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Onboard Fire Safety Assessment Standards for Indonesian Non Convention Roll On Roll Off Passenger Ferries

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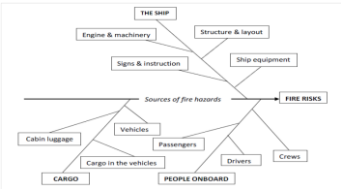
Graphical abstract



Abstract

Roll on roll off passenger ferries play very important role in connecting Indonesia's more than 17,000 islands. Since these ferries are categorized as 'Non-convention' vessels they are not mandatory to comply with international regulations, therefore they are very vulnerable to accidents including fire accident. The study was carried out to establish onboard fire safety assessment standards for Roll on roll off ferries operating on Indonesian waters to be used as guidance for authorities and operators to assess and to ensure the safety of the ferries. The assessment standards are focused on three accident sources include: the vessel; people on board; and the cargo. The standards are derived from fire hazards and their potential risk levels, which are categoriesed as intolerable; tolerable; and negligible. Refer to the risk levels obtained realistic and appropriate actions could then be implemented to prevent the ferries from fire accidents.

Keywords: Assessment; fire; risk; roll on roll off ferries; safety; standards

1.0 INTRODUCTION

Indonesia is the world largest archipelago with more than 17,000 islands and 95,181 km length of coastal line, 2/3 of the country is covered by sea. To connect the islands within Indonesia for logistics and movement of people, beside merchant ships roll on roll off passenger ferries also play very important role for short distance crossing, which is considered in Shipping Law No.17/2008 [1] chapter V section 4 on crossing transport as bridges to connect land roads or railways between the islands. The roll on roll off ferries mainly carry passengers (walking passengers, and car and bus passengers) and vehicles such as: cars, buses and trucks. Directorate General of Land transport, Ministry of Transport Republic of Indonesia [2] describes that there are more than 165 official ferry-crossing routes in Indonesia, and served by more than 240 ferries in various sizes, not included pioneer vessels made of wood and fiber glass that according to Djumena [3] numbered more than 3,000 units nationwide. Gunawan [4] found out most of these ferries are considerably old with the age of up to 25 to 30 years and many are poorly maintained due to busy operational schedules and lack of financial supports, worsen with the lowly educated passengers as mentioned by Oktora [5] the ferries are facing many accident risks, including fire accident. Since the ferries are serving local routes according to Williams and Hoppe [6] they are not mandatory to comply with the International Convention of the Safety of Life at Sea, which is also known as non-convention vessels.

According to the data published by the National Committee for the Safety of Transport [7] between 2007 and 2011, there were 27 recorded major marine accidents consist of: 10 sinking or 37%; 11 fires or 41%; and 6 collisions or 22% with casualty 658 died and 586 injuries which, are mainly caused by technical factors (59%) and human factors (41%). Fire accidents that occurred mainly were caused by explosions in engine room and cargo carried by vehicles onboard.

Muhammad *et al.* [8] investigated that most of these accidents that claimed great number of casualties took place on the very busy routes, which might spread to other entities such as neighboring vessels and port facilities, therefore it is crucial to minimize onboard ferry fire accidents particularly on the busy routes.

Concerned with the high number of accidents and casualties and in attempt to reduce or if possible to eliminate the fire accident onboard the national crossing ferries, the research was aimed to establish assessment standards for the fire safety of the ferries based on identified fire hazards and risks level which, might come from the vessel, the people onboard, and the cargo.

2.0 METHODOLOGY

The research was carried out using cause and effect analysis and formal ship safety assessment method based on the problem and hazards identification through literature study, field surveys and investigations, and some fire safety simulation using available soft-wares such as Fire Dynamics Simulator V5 and Smoke view developed by the National Institute of Standards and Technology (NIST) of the United States Department of Commerce [9].

According to Wang [10] formal ship safety assessment involves using the techniques of risk and cost-benefit assessment to assist in the decision making process and applied to safety issues common to a certain ship type or to a particular hazard (in this case fire), which is different with safety case approach that is only applied to a particular ship. As explained in the Fire Safety In The Workplace Guide published by UK Government [11] that fire risk assessment should be carried out in 5 steps: 1. Identify the fire hazards; 2. Identify people at risk; 3. Evaluate, remove or reduce the risks; 4. Record the findings; prepare an emergency plan and provide training; 5. Review and update the fire risk assessment regularly, and Fire risks assessment process main stages recommended by International Maritime Organization [12] in FSA (Formal Safety Assessment) and Det Norske Veritas [13] are: 1. Hazards identification, 2. Risks analysis, 3. Risks control options, 4. Cost benefit assessment, 5. Decision making, and Biro Klasifikasi Indonesia [14] emphasizes that risk assessment is more than just risk analysis, it also involves the process by which the results from risk analysis are considered against judgment, standards or criteria. Therefore it was decided that in order to be able to assess the fire safety of the Indonesian roll on roll off passenger ferries the fire assessment standards should be derived from the risk levels of the hazards caused by the vessel, the people onboard, and the cargo carried by the vessels or passengers in accordance with their consequence and probability, so that the risks could be controlled, and the safety of the ferries could be improved.

These three aspects of hazards sources are explained in the cause and effect diagram shown in Figure 1, and each of these causes are more elaborated in Table 1 for the fire hazards created by the vessel and the potential hazards that might happen, Table 2 for the fire hazards created by the people onboard, which include passengers, the vehicle drivers as well as the crews of the ferries, possible actions of the people, and the potential hazards created, and Table 3 for the fire hazards created by the cargo, including vehicles carried by the vessels, cargo carried by the vehicles as well as luggage carried by passengers to the accommodation space.

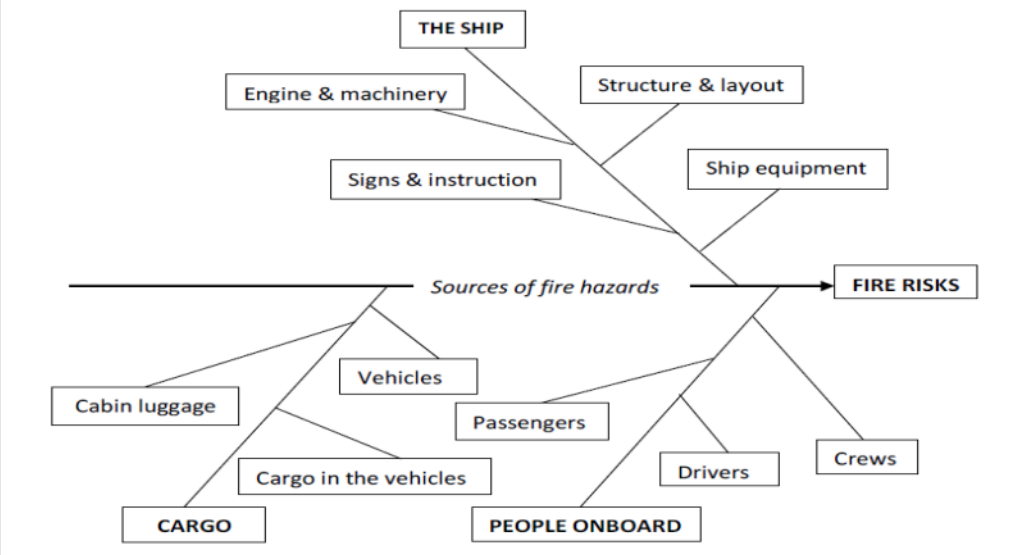


Figure 1 Cause and effect diagram of the sources of fire hazards

Table 1 Potential fire hazards from the vessel

Ship space	Ship part/system	Potential hazard
Engine room	Main engine(s)	Engine blast or explosion
	Auxiliary engines	Engine blast or explosion
	Piping system	Leakage and spillage
	Exhaust system	Blast or explosion
	Oil tanks	Leakage and spillage
	Electrical system	Damaged switchboard
		Life wire
		Short circuit
Pump room and pumping system	Pumps	Blast or explosion
		Leakage and spillage
	Piping system	Leakage and spillage
	Valves	Leakage and spillage

Ship space	Ship part/system	Potential hazard
Store room	Electrical system	Short circuit
Deck	Deck machinery	Heat and sparks
Fuel Tank	Structure	Leakage and spillage
	Piping system	Leakage and spillage
Vehicle decks	Doors	Confusing
		Not functioning
	Piping system	Blockage or leakage
	Electrical system	Damage
		Short circuit
	Ventilation system	Toxic gas
Passengers space	Layout and arrangement	Confusing
	Interior materials	Fume and toxic
	Lighting system	Trapped and chaos
	Ventilation system	Unconscious
		Sultry
Crews space	Lighting system	Trapped and chaos
	Ventilation system	Unconscious
	Interior materials	Fume and toxic
Galley	Gas installation	Leakage

Table 2 Potential fire hazards created by people onboard

People on board	Source	Actions	Potential hazards
Passengers	Careless and lack of knowledge	Smoking	Trigger fire
		Rubbishing	Trigger fire
		Carry dangerous goods	Explosion
	Intentional acts	Sabotage	Explosion
Drivers	Careless	Keep the vehicle engine on	Trigger fire
		Carry dangerous cargo	Explosion
		Stay in the vehicle	
Crews	Low qualification	Fault operation	Trigger fire
		Negligence	Trigger fire
	Exhausted	Fault operation	Trigger fire
	Effect of drug	Fault operation	Trigger fire
	Careless	Negligence	Trigger fire

Table 3 Potential fire hazards created by cargo onboard

Cargo	Source of hazards	Potential hazards
Vehicle	Engine on fire	Fire and explosion
	Electrical faults	Fire
	Fuel leakage	Fire
Cargo on vehicle	Dangerous goods	Explosion
	Bad covering	Fire or explosion
	Bad contentment	Fire or explosion
Cabin cargo	Dangerous goods	Explosion
	Bad contentment	Fire or explosion

Also included in the potential fire hazards from the vessel are the availability, sufficiency, functionality, and practicality of the fire safety system, appliances, and instruction, which are parts of the ship system, as mentioned in some cases summary published by Turnbull Fire Consultancy Ltd. [15] based on its experiences, even though they are not creating hazards but could worsen the potential hazards if their existence is lacking.

The research is begun with the identification of the problems followed by hazards identification, and concluded by the establishment of fire safety assessment standards as shown on Figure 2.

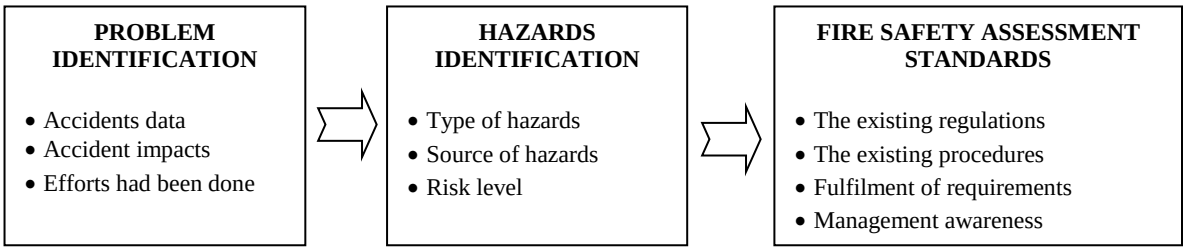


Figure 2 Research methodology diagram

2.1 Problem Identification

The aim of problem identification is to identify the significance of fire accidents and fire incidents onboard roll on roll off ferries that demand for the establishment of fire safety assessment standards. Problems created by fire onboard roll on roll off ferries were identified through data gathered from various sources including government institutions, mass media, journals and other publications, direct interviews to stakeholders and on the spot investigations. The identification consists of number of fire accidents happened in a certain period of time, number of casualties, causes of accidents, impacts of the accidents, efforts have been done by the operators, regulating bodies, and other related institutions, and the outcomes of these efforts that have significant benefits to the safety of the national ferry services.

Azhary [16] indentified that between 2007 and 2011 there were 96 marine fire accidents on Indonesian waters claiming 749 of casualties, which include died, missing, and fatal injuries, as shown in Table 4.

Table 4 Marine fire accident on Indonesian waters 2007–2011

Year	Number of accidents	Casualties
2007	27	221
2008	22	84
2009	26	147
2010	18	198
2011	13	99
TOTAL	106	749

Even though not all of these data derived from ferries accidents but since national roll on roll off passenger ferries are more vulnerable compared to cargo vessels, these data have shown the significant urgency for establishment of fire safety assessment standards to be used for improving the safety of national ferries operating on Indonesian waters.

2.2 Hazards Identification

Hazard is defined by Kuo [17] as something which can lead to an undesired outcome in the process of meeting an objective. This can involved injury to human beings, damage to property, or harm to the environment, or a combination or some or all of these three.

Also according to Kuo [18] the role of hazard identification is to find out what aspects can go wrong in a situation, activity or system. These occur in a random manner and various techniques are used to identify hazards and organize them into a hazard list which may be further divided into various types of hazard. In order to identify what could go wrong the following steps are applied:

- *Step 1*: Determine the desire of meeting the objective and the associated assumptions.
- *Step 2*: Identify possible deviations from the determined desire.
- *Step 3*: List all possible deviations.

In the case of crossing ferry the desire of meeting the objective is to have a safe crossing journey and free from all kind of threatening situation. The possible deviations from the determined desire among other things are: sinking of ship, ship collision, fire onboard, and ship grounding. In this research the focus of the possible deviation is on accident and incident of fire aboard.

With regard to the fire onboard roll on roll off ferries the hazards would include: the heat from fire, smoke, toxic fume or gas from the burning materials, explosion, live electricity, chaotic emergency escape and evacuation routes, people are trapped in the confined space etc. In order to identify the hazards the cause of hazards should be first identified which, include: triggered by the vessel itself, by the people onboard, and by the cargo including the vehicles onboard, cargo carried by the vehicles, and luggage carried by passengers as explained previously, and followed by categorizing the level of risks affected by the hazards.

Based on their acceptance levels as defined by Australian Civil Aviation Authority [19] the risk could be divided into three categories include: intolerable, tolerable, and negligible as shown in Figure 3.

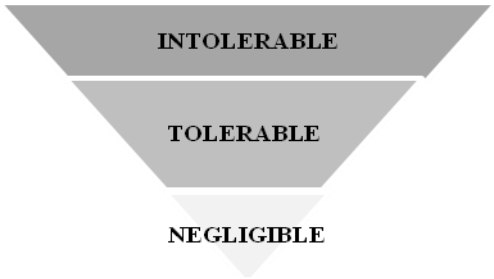


Figure 3 Risks categories

Risks are classified as intolerable regardless of the benefits associated with the activity because they have high level of severe consequences, which might create catastrophic condition, casualties, or major financial loss. An intolerable risk must be eliminated or reduced so that it falls into one of the other two categories, or there must be exceptional reasons for the activity or practice to continue.

Tolerable risks are the risks that people are generally prepared to tolerate to secure their benefits. They might create inconveniences, minor injuries that need only first aid treatments, and minor financial loss but at a certain extent can still be acceptable. Tolerable risks must be properly assessed and controlled to keep the residual risk at acceptable level of safety (ALoS), and must be reviewed periodically to ensure they remain that way.

Negligible risks are those that people would regard as insignificant or trivial in their daily lives, or which exist, but have no practicable mitigation. They might create minor inconveniences but no injuries, or very low financial loss. Improvements are needed if their benefits outweigh the costs of doing them.

According to Russell and Griggs [20] the risk levels can be derived from the following formula:

$$R = P \times C \quad (1)$$

Where R is the risk level, P is the probability of the occurrence, and C is the consequence of the risk. For this purpose the value of R is ranging from 1 to 25, P is ranging from 1 to 5 scale, where 1 is unlikely to happen and 5 is most likely to happen, and C is also ranging from 1 to 5 scale, where 1 is negligible and 5 is severe, which has effect to human life or high financial loss. The justification of both probability and consequence scales are based on statistical data, experience, as well as expert opinions. The occurrence probability, the consequence, and the risks levels are explained respectively in Table 5, Table 6, and Table 7.

Table 5 Occurrence probability classification

Description	Scale	Occurrence
Most likely	5	Above 75%, Imminent–is expected to occur in most circumstances
Likely	4	50% to 75%, Once in a month, will probably occur in most circumstances
Remote	3	25% to 50%, Once in 12 months, might occur at some time
Unlikely	2	10% to 25%, Once in 5 years, could occur at some time
Rare	1	1% to 10%, Once in 10 years–may occur only in exceptional circumstances

Table 6 Consequence classification

Description	Level	Severity
Severe	5	Catastrophic (at least one fatality, huge financial loss or total damages to the ship system/structure)
Major	4	Extensive injuries to one or more people, major financial loss or damages to the ship system/structure
Moderate	3	Medical treatment required, high financial loss and some reasonable damages to ship system or structure
Minor	2	First aid treatment needed, low to medium financial loss and causes panic to passengers
Negligible	1	No injuries only inconvenient to passengers, very low financial loss

Table 7 Risk level category

Risk level	Risk category
15 to 25	Intolerable
5 to 14	Tolerable
Under 5	Negligible

2.3 Fire Safety Assessment Standards

The assessment standards are established based on four references, include:

1. The existing regulations that govern the fire safety of vessels operate in a certain location. Since the aims of these assessment standards are on non convention ferries most of the regulations referred are taken from local products or similar legal products that have been implemented in other country which have same condition as Indonesia;
2. The existing procedures for preventing and combating of fire onboard the roll on roll off pax ferries that should be implemented by the authorized personnel onboard;
3. The official and practical fire safety requirements that must be fulfilled by the operators and regulators;
4. And the management awareness of stakeholders to maintain the fire safety onboard the ferries.

The regulations that are referred to for establishing the assessment standards among others are: Indonesian Flagged Non Convention Vessel Standards 2009, published by Ministry of Transport Republic of Indonesia [21], particularly chapter 3, section 7 on Fire Fighting Equipment, and chapter 9, section 5 on National Safety Management Standard; Regulation No. AP.005/6/14/DRJD/2011 on passengers and vehicles on crossing ferries established by Directorate General of Land transport, Ministry of Transport Republic of Indonesia [22]; Classification rules and regulations, especially those related to fire safety, engines, and accommodation including ship structure and layout, specifications and arrangement of equipment, and documents; International safety regulations for non convention vessels, working regulation onboard ferries etc.

Procedures for preventing and combating fire onboard which are used as guidance for obtaining fire safety onboard are: Fire safety management procedures, fire fighting procedures, evacuation and mustering procedures, fire fighting drilling procedures, vehicles and cargo arrangement procedures, incident and accident reporting procedures etc.

The official and practical fire safety requirements that used as the assessment standards among other things are: requirements relating to fire safety established by local authorities, general practices requirements in conjunction with prevention and combat of fire onboard, specifications and capacity required by equipment makers, recommendations of certain research and studies which have been accepted as norms, experience learned from past accidents or incidents related to fire onboard etc.

Management aspects included in the assessment standards such as policies implemented by vessel owner or operator with regard to manning of the vessel, working schemes, operation and maintenance procedures, management systems required by authorities, and other procedures implemented both by operator as well as the regulator such as port authority etc. Which would involve ship's crews, the passengers, the ship's owner or operator, port authority etc. on fire safety issues such as the implementation of non-smoking policy onboard the ship, paying attention on fire safety instructions, procedures on cargo reporting, scheme on inspection and maintenance of equipment, program on fire safety drillings, and implementation of other fire safety management.

The fire safety assessment is then implemented by analyzing the risks level of each category of fire safety against the related assessment standards. The vessel is considered as safe if individual risk level of each category is less than or equal to 15, and unsafe if above 15, and therefore certain action should be taken to minimize the potential risks before the vessel can be released for the voyage.

3.0 RESULTS

Based on surveys and investigations data, and combined with the risks analysis formula explained in the research methodology, onboard fire safety assessment standards for Indonesian roll on roll off passenger ferries are arranged in the form of matrices in accordance with the category of sources of hazards i.e. the vessel, the people onboard, and the cargo carried by the vessel as shown in Table 8, 9 and 10.

Table 8 Assessment standards for the condition of vessel

Ship space and system	Existing regulation	Procedure relating to fire safety	Fire safety requirement	Management aspect	Existing condition (scale:1 – 5)
Machinery system	NCVS 2009, Ch.V.2; Ch.III.18	Maintenance, Monitoring SOP	System & fire safety arrangement	Maintenance & drilling policy	
Fuel and lub-oil system	NCVS 2009, Ch.V.4	Maintenance, Monitoring SOP	System & fire safety arrangement	Maintenance system	
Electrical system	NCVS 2009, Ch.V.9	Maintenance & Monitoring SOP	System & fire safety arrangement	Maintenance system	
Deck machinery	NCVS 2009, Ch.V.7	Maintenance & Monitoring SOP	System & fire safety arrangement	Maintenance system	
Vehicle decks	NCVS 2009, Ch.III.8	Arrangement & monitoring SOP	System & fire safety arrangement	Maintenance & drilling system	
Passenger lounge	NCVS 2009, Ch.II.15	Arrangement & monitoring SOP	System & fire safety arrangement	Maintenance & drilling system	
Crew's cabin	NCVS 2009, Ch.II.2	Arrangement & monitoring SOP	System & fire safety arrangement	Maintenance & drilling system	
Galley	NCVS 2009, Ch.IV.12	Arrangement & monitoring SOP	System & fire safety arrangement	Maintenance & drilling system	
Ship interior	Classification rules	Maintenance SOP	System & fire safety arrangement	Maintenance system	
Ship layout	NCVS 2009, Ch.VI.11	Maintenance SOP	Escape routes	drilling system	
Fire safety equipment	NCVS 2009, Ch.III.7	Maintenance SOP	Number & capacity	Maintenance system	
Safety signs and instructions	NCVS 2009, Ch.IV.11 Ch.IX.4.8.	Maintenance & drilling SOP	Escape routes & drilling procedures	drilling system	

* NCVS = Non Convention Vessel Standards; Ch = chapter; SOP = standard operating procedures.

Table 9 Assessment standards for people onboard

People	Existing regulation	Procedure relating to fire safety	Fire safety requirement	Management aspect	Existing condition (scale:1 – 5)
Crews					
Qualification	NCVS 2009, Ch.VIII.9	Education & training	Training Certificate	Recruitment policy	
Adequateness	NCVS 2009, Ch.VIII.8	Manning procedures	Number of crews	Manning policy	
Knowledge	NCVS 2009, Ch.VIII.5	Instruction manual	Training scheme	Training schedule	
Skill	NCVS 2009, Ch.VIII.5	Drilling	Drilling scheme	Drilling schedule	
Working scheme	NCVS 2009, Ch.VIII.8	SOP	Work schedules	Company policy	
Working environment	NCVS 2009, Ch.VIII.10	Maintenance procedures	Drilling scheme	Company policy	
Vehicle drivers					
Knowledge	Government regulations	Safety instructions	License	Operator's policy	
Discipline	Government regulations	Safety instructions	Follow the order	Operator's policy	
Behavior	Government regulations	Random checking	Follow the order	Operator's policy	
Passengers					
Knowledge	Government regulations	Safety instructions	Follow the order	Operator's policy	
Arrangement	Port regulations	Safety instructions	Follow the order	SOP	
Behavior	Government regulations	Safety instructions	Follow the order	Operator's policy	
Special needs	Government regulations	Safety instructions	Follow the order	SOP	
Number	NCVS 2009, Ch.II.14	Safety instructions	Follow the order	Operator's policy	

Table 10 Assessment standards for cargo onboard

Cargo	Existing regulation	Procedure relating to fire safety	Fire safety requirement	Management aspect	Existing condition (scale:1 – 5)
Vehicle					
Arrangement	Port regulations	Safety instructions	Space arrangement	Port & operator policy	
Vulnerability	Government regulations	Separation	Risk consideration	Port & operator policy	
Type	Port regulations	Grouping	Risk consideration	Port & operator policy	
Size	Port regulations	Grouping	Risk consideration	Port & operator policy	
Vehicle Cargo					
Arrangement	Government regulations	Grouping	Type arrangement	Port & operator policy	
Vulnerability	Government regulations	Reporting	Risk grouping	Port & operator policy	
Type	Government regulations	Grouping	Risk grouping	Port & operator policy	
Content	Government regulations	Reporting	Risk grouping	Port & operator policy	
Cabin cargo					
Arrangement	Government regulations	Arrangement	Risk consideration	Port & operator policy	
Vulnerability	Government regulations	Reporting	Risk monitoring	Port & operator policy	
Type	Government regulations	Arrangement	Risk monitoring	Port & operator policy	
Content	Government regulations	Reporting	Risk monitoring	Port and operator policy	

3.1 Assessment Procedure

Refer to the assessment standards for particular category of the sources of hazard the fire safety condition of the vessel is assessed based on its risks level. The example of the assessment matrix forms are shown in Table 11, 12, and 13.

Table 11 Assessment form for the vessel's fire safety

Source	Hazard	Probability of occurrence P (0 – 5)	Consequence C (0 – 5)	Risk Level (P X C)
Machinery system	Engine blast or explosion			
Fuel and lub-oil system	Oil leakage and spillage			
Electrical system	Damaged switchboard			
	Life wire			
	Short circuit			
Deck machinery	Spark			
	Short circuit			
Car deck	Bad layout			
	Insufficient lighting			
	Confusing escape routes			
	Improper fire doors			
Passenger lounge	Insufficient lighting			
	Confusing evacuation route			
	Bad arrangement			
	Insufficient emergency exits			
	Flammable materials			
Crew's cabin	Bad arrangement			
	Flammable materials			
Galley	Gas leakage			
Ship interior	Flammable materials			
Ship layout	Confusing evacuation route			
Fire safety equipment	Not functioning			
	Insufficient quantity			
	Wrong arrangement			
Safety signs and instructions	Not available			
	Not clear			
TOTAL VESSEL RISKS LEVEL				

Table 12 Assessment form for the fire safety based on people onboard

Source	Hazard	Probability of occurrence P (0 – 5)	Consequence C (0 – 5)	Risk Level (P X C)
Crews				
Careless/unawareness	Trigger fire			
Unqualified personnel	Fault operation			
Intentional act/sabotage	explosion			
Lack of knowledge	Trigger fire			
	Chaos			
Exhausted personnel	Fault operation			
Unintentional act	Fault operation			
Influence of drug or alcohol	Fault operation			
Drivers				
Lack of knowledge	Trigger fire			
Careless/unawareness	Trigger fire			
Intentional act/sabotage	Explosion			
Unintentional act	Trigger fire			
Influence of drug or alcohol	Dangerous acts			
Passengers				
Lack of knowledge	Trigger fire			
Careless/unawareness	Trigger fire			
Intentional act/sabotage	Explosion			
Unintentional act	Trigger fire			
Influence of drug or alcohol	Dangerous acts			
TOTAL PEOPLE ONBOARD RISKS LEVEL				

Table 13 Assessment form for the fire safety based on cargo onboard

Source	Hazard	Probability of occurrence P (0 – 5)	Consequence C (0 – 5)	Risk Level (P X C)
Vehicles onboard	Fire from the engine			
	Fuel leakage			
	Electrical fault			
	Collision			
Cargo on vehicles	Explosion			
	Cargo spillage			
Passengers' baggage	Explosion			
TOTAL CARGO RISKS LEVEL				

■3.0 DISCUSSION

Continuous efforts in searching the related regulations, procedures, requirements, and policies, and discussions with stakeholders are still needed to refine the assessment standards and assessment procedures especially in identifying more specific hazards, and justification of probability as well as consequence scales, so that objective judgment could be obtained for improving the fire safety of roll on roll off ferries operate on Indonesian waters.

■4.0 CONCLUSION

Based on identified probability and consequence of fire hazards on a particular roll on roll off pax ferry the risks level of the vessel, the people onboard, and the vehicles onboard and their cargo can be objectively assessed both by the regulators as well as the operator of the crossing ferries, so that appropriate actions can be taken to minimize the risks of fire onboard.

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