Human Factor Risk Based Assessment For Roll On Roll Off Passenger Ferry Car Deck Fire Safety System

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Abstract: The research is aimed to assess the fire safety system on the car decks of roll on roll off passenger ferry from the aspect of human factors as a part of efforts for assessing the safety system of national crossing ferries in Indonesia. Roll on roll off passenger ferry is the most accident vulnerable mode of water transports in Indonesia due to several of causes, one of them is fire. In roll on roll off passenger ferries fire might occur in many places, but according to recorded data it mainly occurs in engine room, car decks, and passenger decks. And it is also identified that human factor is the main cause of most of the fire accidents. For this purpose the research was conducted using Human Factor Analysis and Classification System method, where descriptive qualitative investigation of risk level and potential hazards were implemented in the assessment. Four types of hazards and four root causes of fire accidents were identified in the assessment.

1. Introduction

Crossing ferries play important role in connecting the more than 17,000 islands of Indonesia both for transporting goods as well as people, but due to some circumstances such as ship condition, crews qualification, passengers' behaviour, weather condition etc. accidents occur quite frequently, even some were very severe and claimed a number of human lives. Based on the accidents data recorded by the National Transportation Safety Committee (KNKT), Ministry of Transport Republic of Indonesia from 2010 to 2016 there was 54 ship accidents occurred and claimed 337 human lives [1]. The types and percentage of the accidents were identified as 35% due to explosion and fire; 31% due to collision; 24% due to sinking; 4% due to grounding, and 4% due to others causes, as shown on Fig. 1. KNKT also identified four main sources of accidents i.e. human factors; over loaded; technical factors; and weather condition, 80% of most of the accidents happened were caused by human factor, as stated in maritime world [2].

Results of the study on fire accidents happened on Ro-pax ferries conducted by DNV stated that source of fire were 63% originated from engine room; 27% from cargo and accommodation spaces, and 10% from car decks [3], but according to data gathered from many sources showed that in Indonesia fire accidents occurred on crossing ferries mostly originated from ship's engine room and

car decks, and the cause was mainly due to human factor both crews as well as passengers. It was also identified from previous studies that the background of those accidents were because during the crossing there were people (mainly truck drivers) remain in their vehicles and did not leave the car decks for their cargo's security reasons, and in case of the fire in the engine room were due to the messy and dirty condition of the engine room, and low competency of the crews [4].
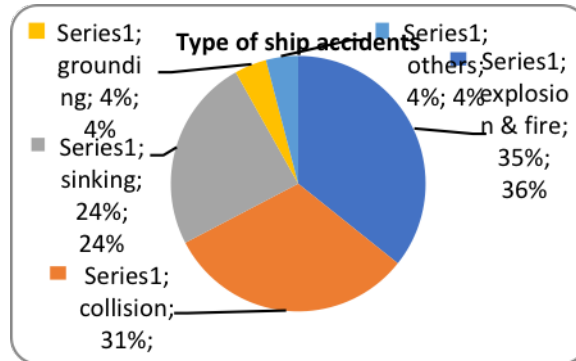

Figure 1: KNKT's Ship Accidents Data 2010 -2016 (Source: KNKT)

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Based on these findings the research was aimed to carry out assessment of the fire safety system on the roll on roll off ferries operated in Indonesian waters from the human factor aspects, and more specifically the study was focused on the fire occurred on the car decks, with the projected objective to improve the safety system of the national ferries.

2. Methodology

Descriptive qualitative approach was carried out in the study using obtainable data and information gathered from ro-pax crossing ferries operate on some busy routes in Indonesian waters, and from secondary resources, such as accidents data published by the National Transportation Safety Committee (KNKT), and news media. The assessment was carried out using Hazard Identification and Risks Assessment (HIRA), and Human Factor Analysis and Classification System (HFACS) methods.

The study was started by identifying primary hazards on the ferries' car decks and the potential influence of human factors on the hazards, then these potential contributions of human influences that might create accidents were investigated. Based on the findings of the investigation the levels of fire risks were analysed, continued with identifying the root causes of the risks. The risk levels were obtained by using risks level formula shown in (1), which states that risk is the result of the likelihood and the consequence of the event and presented in the form of risk level matrix as shown on Table 1.

$$R = L \text{ X } C \qquad (1)$$

Where: R is risk level, L is likelihood, and C is consequence. Likelihoods are categorized as: rare, unlikely, possible, likely, and almost certain. Consequences are categorized as: Insignificant, Minor, Moderate, Major, and Extreme. Risk levels are categorized as: Low; Medium; High; and Extreme.

Table 1: Risk Matrix

| | CONSEQUENCE | | | | |
LIKELIHOOD	1. Insignificant	2. Minor	3. Moderate	4. Major	5. Extreme
1.Rare	1.Low	2.Low	3.Low	4.Low	5.Low
2. Unlikely	2.Low	4.Low	6.Low	8.Medium	10.Medium
3. Possible	3.Low	6.Low	9.Medium	12.Medium	15.Medium
4. Likely	4.Low	8.Medium	12.Medium	16.High	20.High
5. Almost certain	5.Low	10.Medium	15.Medium	20.High	25.Extreme

2.1.Fire Triangle

As explained by National Fire Protection Association (NFPA) [5] fire is not a substance but a process of chemical reaction, an oxidation process between fuel, heath, and oxygen that happens very fast, which is known as Fire Triangle as shown in Figure 2. Fire releases energy and rises temperature, and in many cases produces smoke, toxic gas and waste, including fire's leftovers. NFPA also added another component to the fire triangle, which all together is called "fire tetrahedron" as shown in Figure 3, the uninhibited chain reaction of the feedback of heat to the fuel that produces gaseous fuel in the flame to maintain the fire. The heat energy transfers from the flame that spreads the fire through three different ways i.e. conduction, conviction, and radiation.
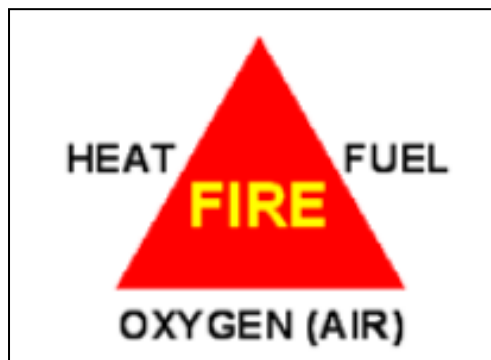

Figure 2: Fire Triangle (Source NFPA)

2.2. Hazard Identification and Risk Assessment (HIRA)

Hazard Identification and Risk Assessment (HIRA) is defined by the Ministry of Community Safety and Correctional Services Ontario Canada in Hazard Identification and Risk Assessment workbook [6] as: A tool for assessing risk to identify hazards that pose the greatest risk, which consist of the liklyhood they are to occur and the greatness of their potential impact. There are four steps to conduct a HIRA:

- Hazard Identification
- Risk Assessment
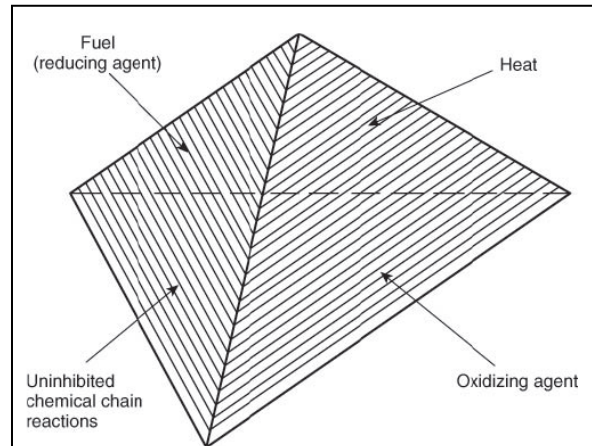- Risk Analysis
- Monitor and Review

Figure 3: Fire Tetrahedron (Source NFPA)

2.3. Human Factor Analysis and Classification System (HFACS)

Health and Safety Executive (HSE) [7] defines human factors as the influence of working behavior to the health and safety through environment, organization and job, and human and individual characteristics. Human factor involves three interrelated aspects i.e. the job, individual characteristics, and organization. The job consists of: the nature of the task, workload, working environment etc., the individual characteristics includes: competence, skills, personality, attitude, and risk perception, the organization includes: work patterns, the workplace culture, resources, communications, leadership etc.

HSE states that human failures have potential to cause or contribute to accidents. The consequences of human failures to accident can be direct or indirect. Active failures have direct consequence and are usually made by frontline people. Indirect failures are usually hidden within an organization until they are triggered by an event likely to have serious consequences. Indirect failures are usually created by people whose tasks are removed in time and space from operational activities.

Reason [8] suggests that the problems of human error can be approached from two points of view: the person approach and the system approach. The person approach is focused on the unsafe acts, and procedural violations as the results of mainly from unusual mental processes such as absentmindedness, lack of concentration, lack of motivation, inattention, negligence, and recklessness. The system approach assumes that humans are fallible and errors are to be expected, even in the best organization, errors are seen as consequences rather than causes. Human Factor Analysis and Classification System (HFACS) [9] was developed by Wiegmann and Shappell, two behavioral scientists in the Unites States Navy as framework for investigating accident, as the supplement to HFACS Soner, Asan, and Celik [10] suggest that the system should use four classifications of failure to identify the root causes of the accident i.e.: unsafe acts, preconditions for unsafe acts, unsafe supervision, and organizational influences.

2.4. Root Cause Analysis

The root cause analysis of the potential fire risks was conducted using Human Factor Analysis and Classification System (HFACS). For the purposes of analysing the root cause, each root cause classification is assigned a particular number as shown in Table 2, 3, 4, and 5.

Table 2: Root Causes of Unsafe Acts

Root Cause	Activity
C1	Fail to give response to operational failure
C2	Panic in responding to the fire accident
C3	Fail to follow fire safety procedures
C4	Ignore in doing routine fire safety inspection
C5	Misunderstanding to the fire safety procedures
C6	Violating on board fire safety drilling
C7	Ignore to the components of safety culture
C8	In disciplinary of the fire safety team
C9	Ignoring information due to bad communication system

Table 3: Root Causes of Preconditions for Unsafe Acts

Root Cause	Activity
C10	Loss of situational awareness
C11	Lack of motivation of crews on board
C12	Psychological unfit states of the crews on board
C13	Unfamiliar to fire safety requirement
C14	Over confidence of the crews to the situation
C15	Physical exhaustion of crews
C16	Time constraint to react to the fire situation
C17	Incompetence of crews to fire safety
C18	Insufficient physical capability in emergency response
C19	Unable to coordinate during emergency condition
C20	Failed to conduct operational planning and briefing
C21	Lack of fire safety warning and signaling system
C22	Lack of safety attitudes due to health problems
C23	Emotional overload of crews

Table 4: Root Causes of Unsafe Supervisions

Root Cause	Activity
C24	Failed to give guidance for fire prevention system
C25	Failed to provide appropriate fire fighting drill
C26	Failed to allocate qualified crews on board
C27	Unable to continuously monitoring crew performance
C28	Failed to provide appropriate crew resting time
C29	Failed to identify fire related hazards on board ship
C30	Failed to ommence fire safety corrective actions
C31	Failed to report unsafe fire prevention action
C32	Lack of conducting fire safety assessment program
C33	Lack of communication between supervisor and crews

Table 5: Root Causes of Organizational Influences

Root Cause	Activity
C34	Lack of company integrated safety policy
C35	Poor personnel recruitment procedures
C36	Poor shore-based personnel management system
C37	Insufficient crew training program
C38	Lack of up dating policy to monitor safety procedures
C39	Ineffective fire safety communication system.
C40	Confusing fire control policy
C41	Excessive time pressure
C42	Ineffective risk control system
C43	Lack of safety continuous improvement

3. Results

3.1. Hazard Identification

Sunaryo, Nugroho, and Talahatu [9] in their previous study identified that the three components of fire triangle that exist on the car decks of ro-pax ferries among other things are: as the fuel for the fire includes: the fuel of vehicles parked on the deck, the cargo carried in the vehicles, inflammable materials of the vehicles; as heat source are the engines of the vehicle, and in some cases sparks of fire due to short circuit of electricity connections; and the oxygen is the air blow from the ventilation system of the car decks.

Results obtained from the on the spot investigation and interviews, literature studies, and discussions with experts suggested that the human factors which might cause fire hazards on the ro-pax ferries' car decks are:

- Drivers and or assistants stayed in the vehicles and did not go to the passenger decks during the crossing time in order to watch for the security of their cargo,
- Engines of the vehicles were on during the crossing time in order to keep the air conditioning in the vehicles on so that the drivers could conveniently stay in the vehicles,
- Passengers smoked on the car decks or threw cigarette butt improperly during the crossing, before leaving the car decks, or when entering the car decks,
- Crews did not check the car decks and their equipment properly before the ferries left the port, due to the limitation of time available for vehicles embarkation,
- Improper inspection and maintenance of the fire safety equipment on the car decks,
- Crews ignorant in implementing safety regulations.

The potential hazards that might trigger fire accidents are:

- Fire from the live cigarette butt ignites the fuel of the vehicles parked on the car decks,
- Heat develops from the vehicles' engine increases the potential creation of fire triangle,
- Short circuit of improper electricity connections might trigger sparks and initiate fire,
- Fire safety equipment might not work properly when they are needed.

3.2. Risk Assessment and Analysis

In order to investigate the risk level of each potential hazard and its root causes the likelihood of the hazards are categorized as shown in Table 6, and the consequences are shown in Table 7, and the grouping of root causes into their consequences are presented by HFACS adjacency matrix in Table 8.

Referred to the likelihood and consequence tables the risk level of each hazard was obtained using (1) and categorized as shown in Table 1, and the root causes of each risk level were identified using HFACS adjacency matrix. Results of the assessment can be used by the stakeholders to justify the safety of the ship and further actions could be taken in accordance to the existing safety standards and regulations.

Table 6: Likelihood

Value	Likelihood	Likelihood Criteria
5	*Almost certain*	Fire occurred every month
4	*Likely*	Fire occurred every 6 months
3	*Possible*	Fire occurred every year
2	*Unlikely*	Fire occurred between 1 – 5 years
1	*Rare*	Fire occurred more than 5 years

Table 7: Consequences

Value	Consequence	Consequence Criteria
5	Extreme	Fatal, can cause death or permanent injury
4	Major	Injury more than 30 days off
3	Moderate	Injury between 10 – 30 days off
2	Minor	Injury between 3 – 10 days off
1	Insignificant	Injury less than 3 days off

Table 8: HFACS Adjacency Matrix

	UA	PUA	US	OI
Extreme	C1, C3, C4, C6, C7	C10, C15, C17, C18, C20	C26, C27, C28, C32	C34, C35
Major	C2, C5	C11, C12, C16, C19, C21, C22, C23	C24, C25, C29	C36, C38, C42, C43
Moderate	C8, C9	C13, C14	C30, C31, C33	C37, C40
Minor				C3 9, C41
Insignificant				

Where: UA is unsafe acts, PUA is pre-conditions for unsafe acts, US is unsafe supervision, OI is organizational influences.

Refer to risk level shown in Table 1 the risk categories are grouped as follows: extreme with risk level 25, where the risk might cause loss of life and total loss of property, and the occurrence is mostly certain; high with risk level 16 to 20, where severe injury might occur to people and fatal damage to property, and the probability near certain; medium with risk level 8 to 15, where the fire involving danger to person(s) and damage to property, and probability of occurrence reasonably likely; low with risk level 1 to 6, where the fire at the most only causing minor injury to person(s) and insignificant damage to property, and the occurrence is never or seldom.

3.3. Application of The Assessment

For immediate application the assessment could be conducted by the safety officer and the crews assigned on board to ensure the safety of the ferry, with the requirements that:
- The safety officer possesses sufficient knowledge of ISM code, and requirements of crews according to STCW 95,
- The safety officer possesses sufficient knowledge of basic safety training for prevention and combating fire accident on board the ship, including survival, basic fire prevention and firefighting,
- The safety officer knows the detail duties of the crews assigned on the car decks,
- The safety officer possesses sufficient knowledge of and capable to carry out Human Factor Analysis and Classification System (HFACS),
- The safety officer will be provided with HFACS adjacency matrix, so that he/she could make appropriate decision for action,
- The safety officer should assess the competency of the crews assigned on the car decks,
- The safety officer is given authority to conduct car decks fire safety assessment based on the points provided in the HFACS.

Results of the assessment are then used as the reference for arranging safety measure to be applied on board as part of the managements' safety policy.

4. CONCLUSIONS

Based on the data and information gathered, and the assessment being carried out in the study, it is concluded that:

- Human factors play highest roles in the potential occurrence of fire accidents on board ro-pax ferries in Indonesia.
- Four hazards and four root causes were identified that might initiate fire on the ro-pax ferry car decks.
- Risk levels of the identified hazards could be obtained using the proposed risk assessment and analysis method.
- Root causes of potential fire accidents on the ro-pax ferry car decks were obtained using Human Factor Analysis and Classification System (HFACS) method.

Acknowledgements

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