Study of Pioneer Sea Transportation’s Safety with Formal Safety Assessment Method

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Abstract. Particularly the safety of sea transportation must meet at least 2 decent criterias, namely seaworthiness and cargoworthiness. During the period 2009 - 2019 there were more than 90 accident cases have been recorded (NTSC, 2020). The types of accidents that occur are sinking (31%), aground (5%), collisions (30%), on fires (32%) and other types of accidents (5%). Ship accidents that occurred in Indonesia shows that the application of regulations relating to the security and safety of sea transportation still need to be given a greater portion in terms of their application and supervision. This research is focused on the study of the safety of pioneer ship with cargo-passanger ship types. Formal safety assessment (FSA) according to the International Maritime Organization standard is used as a method for this study, FSA was developed as a safety planning guide in the maritime field which aims to reduce risks in operations, while enhancing shipping safety, includes protection of life, health, the marine environment, and property. Research using expert judgment techniques with questionnaires. Risk analysis using Fault Tree Analysis method. Ship on fire and sinking are used as a top event. Calculation of minimum cut set on FTA is done using FTA software. In this study identified several risk control options that will be used in an effort to reduce the risk of ship on fire and sinking, by looking at the risk reduction index (ΔR), after which the cost of each Risk Control Option (RCO) is calculated to get the Gross of cost averting effectiveness index fatality (GCAF) and Net of cost averting fatality (NCAF) in order to know whether the RCO option has provided benefits in terms of benefits and costs incurred. Recommendations are submitted by looking at the most optimal cost and benefit options.

1. Background
Safety factor in the maritime world since the 19th century has become a serious concern, because the effects caused by ship accidents will affect many sectors, including the loss of human lives, property and pollution of the marine environment [3]. The cause of the accident cannot only be seen from the design side of the ship, the condition of the ship and the equipment in it, the maritime environment but a very important factor is the people involved in it both as operators on ships, on land and also as ship passengers. The contribution of human factors in ship accident incidents is shown quantitatively one of them is in the review of ship accident data in 2019, factor of human error plays significant in causing 60.5% of ship accident and from the percentage that 71% are human beings who contribute to ship operations [13].

In the case of domestic shipping operations, there are a number of rules related to safety and operational procedures of ships referring to SOLAS-1974, International Regulations on Prevention of Collision at Sea, Standards for Training Certification and Watch Keeping for Seafarer's (STCW), Marine Pollution (Marpol), International Safety Management Code (ISM-Code) and others, for
Indonesian-flagged non-convention vessels referring to Non Convention Vessel Standards (NCVS) provide guidance and instructions for ship crews in the operation of ships so that safety, environmental protection, security and comfort of the crew, goods, and the ship must be insured [4]. But in the implementation of the cruise often accidents occur in sailing. Recorded in accident data from the National Transportation Safety Committee (NTSC) which is an extraordinary event, shipping accidents experience fluctuations in the increase every year. Events that can be categorized into extraordinary events are shipping accidents that cause casualties or injuries [6]. The high case of ship accident in Indonesia shows that there are still many things that must be addressed in the implementation of sea transportation services. During the period 2009 - 2019 there were more than 90 accident cases (NTSC, 2020), an increase in accidents occurred from 2012 to 2017 [6]. The types of accidents that occur on average are sinking (22%), aground (5%), collisions (30%), on fires (32%) and other types of accidents (5%) while the causes of ship accidents are 37% human factors, 23 % of technical errors, 38% of natural conditions and 2% for other causes [19].

IMO as a global maritime organization has issued a safety planning guide, Formal Safety Assessment (FSA) [1]. The FSA is a product of the International Maritime Organization (IMO), which was established in 2002, containing systematic methodologies aimed at improving security in the maritime industry, including life, environment and property protection, using risk analysis and cost benefit assessment [7].

At present the existence of pioneer vessels is to support the “sea highway” program related to the efforts of more effective connectivity between "main lane" with "secondary lane" and to form a regular shipping schedule from West to East in areas not visited by commercial routes, with the hope is that the existence of pioneering sea transport will expand trade networks to remote areas [4]. The vessels used for pioneering transportation at present are cargo-passenger vessels [4].

The number of pioneer shipping routes in general continues to grow in line with regional needs and demands. In 1996 the number of new routes reached 39 routes with 17 port bases, until 2017 the number of routes is 96 routes with 527 transit ports throughout Indonesia [4], and in 2019 it has increased to 113 routes. Even though the government has tried to build pioneering ships with passenger-type goods, some parts of the route still use General Cargo ships which are operated in pioneering sea transportation services to transport goods and people together, especially for pioneering service in Indonesia’s territory eastern part.

![Figure 1. Pioneer ship with cargo-passenger type](image)

The mixing of cargo with passengers can increase the risk of hazards in ship operations which can be caused by many triggering factors, including due to disorderly passengers, careless smoking, the presence of dangerous cargo, or other factors that lead to human negligence. Besides that, the increase in the number of passengers on a voyage must certainly be accompanied by adjustments to accommodation space, safety equipment and ship safety equipment and ship safety management. In the absence of adjustments to these changes, the risk of coordination and evacuation failure will be higher for passengers and crew in the event of an accident at sea.

In this study, a hazard identification study was carried out on the operations of cargo vessels and / or ships carrying passengers in Indonesia, the level of risk of accidents while sailing and the risk reduction strategy. With the FSA method an accurate and in-depth analysis is carried out regarding the
hazards that will occur, risk and cost management in risk control and recommendations for overcoming them.

2. Methodology
The methodology used in this research is qualitative and quantitative methods by following the standards issued by the International Maritime Organization (IMO), namely the Formal Safety Assessment method.

Formal Safety Assessment (FSA) is a methodology as a structured and systematic safety assessment standard that aims to increase safety in the maritime field [7]. Framework of the formal safety assessment method as shown in the following diagram.

![Figure 2. FSA framework](image)

There are 5 steps in the FSA, namely hazard identification, risk assessment, risk control options, cost benefit assessment and recommendations for decision making or recommendation [7].

2.1. Hazard Identification
Hazard identification is a list of all accident scenarios that are relevant to potential causes and their consequences, in answer to the question what errors might occur? The purpose of this stage is to identify a list of hazards and a set of scenarios whose priority is determined by the level of risk of the problem under discussion. This goal can be achieved by using standard techniques to identify hazards that play a role in accidents, by filtering these hazards through a combination of existing data and opinions, and by reviewing general models that have been created when defining the problem [7].

The approach used to identify hazards is generally a combination of creativity and analytical techniques, the aim of which is to identify all relevant hazards. Crude analysis of the causes and consequences of each accident category using certain techniques, in this study the fault tree analysis (FTA) method are used to identify and classify potential hazards.

2.2. Risk Assessment
In the form of an evaluation of risk factors, in answer to the question how severe and how it might occur? The purpose of this Risk Assessment is to [7]:
   a. Investigate in detail the causes and consequences of the scenarios identified in step 1.
   b. Identify and evaluate factors that influence the level of risk.

These objectives can be achieved by using techniques that are appropriate to the risk method created and attention is focused on the risks that are considered high. The value in question is the level (level) of risk, which can be divided into [17]:
   • Intolerable risk.
• The risk that has been created is so small that it does not need further prevention (negligible).
• Risk whose level is between intolerable and negligible levels (as low as reasonably practicable = ALARP).

Construction and quantification / calculation of standard risk assessment techniques used for risk models in the form of error trees and event trees. The output from step 2, in the form of conveying an identification of the risks that are assessed as high [15].

2.3. Risk Control Option
The purpose of step 3 is to propose effective and practical Risk Control Options, through four principle steps as follows [18]:

a. Focus on risks that require control, to filter the output from step 2, so that the focus is only on those areas that most need risk control.
b. Identify actions to control potential risks (RCMs).
c. Evaluate the effectiveness of RCMs in reducing risk by re-evaluating step b.
d. Grouping RCMs into practical choices.

2.4. Cost and Benefit
The purpose of the cost benefit assessment is to identify and compare the benefits and costs of implementing each RCOs identified in step 3. Costs must be stated in the life cycle costs which include the initial period, operation, training, inspection, certification, decommissioning, etc. While the benefits can include reduction in terms of death, injury / loss, accidents, environmental damage & clean-up, indemnity by the third party, and an increase in average life of the ship [18].

The output of the cost benefit assessment consists of:

a. Costs and benefits for each RCO identified in step 3.
b. Costs and benefits for the RCO are of concern (most affected by the problem).
c. Economic uses are stated in the appropriate index.

In this study the effectiveness index is used to determine the effectiveness of risk control options (RCO), namely the calculation of cost due to risk or cost of averting fatality (CAF), in the CAF calculation two indicators will be used namely Gross of CAF (GCAF) and Net of CAF (CAF) NCAF).

The formulation of GCAF and NCAF calculations is as follows [7].

\[
GCAF = \frac{\Delta C}{AR} \quad \text{and} \quad NCAF = \frac{\Delta C - \Delta B}{AR} \quad (1)
\]

\[\Delta C = \text{total cost of mitigation efforts} - \text{total cost of no mitigation efforts}\]
\[\Delta B = \text{total benefit of mitigation efforts} - \text{total benefit of mitigation efforts}\]

Where,
\[\Delta B = \text{The economic benefits of implementing risk control}\]
\[\Delta C = \text{Risk return costs}\]
\[\Delta R = \text{Risk reduction after controlling}\]

2.5. Recommendation
Recommendations in the form of information about the hazards that are owned, relating to risks and the economic usefulness of alternative choices in controlling the existing risks, in response to the question what actions should be taken.

Recommendations are based on [18]:

a. Comparison and ranking of all hazards and their causes.
b. Comparison and reduction of levels of risk control options as a function of the combined costs and benefits
c. Identification of risk control options that keep risks as low as possible so that it makes sense to be implemented.
3. Result and Discussion

3.1. Hazard Identification

From the accident data published by NTSC a number of Hazards were identified that might occur in the operations of general cargo type vessels, passenger ships and roro-passenger vessels in the 2009-2019 period. Then the risk matrix is made based on the suitability of the frequency of events and the consequences of events with the standard provisions of the IMO Rule-Making Process MSC-MEPC.2/Circ. 12/Rev.2-2018 where after the index frequency and severity index are obtained, the risk matrix is obtained with the following formula.

\[
\text{Risk index} = \text{Frequency index} + \text{Severity index}
\]  

(2)

The following table presents the risk matrix construction based on the risk index.

Table 1. Ships operational risk matrix in Indonesia

| Code   | Basic event                  | (Q)  |
|--------|------------------------------|------|
| Eve1-1-1 | Flammable goods              | 2.56E-02 |
| Eve1-1-2 | The cargo is not reported    | 1.71E-02 |
| Eve1-2-1-1 | Component is outdate        | 5.98E-02 |
| Eve1-2-1-2 | Component nonstandard       | 5.98E-02 |
| Eve1-2-3-1 | Short circuit               | 7.69E-02 |
| Eve1-3-1 | Smoking carelessly          | 3.42E-02 |
| Eve1-3-2 | Unsafe electrical equipment  | 2.56E-02 |
| Eve1-3-3 | Heatworking on board        | 4.27E-02 |
| Eve1-4-1 | Lighting                    | 0.00E+0   |

From the risk matrix (table 1) it can be seen that the risk that cannot be tolerated is the risk of a ship sinking and on fire (red zone). While the risk of ship collision and aground is the risk that still can be tolerated (yellow zone).

From the hazard identification analysis based on ship accidents historical data of general cargo ship, roro-passenger and passenger ship types in the last ten years in Indonesia, the next discussion of hazards will focus on mitigation measures for ship on fire and sinking.

3.2. Risk Analysis

In this study the probability value is calculated using the assumption that the respondent's data is sailing experience for the past ten years, then the probability value is obtained from the quotient of the respondents' input data on each basic event item divided by the number of pioneering cruise ship during the last ten years.

Table 2. The probability value for every basic event of sinking and ship on fire
Eve2-1-1  Over capacity  2.56E-02
Eve2-1-2  The cargo is not reported  8.55E-03
Eve2-1-3  Unsafe loading arrangement  1.71E-02
Eve2-1-4  Unsafe cargo tied  1.71E-02
Eve2-2-1  Lack of competence/experience  8.55E-03
Eve2-2-2  No discipline/responsibility  2.56E-02
Eve2-2-3  Not according to regulations  0.00E+0
Eve2-2-4  Pumps didn’t work properly  5.13E-02
Eve2-3-2  M/E didn’t work properly  3.42E-02
Eve2-3-3  Navigation equipment error  3.42E-02
Eve2-3-1-1  Corrosion  1.71E-02
Eve2-3-1-2  No replating  2.56E-02
Eve2-3-1-3  Bulkhead leaked  2.56E-02
Eve2-3-2  Ship openings are not impermeable  8.55E-03
Eve2-4-1  Extrim weather  3.42E-02
Eve2-4-2  Narrow fairway  1.71E-02

From the initiating event then developed again to find out the basic causes why initiating events can occur. After calculating, the following is a fault tree model of the risk of failure that causes ship on fire and sinking.

**Figure 3.** FTA ship on fires as top event.

The results of the minimum cut set produce the probability value of each event on the fault tree diagram and are presented in the following table.

| Code          | Event                           | Probability   |
|---------------|---------------------------------|---------------|
| TOPEVENT01    | Ship on fire                     | 5.05E-03      |
| TREE01-1      | Cargo                           | 4.38E-04      |
| TREE01-2      | Technical factors                | 4.60E-03      |
| TREE01-3      | Human factors                    | 1.12E-05      |
| EVE01-1-1     | Flammable goods                  | 2.56E-02      |
| EVE01-1-2     | The cargo is not reported        | 1.71E-02      |
| EVE01-2-1     | Component is outdated            | 5.98E-02      |
| EVE01-2-2     | Short circuit                    | 7.69E-02      |
| EVE01-3-1     | Smoking carelessly               | 2.56E-02      |
| EVE01-3-2     | Unsafe electrical equipment       | 1.71E-02      |
| EVE01-3-3     | Heatworking on board             | 2.56E-02      |
| Code      | Event                      | Probability |
|-----------|----------------------------|-------------|
| TOPEVENT02 | Sinking                    | 2.87E-01    |
| TREE2-1   | Cargo                      | 6.67E-02    |
| TREE2-2   | Human factors              | 3.39E-02    |
| TREE2-3   | Technical factors          | 1.66E-01    |
| TREE2-4   | Environment factors        | 5.07E-02    |
| Eve2-1-1  | Over capacity              | 2.56E-02    |
| Eve2-1-2  | The cargo is not reported  | 8.55E-03    |
| Eve2-1-3  | Unsafe loading arrangement | 1.71E-02    |
| Eve2-1-4  | Unsafe cargo tied          | 1.71E-02    |
| Eve2-2-1  | Lack of competence/experience | 8.55E-03   |
| Eve2-2-2  | No discipline/responsibility | 2.56E-02   |
| Eve2-2-3  | Not according to regulations | 1.00E-10   |
| Eve2-3-2-1| Pumps didn’t work properly | 5.13E-02    |
| Eve2-3-2-2| M/E didn’t work properly  | 3.42E-02    |
| Eve2-3-2-3| Navigation equipment error | 3.42E-02    |
| Eve2-3-1-1| Corrosion                  | 1.71E-02    |
| Eve2-3-1-2| No replating               | 2.56E-02    |
| Eve2-3-1-3| Bulkhead leaked            | 2.56E-02    |
| Eve2-3-2  | Ship openings are not impermeable | 8.55E-03 |
| Eve2-4-1  | Extrim weather             | 3.42E-02    |
| Eve2-4-2  | Narrow fairway             | 1.71E-02    |

3.3. Risk Control Option

At the risk control option stage, the risk area is identified first at each event and then a sensitivity analysis is carried out to see how much the effect of the decline and the increase in the probability of a ship on fire event. The change in sensitivity value to see the decrease or increase in events is based on the assumption that ship accident events can be reduced up to 10 times. In the setting of a one-time increase, it will be considered that the event of an accident occurs 1 time this year and if no risk control option is made then next year the same accident will be repeated, because the probability value will be multiplied by 1.

The following table presents the results of the calculation of changes in the risk value of each causal factor related to the event of a ship on fire and sinking.

| Causative Factor | Top event01 | Topevent02 |
|------------------|-------------|------------|
|                  | EVE1-2-1    | EVE2-1-1   | EVE2-2-2   | EVE2-3-1-1 | EVE2-4-1 |
| Environment      | -           | -          | -          | -          | 9.2%     |
| Technical        | 86.5%       | -          | -          | 21.0%      | -        |
| Human            | -           | -          | 40.7%      | -          | -        |
| Cargo            | -           | 10.2%      | -          | -          | -        |

Source: Analysis, 2020

In table 5 above shows, the risk areas that influence the event of a ship on fire are outdated components (Eve1-2-1) with a value change of 86.5% (changes in initial sensitivity and after a decrease in probability). For ship sinking events the influential factor is corrosion on the ship plate with a change in value of 21%.
In accordance with table 5, risk control will be focused on technical factors, both in the event of a ship on fire and the ship sinking. The following table provides risk control options.

| Mitigation A- for ship on fire | Basic Event | Description |
|-------------------------------|-------------|-------------|
| RCO-A1                        | Component is outdate | Replacement of outdated electrical components with standard marine components and routine maintenance of these components |
| RCO-A2                        | Short circuit | Periodically checking and replacing cables / electrical wiring of ships. |
| RCO-A3                        | Unsafe electrical equipments | Replacement of unsafe electrical equipment such as water heaters, irons, cooking utensils, etc. |

| Mitigation B- for ship sinking | Basic Event | Description |
|-------------------------------|-------------|-------------|
| RCO-B1                        | Corrosion | The thickness of the plate is checked and repainting and the protection system against corrosion or plate replacement if necessary. |
| RCO-B2                        | No replating | Plate replacement is performed in accordance with the provisions of the classification |
| RCO-B3                        | M/E didn’t work properly | Performed over-haul and regular machine maintenance according to the manufacturer's standards |
| RCO-B4                        | Navigation equipment error | Performed replacement and maintenance of navigation equipment according to standards |
| RCO-B5                        | Pumps didn’t work properly | Periodically checking the workability of pumps on a ship, periodically changing pumps and supporting systems |
| RCO-B6                        | Bulkhead leaked | Plate conditions were checked on all ship bulkheads, replacing and repainting with quality materials according to marine standards |
| RCO-B7                        | Ship openings are not impermeable | Check and replacement of waterproof components at all openings |

Furthermore, the amount of risk reduction (\( \Delta R \)) is calculated as an effect of mitigation carried out. Risk reduction is calculated using the following formulation.

\[
\Delta R = (r_{RCO} \times \text{sensitivity}) \times T_e
\]  

(3)

Where \( r_{RCO} \) is obtained based on the calculation of sensitivity analysis in % and the value of \( T_e \) is the lifetime of the components by years. The following table presents a risk reduction matrix for incidents of ships on fire and sinking.

| RCO   | Rate of RCO | Sensitivity | Lifetime (years) | \( \Delta R \) (%) |
|-------|-------------|-------------|------------------|-------------------|
| RCO-A1| 86.5%       | 9.11E-01    | 5                | 3.940             |
| RCO-A2| 86.5%       | 9.11E-01    | 5                | 3.940             |
| RCO-A3| 0.3%        | 2.22E-03    | 5                | 0.000             |
| RCO-B1| 21.0%       | 1.21E-02    | 10               | 0.466             |
| RCO-B2| 17.4%       | 1.10E-02    | 10               | 0.322             |
| RCO-B3| 14.6%       | 2.10E-03    | 10               | 0.216             |
| RCO-B4| 14.7%       | 1.41E-03    | 10               | 0.217             |
| RCO-B5| 10.9%       | 1.96E-03    | 10               | 0.121             |
| RCO-B6| 10.9%       | 1.96E-03    | 10               | 0.121             |
| RCO-B7| 7.3%        | 1.27E-03    | 10               | 0.054             |

Source : Analysis 2020

From the risk reduction matrix above, it can be seen that the choice of maintenance and replacement of obsolete components (RCO-A1) can contribute to the risk reduction (\( \Delta R \)) of event ship on fire by 3.94 (394%), a significant value to reduce the risk of ship on fire. For the mitigation of sinking the choice of replacing corrosion-resistant plates will be able to contribute \( \Delta R \) of ship sinking by 0.232 (23.2%). This contribution indicates that mitigation carried out on the choice only on RCO-B1 can only contribute reducing the risk of sinking by 23.2%, so that additional mitigation is needed.
that can contribute to the reduction in the risk of sinking events, namely RCO-B2; RCO-B3; RCO-B4; RCO-B5; RCO-B6 and RCO-B7, so the contribution to ΔR becomes 0.668 (66.8%).

3.4. Cost and Benefit Analysis

In analyzing costs and benefits, a combination of the value of risk reduction and the value of failure and the cost due to mitigation is carried out. The following are lists of the cost components that appear in every “do something” they’re: replacement of components as needed, annual docking, 2-year docking, 4-year docking, ship operations and “do nothing” they’re: total loss, annual docking, 2-year docking, 4-year docking, ship operations.

Benefits of mitigating: avoided total loss, ship operations are still ongoing, services can continue, broadly the condition of economic stability and community movement in the working area of pioneer vessels can remain stable, and public trust in the Government is increasing. Benefits if not mitigating is only ship operations are still running at risk.

| Table 8. GCAF and NCAF calculation |
|-------------------------------|-------------------|-------------------|
| Cost components               | Cost (IDR)        |                  |
|                               | Ship on fire      | Ship sinking      |
| Lifetime of components        | 5 years           | 10 years          |
| Total loss                    | 80,208,000,000    | 82,440,000,000    |
|                               | 1,260,000,000     | 1,260,000,000     |
| Benefit from transportation per year (transport ticket and cargo tariff) |                  |                  |
| Benefit from transportation during lifetime | 6,300,000,000 | 12,600,000,000   |
| Cost of replacing, overhaul, navigation equipment etc | ---             | 4,800,000,000    |
| Cost of replacement of ship's electrical components | 400,000,000 | ---              |
| Annual docking cost           | 2,800,000,000     | 2,800,000,000     |
| Total annual docking cost during lifetime | 8,400,000,000 | 14,000,000,000   |
| 2-year docking cost           | 4,000,000,000     | 4,000,000,000     |
| Total 2-year docking cost during lifetime | 8,000,000,000 | 12,000,000,000   |
| 4-year docking cost           | 4,600,000,000     | 4,600,000,000     |
| Total 4-year docking cost during lifetime | 4,600,000,000 | 9,200,000,000    |
| Mitigation benefits           | 86,508,000,000    | 95,040,000,000    |
| No mitigation benefits        | 7,560,000,000     | 13,860,000,000    |
| ΔB                             | 78,948,000,000    | 81,180,000,000    |
| Cost due to mitigation        | 21,400,000,000    | 36,800,000,000    |
| Cost due to no mitigation     | 101,208,000,000   | 117,640,000,000   |
| ΔC                             | (79,808,000,000)  | (80,840,000,000)  |
| ΔR (%)                        | 3.94              | 1.517             |
| GCAF                           | (20,255,837,563)  | (51,186,741,595)  |
| NCAF                           | (40,293,401,015)  | (104,707,345,442) |

Source: Analysis, 2020

The effectiveness of the risk control options is shown in the calculation of the NCAF (Tabel 8) where the NCAF value on the ship on fire is IDR 40,293,401,015.- and NCAF on the ship sank IDR 104,707,345,442. - , both of them are negative value which shows there is a higher economic benefit compared to the costs incurred for mitigation.

3.5. Recommendation

Risk assessment is based on the value of risk probability and the benefits derived from the application of risk control options need to be filtered to make decisions as a recommendation for improving risk levels.

At the risk of ships on fire because the source of fire due to obsolete components, RCO-A1 was chosen, namely by replacing ship components according to standards and needs, besides controlling dangerous cargo must be increased during operations.
At the risk of a sinking ship some RCO is needed for mitigation measures (RCO-B1 to RCO-B7) in order to achieve a maximum risk reduction value. The selection of RCO-A1 and RCO-B has an impact on reducing the risk level in the risk matrix to one stage lower than before as presented in the following table.

Table 9. Level change on risk matrix after mitigation

| RISK INDEX (RI) | FREQUENCY          | 1 | 2 | 3 | 4 |
|----------------|--------------------|---|---|---|---|
| 7              | Frequent           | 8 | 9 | 10| 11| Move to 1 level down |
| 5              | Reasonably probable| 6 | 7 | 8 | 9 | Collision |
| 3              | Remote             | 5 | 6 | 7 | 8 | Sinking |
| 1              | Extremely remote   | 2 | 3 | 4 | 5 | On Fire |

4. Conclusions

After identifying the risks in stage 1 of the FSA, 2 risks (ship on fire and sinking) are found at level 9 with Intolerable category or should receive serious attention, 1 risk (collision) at level 8 with ALARP category or still within tolerance, 1 risk (ship aground) is at level 6 with ALARP category.

The greatest risk in the operation of cargo-passanger type pioneering ships is the ship on fire and sinking, overcome by the choice of risk control on the risk of ship on fire by replacing obsolete electrical components with standard marine components and routinely maintaining those components, where the benefits of the application of RCO-A1 is IDR 86,508,000,000,-, the risk of a sinking event is overcome by RCO-B1; B2; B3; B4; B5; B6 and B7, namely checking the thickness of the ship plate, replacing and coating anti-corrosion according to the standard, overhauling the main engine, checking and replacing the ship pumps, checking and renewing ship navigation equipments as well as checking and replacing waterproof components at openings on the ship, where the benefits of the mitigation application are IDR 95,040,000,000.

The effectiveness of the risk control options is shown in the calculation of the NCAF where the NCAF value on the ship on fire is IDR 40,293,401,015,- and the ship sank IDR 104,707,345,442,- and both of them are negative value which shows there is a higher economic benefit compared to the costs incurred for mitigation.

The policy to do all the recommended mitigations can have a significant influence on the risk matrix, namely by shifting the risk of ships on fire at level 6 (out of 9) and the risk of ships sinking at level 7 (out of 9), and both risks now are included in the ALARP region.

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