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Causative Factor Analysis of Passenger Ship Accident (Fire/Explosion) in Indonesia

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Abstract. Number of ship accidents in Indonesia in these two years has been increasing from 355 cases in 2018 to 409 cases in 2019. It means that, 31-32 accident occurred each month or at least 1 ship accident every day along 2018 to 2019. Among all the accidents, Passenger ship (including Passenger ship/Ferry, Ferry Ro-Ro, and High Speed Craft for Passenger) is the most common ship type with percentage up to 30% with 210 people dead/missed and 775 people wounded. It is important to look further how the passenger ship accident happen to understand what are the causative factors contributing to the accidents. National Transportation Safety Committee (NTSC) in Indonesia investigated some accidents then published the report to their website and it can be re-analysed to get the causative factors. Investigation reports from NTSC provide fire/explosion cases more than other nature of accident. Thus, in this paper, the analysis focuses on the fire/explosion accidents of Passenger Ship that began in car deck. The causative factors are found using new development of MOP Model that classifying failures into 4 M (Man, Machine, Media, Management) and several categories and sub categories.

1. Introduction

Ship accident news are still being informed, mostly, through online mass media including in Indonesia. Indonesian National Transportation Safety Committee (NTSC) has been started collecting any ship accident from search engine from end of 2017 [1]. From the collected data, in 2018, there were 355 accidents, involving various types of ships and 6 types of accidents. In 2019, the number has increased become 409 accidents. In total, there were 73 accidents that involving 10 types of ships and 7 types of accidents. The 10 types of ships are categorized based big category on Guidance for Class Notation by Biro Klasifikasi Indonesia (BKI), from now on it will be written as Class Notation Book [2]. Figure 1 shows percentage of ship types that were involved to ship accidents in 2018-2019 and Figure 2 shows percentage of accident types that have been categorized by NTSC.

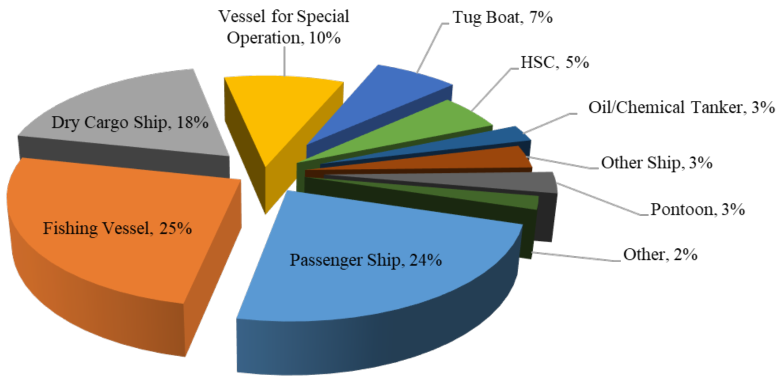

Figure 1. Percentage of ship accidents based on ship type in 2018-2019 [1].

Based on Figure 1, among 763, 25% of the ship accidents is fishing vessel then followed by 24% of passenger ship. However, most of the 5% of HSC is also transporting passengers more than 12 people. Thus, in this paper (from now on), HSC is included into passenger ship, then the accident percentage of passenger ship become 29% as the most common ship type of accident. From 763 accident cases, the number of fatalities were 714 people dead or missed and 1052 people injured. For the case of passenger ships, 210 people dead/missed and 775 people wounded. In other words, almost 30% of the people died/missed caused by ship accidents in 2018 was from passenger ship accident. It becomes very important to find out what happen to the passenger ship cases to know what are the most critical event leads to the accidents in Indonesia.

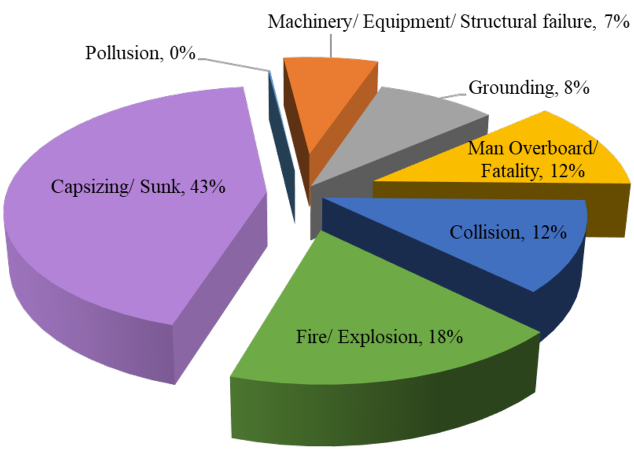

Figure 2. Percentage of ship accidents based on accident type in 2018-2019 [1].

To learn what happen to the accidents, official accident investigation reports can be utilized. The accident investigation reports are provided by investigator institution that exist in the country. Indonesia has Indonesian National Transportation Safety Committee (NTSC) that has published all the final investigation reports on its website, allowing interested parties to utilize the reports. There are many report cases that happen from 2003. However, in this study, only cases that happen in these past 10 years (2008-2018) that will be re-analysis. There are 61 investigation reports from ship passenger cases available in NTSC's website. 59% of the cases are involving ships that classified by BKI or Indonesian Classification Company.

BKI is a national classification that being recognized by Indonesian Government as Flag Administration to classify ships and carry on statutory certification to certain ships. It publishes rules that regulating how ships are constructed following international rules, regulations, and codes. This study is carried out to review accident as an input of the next research ‘what are the BKI’s rules that may have some limitation or ineffective, allowing many accidents are still happen’.

There are several model for accident analysis. All accident models can be distinguished as three main types, sequential, epidemiological, and systemic [3] [4] [5]. This categorization relates to assumptions of accident causation. It helps researchers explain system theory concepts into accident models [5].

Sequential Accident Models is the simplest type of accident model describing accidents as the result of time-ordered sequences of discrete events. It assumes that an undesirable event, i.e. a 'root cause' initiates a sequence of events which lead to an accident and that the cause-effect relation between consecutive events is linear and deterministic. This implies that the accident is the result of this root cause which, if identified and removed, will prevent a recurrence of the accident [5]. Examples of this model are: Domino Model (Heinrich in 1931), Five Whys Method (Ohno in 1988), Framework for Maritime Risk Assessment (Harrald et al in1998), Fault Tree Analysis (Watson, 1961 cited in Ericson in 1999), and Bowtie Model (Hollnagel in 2008).

Epidemiological Accident Models describes an accident like a disease, an outcome of a combination of factors, some manifest and some latent, that happen to exist together in space and time [3]. In other words, contributing failures are 'latent' and 'active' failures [5]. Latent conditions, e.g. management practices or organizational cultures, are likened to resident pathogens and can lie dormant within a system for a long time. Such organizational factors can create conditions at a local level, i.e. where operational tasks are conducted, which negatively impact on an individual's performance (e.g. fatigue or high workload). The scene is then set for 'unsafe acts', such as errors and violations, to occur. Therefore, adverse consequences of latent failures breach the defenses of a system. Examples of this model are: Swiss Cheese Model (Reason in 1990 and 1997), 'Sharp end'-'blunt end' interactions (Wood et al in 1994), Cognitive Reliability and Error Assessment Method (CREAM) (Hollnagel in 1998), Human Factors Analysis and Classification System (HFACS) (Wiegmann and Shappel in 2003), Models of pathological system (organization) states, and Tripod Beta.

Systemic Accident Models is designed to describe characteristic performance at the level of the system as a whole, rather than on the level of specific cause-effect "mechanisms" [3]. It describes the losses as the unexpected behavior of a system caused by uncontrolled relationships between its constituent parts [5]. In Underwood and Waterson's report, accidents are not created by a combination of latent and active failure, or the result of a sequence of cause-effect events. Accidents are the result of humans and technology operating in ways that seem rational at a local level, but unknowingly create unsafe conditions within the system that remained uncorrected. Simply removing the 'root cause' from a system is not the key for preventing the recurrence of an accident. A holistic approach is required, whereby safety deficiencies throughout the entire system must be identified and addressed. Examples of this model are: Control Theory (Sheridan in 1992), Accimap (Rasmussen in 1997), Neural Networks (NN) Concept (Hashemi et al in 1995; Le Blanc et al in 2001), Simulation and Expert judgement (Harrald et al in 1998), Fuzzy Logic (Sii et al in 2001), Bayesian Belief Network concept (BBN) (Merrick and Singh, 2003; Trucco et al in 2008), Systems Theoretic Analysis Model and Processes Model (STAMP) (Leveson in 2004 and 2011), The Functional Resonance Analysis Method (FRAM) (Hollagel in 2004 and 2012), Risk Based Approaches (Vanem and Skjong in 2006; Celik et al in 2010), and SHEL Model (Elwyn Edwards in 1972 then modified by Frank Hawkins in 1984).

Underwood and Waterson has analyzed the utilization of the accident models for several fields by putting all fields into charts then divide it what model is fit to the field [5]. From the analyzes it is understand that Maritime Transportation System (MTS) is better analyzed by finding the latent and active failures to describe how the accident occurred as epidemiological model. However, nowadays research has been combined models in epidemiological and systemic models. Even though it is better to understand by epidemiological model, many researchers are trying to develop several models in systemic model for MTS.

Most of the accident models stated above are focused on human factor and its causation. However, in the MTS, there is a contribution possibility from interaction among environmental, technology, and management/ organizational condition. To coverage the deficiency, authors propose the utilization of

MOP (4M Overturned Pyramid) Model. MOP model was introduced in 2017 [6] for accident analysis. The accident investigation report is a source where we can collect what are the events related to accidents, called as failure events, then being categorized into 4 M (Man, Machine, Media, Management) based on MOP model concept.

2. Indonesian Passenger Ship Accident

Based on Class Notation Book, Passenger Ship is a ship which carries more than 12 passengers [2]. Passenger is every person other than:

- the master and the members of the crew or other persons employed or engaged in any capacity on board a ship on the business of that ship, and
- a child under one year of age.

Passenger ships are able to carry cargoes, containers, and/or cars if the ship has its special notation, assigned at the class approval, as seen in Figure 3.

✠	A100	Ⓘ	P	Passenger Ship
✠	A100	Ⓘ	P	Passenger Ship, Cargo carrier
✠	A100	Ⓘ	P	Passenger Ship, Container carrier
✠	A100	Ⓘ	P	Passenger Ship, Car carrier
✠	A100	Ⓘ	P	Passenger Ship, Cargo carrier, Container carrier, Car carrier

Figure 3. Example of Passenger Ship Class Designation in BKI Register.

For the passenger ship which carries vehicles, especially engaged short services between two or three harbors regularly, subject to the corresponding National Regulations has different notation, namely Ferry RO-RO. It has 2 qualifiers that identify its special way of carrying vehicles, which are Open space and Enclosed space. Open space is assigned to Ferry which carries vehicles on open or weather deck only. Enclosed space is assigned to Ferry which carries vehicles on enclosed deck. Example of Class Designation for Ferry RO-RO in BKI shown in Figure 4. The other two type of passenger ship are the ship that has high speed, meeting the requirement of the Rules for High Speed Craft (Pt.3, Vol.III), namely High Speed Craft with special notation Passenger A (up to 450 passengers) and Passenger B (over 450 passengers). The class designation in BKI for this type of ship is shown in Figure 5. There are 592 passenger ships from 12.779 ships registered in BKI in February 2020. It includes all types of passenger ships, such as Passenger Ships/ Ferry, Passengers with Car/Cargo/ Container Carriers, Ferry Ro-Ro and HSC Passengers.

✠	A100	Ⓘ	P	Ferry RO-RO (Open space)
✠	A100	Ⓘ	P	Ferry RO-RO (Enclosed space)

Figure 4. Example of Ferry RO-RO Class Designation in BKI Register.

✠	A100	Ⓘ	P	HSC, Passenger A AL, CAT
✠	A100	Ⓘ	P	HSC, Passenger B AL, CAT

Figure 5. Example of HSC Class Designation in BKI Register.

As stated in previous section, percentage of passenger ship accident in 2018-2019 counted for 24% and HSC 5% which most of HSC bring passengers. In total, there were 220 passenger ships in 2018-2019 or in other words there were 9 to 10 passenger ship accident every month in 2018-2019. The top three accident types are capsized/sunk (40%), followed by grounding (16%) and fire/explosion (14%), see Figure 6. Thus, it will be better if the study begins from these three type of accidents.

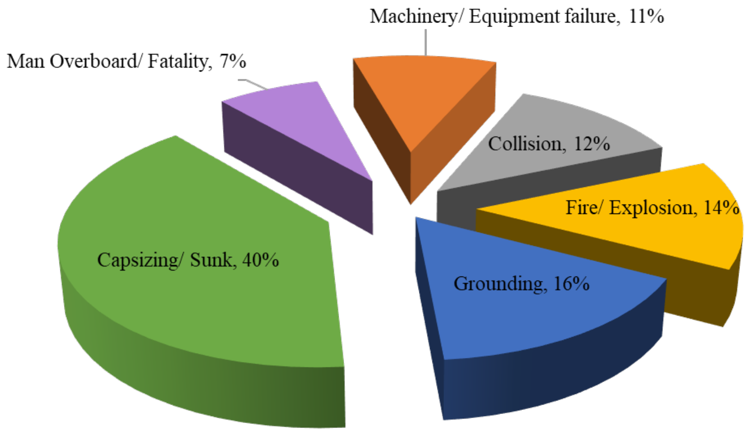

Figure 6. Percentage of passenger ship accidents based on accident type in 2018-2019 [1].

Not all accident cases as shown in Figure 6 are investigated by NTSC. However, there are many reports that can be re-analysed and got the lesson learned. There are 61 accidents that have been investigated by NTSC in 2008-2018. 59% of the cases involves ships classed by BKI where fire/explosion is the most common accident type. Among all the involved ship classed by BKI, 33% of the cases (13 cases) are fire/explosion accidents. In this paper, the analysis focuses on these fire/explosion cases that begin in car deck (9 cases). However, among those number, there are several reports that has not been published yet. In total, there are only 7 reports available.

3. Methodology

MOP (4M Overturned Pyramid) Model is a new model developed by Mutmainnah and Furusho since 2014 [7] that can be utilized to describe characteristics of MTS which is a socio-technical environment system. The MOP model, was utilized to describe the characteristics of the MTS, which is a socio–technical environment system. The model is based on the epidemiological model that consists of the latent condition, barriers, and active condition. Figure 7 shows an image of the MOP model and Table 1 explains the definition and the example.

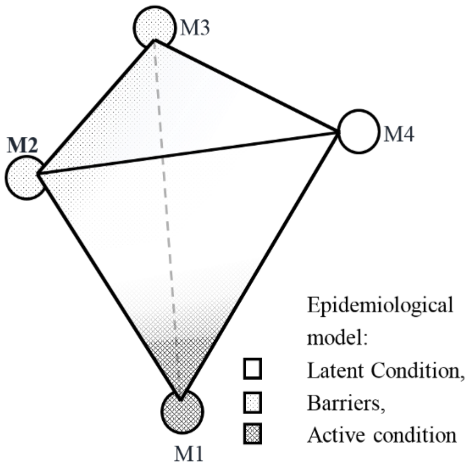

Figure 7. MOP Model.

The MOP model in Figure 7 is drawn in three-dimensions as a three-sided inverted pyramid that has four corners, representing the 4M (Man, Machine, Media, and Management) factors and six edges, representing an interaction between two 4M factors that are connected by the edges. The edges, called line relations, show that the system is a result of the interactions between the 4M factors. In Figure 7, M1, M2, M3, and M4 refer to the factors of Man, Machine, Media, and Management, respectively.

Failures do not occur only because of a single factor represented by a corner of the MOP model. Often, a failure is caused by a combination of corners, indicating that the corners are related. Thus, the line relations connecting the corners also contribute to the instability of the system.

Table 1. Corner definition of MOP Model.

4 M Factors	Definition	Example
Man (M1)	Human elements that affect people doing their tasks	Knowledge, Skills, Abilities, Memory, Motivation, Alertness, Experience, etc.
Machine (M2)	Tools that help people to complete their tasks, including technology	Equipment, Information displays, Environmental design, Crew complements, Construction, etc.
Media (M3)	Environmental factors that affect the system and/or people	Climatic/ weather conditions (temperature, noise, sea state, vibration, wave, tide, wind, etc.), Economic conditions, Social politics, Culture, etc.
Management (M4)	All elements that can control the system and/or people	Training scheme, Communication, Work schedule, Supervising/ monitoring, Regulatory activities, Procedures, Rules, Maintenance, etc.

For example, consider a communication failure. Communication cannot be considered under only one of the corners because it is related to all the four corners. A failure in communication between seafarers is classified as M1 because this type of communication depends on a person. Often, several seafarers do not share information with other seafarers. However, communication failure between ships and port administrations does not belong to the category of M1. It can belong to either M4 or M2 that are affected by the media factor. The classification of failure depends on the conditions of the accidents. When a line relation contributes to an accident, a preventive action for the same has to be determined. Thus, for a safe system, all the corners and edges should be reliable and balanced.

In order to utilize this model, there are two steps to be done, namely, corner analysis and line relation analysis. First, Corner Analysis (CA). In this step, all failures that caused accidents are traced and listed, called causative factors (CFs), and then divided based on the definition of each corner of the MOP model. Second, Line Relation Analysis (LRA). This line relation analysis step connects one corner to the other corners that are related to the causative factors that occurred, such as those caused by other factors even affecting others. In this step, of all the causative chains listed, the relationship among the corners of the MOP model is explored. The chains that is performed by several CFs is called as causative chains (CCs). By performing line relation analysis, we can understand which line relation is the most vulnerable to failure.

MOP model has been applied to 81 collision cases in 4 countries, involving 129 ships [6]. From CA, there were 27 CFs in M1, 15 CFs in M2, 11 CFs in M3, and 15 CFs in M4 for those 81 cases. In other paper that comparing the characteristics of CFs in Collision and accidental work cases in Japan, MOP model can show the differences [8]. For example, while in accidental work, CFs in M1 are classified into 6 parts (careless workmanship, doing personal decision, disobeying procedure manual, carrying out irregular procedure, incapability of seafarers/workers, and human element problem) and CFs that happen in collision are classified into 3 parts, namely careless workmanship, incapability of seafarers, and human element problem. However, CF that is the most happen in both accidents is failure in identifying/ monitoring accident risk. Both in collision and accidental work cases, most of CFs are in M1, compare to all 4M factors.

In this paper, MOP Model is developed by making a fix classification of CFs in each category of 4M, adopting several classification of Human Factors Analysis and Classification System (HFACS) method that was introduced by Wiegmann and Shappell in 2003. HFACS is a robust accident analysis and investigation tool that has a wide human error framework in order to investigate and analyze human error causation. Originally it was developed for aviation industry, however it has been successfully applied in maritime, rail transportation, mining, healthcare practice, and surgery operation [9] [10].

The HFACS consists of four main levels of investigation schema: unsafe acts, preconditions for unsafe acts, unsafe supervision, and organizational influences. Then each main levels has several sub-factors. In unsafe act level, it includes errors and violations. The precondition for unsafe acts includes environmental factors, condition of individuals, and personal factors. The supervision level includes inadequate supervision, inappropriate operation, failing to correct problems, and supervisory violations. The organizational influences includes resource management, organizational climate, and organizational processes [9]. The classification of framework in HFACS is much related to MOP model. The factors in HFACS is adjusted to MOP model to see how is the interaction from all the factors, or in MOP model it is called as CFs, seen by 4M classification point of view to make the accident investigator easier to do analysis. The modification of MOP model and HFACS can be seen in Table 2.

Table 2. New MOP model with the Categories and Sub-Categories.

4 M Factors	Code	Categories and sub categories of Causative Factors
Man (M1)		Unsafe acts
	M1010100	Slip
	M1010200	Lapse
	M1010300	Mistakes
	M1010400	Routine Violation
	M1010500	Exceptional Violation
		Precondition of unsafe acts
	M1020100	Adverse mental
	M1020200	Adverse physiological
	M1020300	Physical and/or mental limitations
	M1020400	Personal readiness failures
Machine (M2)		Ship Construction/ Equipment
	M2010100	Equipment Failure/Damage
	M2010200	Construction Damage
	M2010300	Incomplete/Deficient/inadequate equipment/systems
		Port Construction/ Equipment
	M2020100	Port Facility Failure/ Damage
	M2020200	Incomplete/Deficient/inadequate Port Facility
		Onshore Facility
	M2030100	Onshore Facility Failure/ Damage
	M2030200	Incomplete/Deficient/inadequate onshore Facility
Media (M3)		Weather
	M3010100	Strong flow tide
	M3010200	Strong wind
	M3010300	Rainy
	M3010400	Strong current
	M3010500	Flood
	M3010600	Restricted visibility (fog, rainfall, obstruction)
	M3010700	Poor lighting
	M3010800	Sound pollution
		Waterway conditions

Table 2. New MOP model with the Categories and Sub-Categories.

4 M Factors	Code	Categories and sub categories of Causative Factors
	M3020100	Busy traffic
	M3020200	Narrow waterways
	M3020300	Submerged debris
		Work space condition
	M3030100	Ergonomic related design
	M3030200	Cleanliness
	M3040000	Economic pressure
	M3050000	Culture
Management (M4)		Supervision
	M4010100	Inadequate supervision
	M4010200	Planned inappropriate operations
	M4010300	Failure to correct known problems
	M4010400	Leadership violation
		Organizational influences
	M4020100	Resource management
	M4020200	Organizational climate
	M4020300	Organizational process

4. Result

There are 13 fire/ explosion accident investigation reports available in NTSC's website that involving passenger ships classed by BKI. The fire started from different places in ship, as seen in Figure 8. The ships are vary in length, from 31 m (162 GT) to 151.13 m (15,380 GT). For the ships that has more than 90 m of length, the beginning of fire was in car deck (7 cases). However, there are other 2 cases that involving ships with less than 90 m of length fired in car deck. The fire/explosion cases that begin in car deck become the majority cases (65% or 9 cases out of 13), as seen in Figure 8. In this paper, we focus on cases that begin in Car deck as these cases becomes the majority.

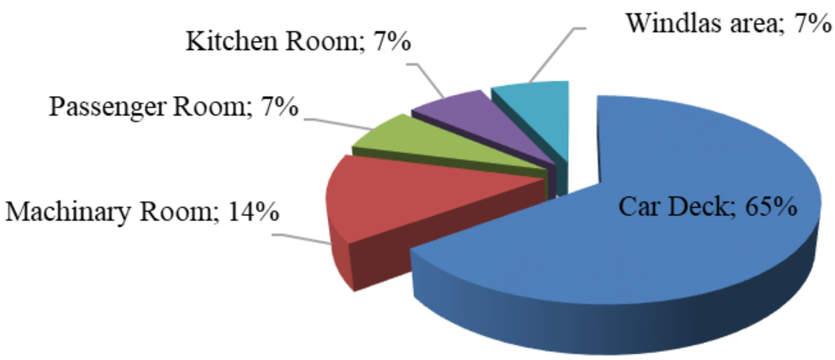

Figure 8. Percentage of fire/explosion beginning place.

However, only 7 out of 9 cases that are analysed in this paper due to the availability in NTSC's website. Among those 7 cases, the beginning of fire can be categorized into three sources: inside the cargo of the truck (4 cases), refrigerated box truck problem (2 cases) and bus electrical system (1 case).

Main objective of this paper is constructing a Causative Factor (CF) list using MOP model by categorizing all the findings into categories and sub categories, called Corner Analysis (CA) then the findings are traced, what findings are causing the other findings, by Line Relation Analysis (LRA) to get Causative Chains (CC). CF is events or conditions or failure events that lead to accident/ incidents. It happen both as active failures and latent failures. It can be both as an effect and cause. From 7 cases, there are 74 failures found in total, from 31 type of CFs. This means that there are 10 to 11 failures in each case in average. Table 3 shows the CFs that found in 7 fire cases in car deck.

Table 3. Causative Factor List.

4M Factors	Categories and sub categories of Causative Factors	Code	CFs	Amount
Man (M1)	Unsafe acts			
	Mistakes	M1010301	Ineffective effort of extinguishing fire	6
		M1010302	Late decision of crew to wear fireman outfit	1
		M1010303	Late to find out the fire	2
		M1010304	Ineffectiveness of fire patrol	1
		M1010305	Inappropriate utilisation of fireman outfit or other protective equipment	2
		M1010306	Inappropriate fire extinguisher equipment to be used	3
	Routine Violation	M1010401	Un-fulfilment of minimum requirement for vehicle safety distance	3
		M1010402	Drivers/ passengers stayed on vehicle	2
		M1010403	Not limiting the maximum height of cargo dimension	2
	Precondition of unsafe acts			
	Physical and/or mental limitations	M1020301	Lack of fire extinguishing knowledge of crew, including its effect	2
		M1020302	Lack of crowd and crisis management skill	1
Machine (M2)	Ship Construction/ Equipment			
	Equipment Failure/Damage	M2010101	Sprinkler did not effective to extinguish fire	5
	Construction Damage	M2010201	Construction and electrical discharge ran down, making another fire on lower deck	1
	Incomplete/Deficient/inadequate equipment/systems	M2010301	Inadequate sprinkler clearance to vehicle	3
		M2010302	fuel pipe installation is above the burnt bus	1
	Cargo Related Problem			
	Cargo condition	M2020101	Over dimension of cargo vehicle	4
		M2020102	Utilization of tarpaulin to cover oversized cargo on vehicle	4
		M2020103	Existence of exhaust gas from cooler independent system of vehicle as heat source*	1
		M2020104	Overheat of brake system as heat source*	1
	Damage in cargo	M2020201	Short circuit in bus electrical system*	1
Media (M3)	Weather			
	Rainy	M3010301	Heavy rain	1
	Work space condition			
	Ergonomic related design	M3030101	Inappropriate vehicle arrangement (too close)	3

Table 3. Causative Factor List.

4M Factors	Categories and sub categories of Causative Factors	Code	CFs	Amount
	Existence of hazardous item	M3030301	Unknown heat source meet unknown hazardous item in cargo inside vehicle*	3
		M3030302	Unknown heat source around cargo area*	1
Management (M4)	Supervision			
	Failure to correct known problems	M4010301	No control of cargo dimension	4
		M4010302	Lack of controlling from management for passengers inside vehicle	2
	Organizational influences			
	Resource management	M4020101	No weighting measurement facility in port	1
	Organizational process	M4020301	No procedures for fire drill in car deck	4
		M4020302	Ineffective procedures for extinguishing fire	1
	Regulatory Factors			
	Absence of regulation	M4030201	No regulation for recording all the cargo in detail (content, weight, dimension) from customer > expedition company > brought by driver > submit to port authority	4
		M4030202	No regulation for inspection and control of dimension limit/ weight/ and amount of cargo on vehicle	4
			Total:	74

Note:
* is heat source that ignited fire

5. Discussion

There is lesson learned that people can get from investigation reports published by NTSC. Among 13 fire/ explosion cases of ferry roro classed by BKI, 9 of them happen in car deck in the beginning. 2 of the cases happen in machinery room, 1 case in windlass area, 1 case in passenger room, and 1 case in kitchen room. Among those 13 cases, cases in passenger room, kitchen room, and 1 case in car deck still could continue the passage not like the others. The other cases were sank and could not continue the passage without tug boat. In other word, there is possibility that existence of fire in machinery room or car deck will cause sink or unable to continue its passage by itself. However, it need a deep research related this topic. This research explain how the 7 cases of fire/explosion in car deck happen from two points of view, namely fire development stage and categorization of CF based on 4M factors.

5.1. *Fire Development Stage and Active Failures*

As known widely, fire is generated by three main component, namely oxygen, heat source, flammable material. When three of those component are existed at the same time and place, then fire will appear. The first stage of fire development is called as ignition stage then followed by growth, fully development, and decay. As long as 3 components are existed, the fire will not go out. In other side, in the whole accident development, there are active failures and latent failures. Active failures are failures that happen just before incident happen. Latent failures are failures that underlying the active failures happen and they appeared long time before incident. In the fire/explosion cases, every fire development stages has latent failures that allow the 3 components of fire kept existed. The causes are several latent failures are exist.

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As seen in Table 3, there are five types of heat sources (CF marked with *) as active failures. **Table 4** shows the resume of the heat sources. The most common heat sources is the existence of unknown heat source meet unknown hazardous item inside the truck cargo. From LRA, the cause of this condition is found. No regulation for recording all the cargo in detail (content, weight, dimension) from customer > expedition company > brought by driver > submit to port authority (M4030201) and No regulation for inspection and control of dimension limit/ weight/ and amount of cargo on vehicle (M4030202) are the causes as latent failures. Thus, there was no strict control to make sure what was inside the truck cargo.

Table 4. Heat sources from 7 cases.

No.	Heat Sources	Cases
1.	Unknown heat source meet unknown hazardous item in cargo inside vehicle	3 cases in cargo area of truck
2.	Unknown heat source around cargo area	1 case around cargo area of truck
3.	Existence of exhaust gas from cooler independent system of vehicle as heat source	1 case in truck box
4.	Overheat of brake system as heat source	1 case in truck box
5.	Short circuit in bus electrical system	1 case in bus

Among 7 cases, only 1 case that the ship was able to continue its passage. That case is caused by Overheat of brake system as heat source that happen in truck box. The final condition of the other 6 cases are sank (3 cases) and unable to continue its passage by it selves (3 cases). Fire in those 6 cases involving truck with cargoes around the heat source. The analysis shows that passengers ships that also carry truck with a lot of cargoes are vulnerable to be sank or unable to continue passage by it selves as the result if there is fire in car deck.

5.2. Categorization of CF based on 4M factors
Categorization of CF based on 4M factors is aimed at a simplicity of the causative analysis of accident. The MOP model then is modified, inspired by HFACS, to make people including investigators easier to find the causative factors or failures to consider what action should be done to prevent the same accident.

5.2.1. Man Factors. This is the highest number of CFs. There are 11 CF that is classified into man factor with two categories (Unsafe acts and Precondition of unsafe acts). In unsafe acts category, there are only two subcategories exist for these 7 cases, namely mistakes and routine violation. The most common CF or failures from man factor is Ineffective effort of extinguishing fire. This failure is one of active failures that happen when crew tried to extinguish fire. However, this mistakes have underlying causes that are also in man factor and in other M factors, from LRA step. The underlying causes that classified into man factors are Late decision of crew to wear fireman outfit, Late to find out the fire, Inappropriate utilisation of fireman outfit or other protective equipment, Inappropriate fire extinguisher equipment to be used, and Lack of fire extinguishing knowledge of crew, including its effect. The other underlying causes from other M factors are Inappropriate vehicle arrangement (too close) from media factors, No procedures for fire drill in car deck, and Ineffective procedures for extinguishing fire from management factors.

5.2.2. Machine Factors. The most common CF in this classification is Sprinkler did not effective to extinguish fire that is also an active failure that happen in attempt to extinguish fire. The sprinkler were not broken at that time but still fail to extinguish fire because of several underlying causes. They are Inadequate sprinkler clearance to vehicle, Over dimension of cargo vehicle, Utilization of tarpaulin to cover oversized cargo on vehicle that are also classified in machine factors.

5.2.3. Media Factors. There is only one weather condition that was affecting accident, namely heavy rain. The other CFs are related to workspace condition. Two of them are heat source and another one is the condition of the vehicle arrangement that reducing the effectiveness of crew extinguishing fire.

5.2.4. Management Factors. All the CF in this classification are latent failures that exist long time before accident happen. The CFs from management factors happen in 4 cases are No control of cargo dimension, No procedures for fire drill in car deck, No regulation for recording all the cargo in detail (content, weight, dimension) from customer > expedition company > brought by driver > submit to port authority, No regulation for inspection and control of dimension limit/ weight/ and amount of cargo on vehicle.

6. Conclusion

This new development of MOP model allows people to easily analyze accident causation based on human factor approach, qualitatively. Maritime Transportation System is consisted by Man, Machine, Media and Management factors that causing and affecting continuously. If there is active failure happen, there must be latent failures exist causing accident.

Application of MOP model for 7 fire/ explosion cases in Ferry Roro conclusion is as follows:

1. There are five types of heat sources causing fire/ explosion accidents: Unknown heat source meet unknown hazardous item in cargo inside vehicle, Unknown heat source around cargo area, Existence of exhaust gas from cooler independent system of vehicle as heat source, Overheat of brake system as heat source, and Short circuit in bus electrical system
2. The most common failure is Ineffective effort of extinguishing fire (M1010301) that is classified into man factors, as mistakes in unsafe acts. However, there are several underlying causes that coming from other M factors and categories of CF.

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