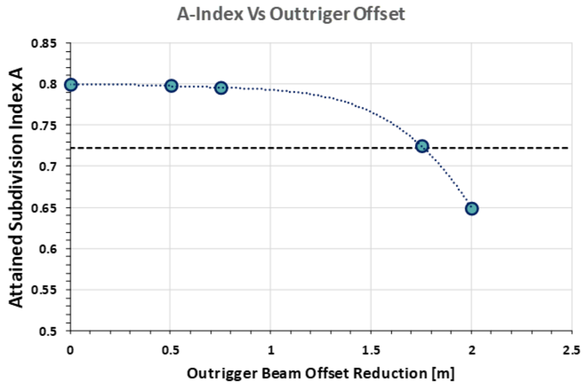

Figure 16: Attained Subdivision Index Sensitivity to Outrigger Beam Offset

Table 7: Impact of Outrigger Offset on Attained Subdivision Index

Outrigger Beam Offset Reduction [m]	A-Index
0.00	0.79909
0.50	0.79749
0.75	0.79564
1.75	0.72499
2.00	0.64937

4.13 RCO 3 – Passive foam installations

4.13.1 Description of RCO

Passive foam installation has been identified as the most efficient and cost-effective RCO during the EC-funded project FLARE and has again been considered in this instance. Unfortunately, the highest risk areas within the vessel are the passenger seating area and engine room, where it would not be possible to install foam. However, both the fore and aft peak voids and the outriggers have been targeted, as shown in Figure 16. This protects all the most exposed areas of the vessel, and although the high-risk spaces could not be targeted for foam application directly, the fore and aft peak voids, in addition to the outriggers, will now be able to provide additional buoyancy in cases where multiple compartments are breached.

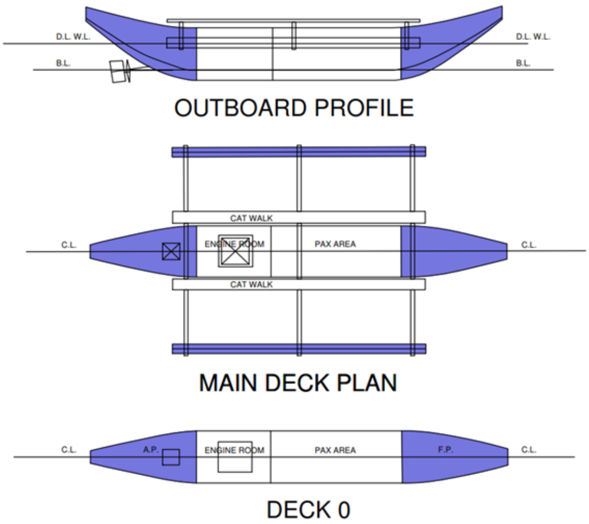

Figure 16: Foam Installation Locations (10m^3 foam volume)

4.13.2 Re-evaluation of Attained Subdivision Index

Having implemented the foam solution in addition to the proposed outrigger modifications, the vessel Attained Index has once again been calculated. The results of this process are provided within Table 8, where it can be observed that an Attained Index value of 0.874 has been achieved, which greatly surpasses the SOLAS 2020 requirement of 0.722.

Table 8: Updated Attained Index Calculation - Passive Foam & Outrigger Modifications

Initial Condition	T [m]	TR [m]	GM [m]	A/R	COEF	A*COEF
DL	1.345	-0.1	14.741	1.258	0.2	0.182
DP	1.354	0	14.473	1.99	0.4	0.346
DS	1.36	0	14.273	1.99	0.4	0.346
Attained Subdivision Index A						0.874
Required Subdivision Index R						0.722

4.13.3 Re-evaluation of the Risk Profile

The updated risk profile of the vessel has been produced following the RCO implementation and is provided within Figure 17. Here, it is evident that the RCOs have worked to eradicate the majority of the flooding risk within the vessel design, with only a single damage scenario presenting significant risk when the two midships compartments are breached.

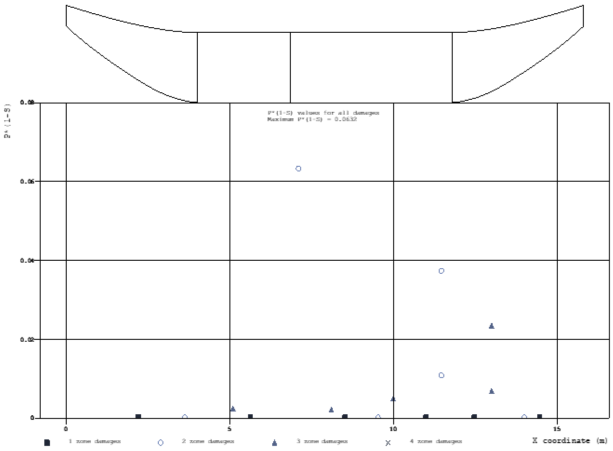

Figure 17: Updated Risk Profile

4.14 Risk Analysis & Calculation of RCO Cost-Effectiveness

4.14.1 PLL Calculation

The cost effectiveness of RCOs has been evaluated in relation to the reduction in PLL they yield relative to the value of statistical life within the Philippines. In estimating the cost of each RCO, the following assumptions have been made:

- Pontoon modifications - $1,500 per pontoon
- Passive Foam - $6 per kg installed.

The results of this process are provided within Table 9, where it can be observed that each RCO configuration has been found to be cost-effective. This serves to indicate that the RCOs explored hold great potential as a solution to many of the damage stability problems faced by this vessel type.

Table 9: Cost Effectiveness Calculation on the Basis of PLL, NPV & NCAF

Item	As-Built	RCOs 1 & 2	RCO 3	RCOs 1, 2 & 3
Attained Index	0.6741	0.7988	0.8215	0.874
PLL	0.003	0.0018	0.0016	0.0011
ΔPLL/ship-year	N/A	0.001	0.001	0.002
ΔPLL/ship-life	N/A	0.005	0.006	0.009
Costs for financing, insurance etc ($)	N/A	320	520	840
CAPEX ($)	N/A	2160	2700	4860
Net Present Value NPV ($)	N/A	2376	2970	5346
GCAF Limit ($)	N/A	4358	5151	6985
GCAF/NPV	N/A	1.83	1.73	1.31

4.14.2 Risk Acceptance Criteria - FN Diagram

An FN diagram has been produced in order to indicate if the flooding risk relating to the vessel falls within tolerable limits. This diagram is provided in Figure 18 below, where we can observe that the as-built vessel design, shown in black, falls within the ALARP region. This may come as a surprise, given that the vessel's damage stability performance was inadequate. However, in the case of motor bancas, the collision frequency was found to be much lower than that of conventional passenger vessels. Furthermore, the limited passenger capacity of these vessels means that the people at risk is also low. Nevertheless, the implementation of RCOs has shown that the risk can be further reduced into the negligible region. This is a significant finding.

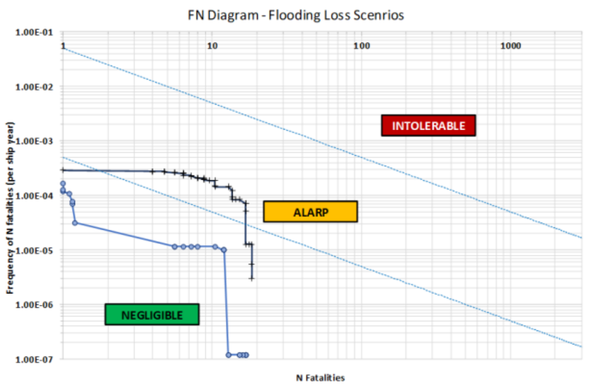

Figure 18: FN-Diagram Showing the Impact of RCOs

5. CONCLUSIONS / RECOMMENDATIONS

Concluding remarks pertaining to the ships being addressed in this paper, include the following:

There are some specific features in the design of the currently operating fleet of motor bancas in the Philippines that makes these boats susceptible to flooding risk, namely (a) lack of subdivision, (b) unprotected openings, (c) lack of adequate freeboard, (d) lack of adequate buoyancy in the outriggers; (e) distance of outriggers from the main hull. Most importantly, they also operate at distances from shore and in environmental conditions beyond their design envelope.

Moreover, considering the current state of enforcement and verification of damage stability standards (lack of fit for purpose regulations; gaps in enforcement and verification – frequency and rigor), ships must be made more robust to withstand this hazard by adopting risk control measures that are cost-effective to incentivise the operator to meet higher standards, which in turn will fuel a virtuous cycle for continuous safety enhancement.

Working with this incentive in mind, and armed with significant research findings and knowledge from a series of large-scale, EC and industry-funded projects on damage stability and flooding risk, the most-effective and practicable solutions have been selected and applied to the selected sample of ships, as described in this paper, enabling these most rudimentary means of transport to reach damage stability standards applicable to passenger ships engaged in any domestic or international voyages. This is unprecedented and exciting, enabling Philippines in the short-medium term to showcase the safety of their domestic fleet against the best in the world.

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