WORLD MARITIME UNIVERSITY

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CONTEMPORARY ISSUES IN DOMESTIC RO-RO PASSENGER FERRY OPERATION IN DEVELOPING COUNTRIES

Identification of safety issues in domestic ferry operation based on accident investigation reports on ferry involved accidents in Indonesian waters, 2003 - 2013

By

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Declaration

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

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"Failure as an essential part of a process that allows you to see what it is you really need to do more clearly because of the shortcomings"...anonymous

Abstract

Title of Dissertation : **Contemporary issues on the domestic Ro-ro passenger ferry operation in developing country: Identification of safety issues in domestic ferry operation based on the ferry involved accident investigation report in Indonesian water year 2003 - 2013**

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The dissertation is a study to present recent overview to the safety issues in the domestic ferry operation in developing country. This was done by taking example Indonesian domestic ferry operation.

The ferry operation considered as the most successful maritime operation in sense of its transporting people, vehicle and goods. In developing countries, ferry is not just a transportation tools but it also use to maintain national integrity by providing access to remote islands or isolated by water location. However, accident to ferry in typical developing country more likely resulted in a catastrophic consequence of losing life and damaged to the property. Investigation into the accident had been done to reveal the causal root and present the outcome to the related stakeholders. The main idea of the dissertation is to review 16 ferry involved investigation report issued in 2003-2013 with appropriate accident causation model and determine which factors were missing and contribute to the development of accident from cultivation of risk to the greater consequences. The review mainly focused on the three different type of accident namely fire, collision and capsize.

The utilisation of state of the art, SEMOMAP model to the selected cases has presented detail outcome and useful information on the issues in the domestic ferry operation. Each of type of accident has shown various and interdependent factor that describe how the accident developed from contributory factor to the evacuation process. The model also made possible to review how human and equipment interact during the critical stage and later the model also identify the miss, lack and gaps within the process of accident.

Further analysis and extensive discussion to the outcome of the model conducted to properly presents the outcome of the models. Relatively not surprisingly that the outcome of the SEMOMAP model showing the human failure contribution to the overall mishaps and significantly contribute to the overall accident process. Certainly that the accident causation models utilised and developed under the dissertation are immature system, some areas also requires further development in order to achieve better utilisation and handier outcome.

Within the concluding chapter, the trend of safety issues in domestic ferry operation revealed and relevant recommendation are developed so it could be a reference for safety improvement in Domestic ferry operation.

KEYWORDS: Domestic RoPax Ferry, Safety issues, accident causation model,

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List of Abbreviations

ATSB	:	Australian Transport Safety Bureau
COLREGs	:	International Regulations for Preventing Collisions at Sea 1972
DGLT	:	Directorate General of Land Transportation
DGST	:	Directorate General of Sea Transportation
HFACS	:	Human Factors Analysis and Classification System
HRA	:	Human Reliability Analysis
IMO	:	International Maritime Organisation
MARPOL	:	International Convention for the Prevention of Pollution from Ships
NTSC	:	National Transportation Safety Committee, of Indonesia
Ro-ro	:	Roll On - Roll Off
RoPax	:	Ro-ro Passenger
SCM	:	James Reason's Swiss Cheese Model
SEMOMAP	:	SEquential MOdel of the Maritime Accident Process
SOLAS	:	International convention to safety of life at sea
STCW	:	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers
TRACEr	:	Technique for the Retrospective and predictive Analysis of Cognitive Error

1 Introduction

1.1 Background

Ro-ro ferries are considered the most successful maritime operation in the world from the perspective of service reliability, capacity carried and flexibility in operation (IMO, 2014). Ferry transport has been considered by stakeholders as a more affordable, timely service and reliable transport mode to transport passengers and goods between islands. Its capability to provide cost effectiveness and support other transport modes' operational efficiency has also led to the use of ferry transport to connect islands and create shortcuts to reduce distance and operation time.

Ferry operation has been utilised worldwide. For developed countries, ferries are considered as the safest form of transportation. Their safety record shows significant achievement. For developing countries, domestic ferries have been a major backbone for national economic activities. The common ferry type used in the developing world is the RoPax ferry. That is the typical ferry that provides space to carry passengers, vehicles and cargo at the same time.

In further detail, for archipelagic countries, domestic ferries play a significant role in the timely transhipment of large numbers of passengers. They also connect islands to provide access to commercial activity which, in the wider perspective, maintains national integrity.

The development of technology utilised in RoPax ferry operation allows the ships to operate as connecting bridges. RoPax Ferries are still considered as the most affordable transport means compared to actual bridges themselves. Therefore, their service needs to be fast, reliable, structurally robust and intact, and punctual in operation, while at the same time, providing a sufficient level of safety.

Despite its success story, ferry operation also contains a significant degree of operational risk. Due to the nature of operation, ferry disaster cases have the potential to result in catastrophic consequences. The cases of the Herald of Free Enterprise (UK, 1989), Estonia (Baltic Sea, 1992), Dona Paz (Philippine 1985), Al Salam

Boccaccio (Red sea, 2001), and Princess Ashika (Tonga, 2009) have raised public concern about the safety level of domestic ferry operation in developing countries. The international maritime community has also expressed its concern following continuous accidents involving domestic ferries despite the fact that improvements have been introduced to every aspect of their operation. In 2006, the International Maritime Organisation (IMO) along with the international ferry operators' community known as Interferry established a pilot project program to provide technical assistance to improve safety in developing countries' domestic ferry operations. The project took place in Bangladesh, which has been known for its disastrous ferry accidents.

Significant findings following investigations into ferry-involved cases have been provided to all ferry operation stakeholders. This was done to raise awareness of safety issues and as a reference to develop and improve the level of safety in shipboard operation. However, disastrous accidents continued to occur, as evidenced by the Sewol case in South Korea in early 2014. Obviously, despite improvements to safety following easy access to technological development, public interest and human involvement, there is always room for error that could lead a ferry operation to a catastrophic accident. In other words, there are factors that latently contribute but are ignored and later accumulate into a single catastrophic accident.

As an archipelagic country, Indonesia understands well the importance of maritime transport to support every aspect of the Nation's development. For Indonesia, domestic RoPax ferries play a significant role in maintaining the nations' integrity. The current system has been developed to connect its major islands and works as a transport hub for other transport modes. In the general perspective, domestic ferries connect islands and provide opportunities for regional development, hence supporting the national equality development program. In a more specific view, the transport system supports logistic distribution, and access to equalise economic development by providing low cost transport across the nation.

Since the ferry transport system was introduced, there have been fluctuations in its safety level as indicated by a number of incidents and mishaps. Accidents related to domestic ferry operation continue to occur. DGST data from 2003 to2013 indicates that nearly every year one or more ferry accidents occur with the consequence of a high number of fatalities, missing persons and serious injuries.

Systemic investigations into the related accidents have been conducted to determine contributing factors and reports have also been published to increase public and stakeholder awareness of the safety of domestic RoPax ferry operation. Investigation reports were made public with the objective of presenting the main factors causing the accidents. However, some of the reports did not sufficiently provide details on the factors that contributed directly and indirectly to the accidents. Some missing important information could be useful to present the facts pertaining to the current issues of ferry operation. To some extent, investigation reports themselves are considered insufficient to analyse and properly identify the factors contributing to accident/incidents. Therefore, additional analysis by adopting a sufficient accident causation model could enhance the outcome of the investigation and provide feedback to the investigation process itself (Wiegmann & Shappel, 2001).

It is necessary to identify and understand how the accidents developed starting from small operational and management issues that occurred in the past and contributed to the development of risk that resulted in the accident itself. The aspect of emergency response from both shipboard and shore based activities also plays an important role in determining whether the consequences of the incident could have been mitigated or whether the response resulted in greater loss.

To sum up, concerning the significant role of the domestic ferry in every aspect of the country's development, there should be greater awareness to improve the level of safety of its operation. However, there are still issues that might not be properly identified and result in the continuation of tragic accidents involving Indonesian domestic ferries. A thorough analysis of the previous mishaps in RoPax ferry operation by utilising proper assessment tools is deemed necessary. Following this reason, the writer has been motivated to conduct this study

1.2 Objectives

Following the background information mentioned above, the dissertation attempts to identify the current safety issues involved in the operation of domestic ro-ro passenger ferries in the Indonesian domestic ferry operation system. As a more specific goal, the dissertation provides related information with regard to safety issues involved in domestic ferry operation including, but not limited to, the following topics.

- To identify critical safety factors existing in domestic ferry accidents by developing and utilising an accident analysis model.
- To analyse the main safety issues that contribute to domestic ferry accidents
- To identify the adequacy and comprehensiveness of accident investigation reports to provide a reference for related parties to improve the investigation system in the future.
- To propose recommendations for related stakeholders to improve the safety of domestic ferry operation in Indonesia, and possibly internationally.

1.3 Scope of works and methodology

The dissertation does not attempt to present all related information on Indonesian domestic ferry operation issues. In order to sufficiently achieve the objectives stated above, the dissertation only focuses on analysing accidents involving domestic ferries operating in Indonesian waters, based on 16 RoPax ferry related accident investigation reports issued by the National Transportation Safety Committee (NTSC) during the period 2003 – 2013.

In addition, the dissertation covers the following:

- A literature review on domestic ropax ferry operation systems from a regulatory perspective to support domestic ferry operation, which will be cross referenced with relevant international resolutions, regional agreements, accident development processes, and concepts of safety analysis

- An exploration and review of accident causation models by utilising them in different cases
- An Identification and analysis of safety issues by utilising the SEMOMAP model on the selected investigation reports.

1.4 Structure and organisation

In order to accomplish the main goals of the dissertation, the structure has been arranged in the following order

Chapter I presents the background and main objective of the dissertation by briefly describing its general concept and methodology.

Chapter II is mainly focused on the literature review to present the general aspects of the domestic ferry operation system. It covers the rules and regulations for domestic ferry operation, the technology involved, and the operational pattern utilised.

Chapter III provides brief information on the current domestic Ro-ro ferry operation in Indonesia focusing on the development of policy, fleet status, transport productivity, operation pattern and recognised operational issues.

Chapter IV presents general concepts to identify safety issues in maritime transport. This covers the concept of accident development, discussion of the tools used to analyse accidents and introduction to the SEMOMAP as the main model used to analyse the safety issues in domestic ferry operation. The chapter discusses briefly the idea of accident analysis from the perspective of both a formal investigation method and an accident causation model. In addition, the chapter introduces the features of the SEMOMAP model by explaining its general concept and development, its operational workflow and terminology used in the model.

Chapter V provides an overview of the accident cases that are used in the model. The chapter also discusses and summarises the outcome of the SEMOMAP model to the cases used and analyses the outcome to determine the factors related to the operation of Indonesian Domestic RoPax ferries.

Chapter VI discuss and analyse the SEMOMAP outcome and provide comparison with other similar analysis results published by other institutions. Lastly, comments on the issues and improvements regarding utilisation of the model are presented.

Chapter VII presents a conclusion to the information and, based on the analysis of the issues involved in domestic RoPax ferry operation, recommendations are proposed.

2 Domestic Ferry Operation System

The chapter presents general information on the nature of ferry transport from the perspective of technology, operation, regulation development and common issues that take place in the operation of domestic RoPax ferries.

2.1 Past and present domestic ferry operation development

Recently, speed, reliability, safety, efficiency and environmental sustainability have been the major factors demanded by transport users. Considering the aforementioned requirements, ferry transport is the best solution since Ferry transport is able to provide shortcuts in terms of time and distance, as well as being flexible in operation and affordable.

Globally, there were about 1,162 units ferry ships with size more than 1000 GT, with a total capacity of 1.15 million passengers and car capacity of 226,210 or equal to 769,210 lane metres of commercial vehicles. Combined gross tonnage was 12.8 million and the average age of the fleet was 21 years. According to ShipPax data, in 2009, more than 2 billion passengers, 251 million cars, 32 million trailers were carried by ferries globally. Interferry database records show there were 1300 ferry ships above 1000 GRT operating globally (Interferry, 2014).

Ferry operation can be traced back historically by observing its service in ancient times. The first modernised ferry was built in 1849 when the Leviathan provided a connection for the railway line from Dundee to Aberdeen, UK (Marshall, 1989). The main reason for the development of the new transport system was that existing bridge technology was incapable of supporting rail traffic in the region. In addition, during its early application, the ferry system was renowned for providing short distance transport from port to port. It also opened access to movement and ease of commerce activity where centres were divided by waters. Later, following increased demand for higher capacity transport, the ferry system was also considered as support for other modes of transportation such as railways and land transport.

During World War II, typical ferry operations of landing ship tank (LST) were used to support the transhipment of troops, military vehicles and trains across European countries, the Mediterranean region, Greek islands and English Channel. During that time, ferry transport played a significant role as it was flexible and required no additional infrastructure such as port facilities or complex berthing operations. After the World War, the ferry transport system developed to continuously support and even accelerate the overall transport process, commercial activity and logistics supply.

In Europe, Ro-ros have also proved extremely popular in association with pleasure activities and for private car owners and have significantly contributed to the growth of tourism. Until the early 1950s someone wishing to take a car from one country to another by sea had to get it loaded into a ship's hold by crane, a time-consuming and expensive process. The development of the ro-ro car ferry changed all of that and many ports boomed as a result.

Today the world ro-ro fleet can be subdivided into a number of different types. They include ships designed to carry freight vehicles only, and those designed to carry a combination of containers and freight vehicles and to transport cars without passengers. There are various other types and freight-only Ro-ro ships form about two thirds of the world ro-ro fleet at present.

The term “domestic ferry” is strongly related to the type of operation and legal jurisdiction that applies to the ship. More specifically, for instance, under the Canadian system, the term “domestic ferry” defines a vessel that is entitled to fly the Canadian flag, carries passengers on a regular schedule and operates on a route set out in a schedule. Since the ship is operated within the State’s jurisdiction, local legal regulations apply to all aspects of its operation such as structure, registration, manning, operating route and other relevant regulations.

2.2 Technology, safety and operational patterns involved in Domestic Ferry operation

There are various types of ferries. According to the guidelines for ferry transportation service issued by the Transport Research Board of the USA, there are three ferry types, namely:

- Water Taxis: small watercraft that typically serve short cross-waterways or waterway circulation routes;
- Passenger Ferries: larger vessels that have higher passenger capacity and speeds than water taxis and typically serve short- to moderate-length routes; and
- Auto Ferries: also known as roll-on, roll-off ferries, these ferries transport vehicles as well as passengers. They are typically used on longer routes across major bodies of water and on low-volume rural roads crossing rivers.

The RoPax ferry is one type of ferry. The acronym ROPAX (roll-on/roll-off passenger) describes a RO-RO vessel built for freight vehicle transport along with passenger accommodation. Passenger ferries are larger vessels that have more passenger capacities and speeds than water taxis and that typically serve short to moderate-length routes. The RoPax ferry also has distinctive technology, safety system and operation pattern.

2.2.1 Ship structure

From the ship-structure perspective, a ferry ship has its own technical characteristics to support its operation pattern. For the purpose of carrying vehicles in an affordable number, the ship is designed to have a continuous deck over its entire length (Dokkum, 2012). A RoPax ferry can also be easily identified by its ramps, which are located either at its forward/after end and/or on its side. The ramps work as connecting means for vehicles from the port to the ship, unlike early ferries, which required massive and complex crane operation. However, from hull type and vessel dimensions point of view, ferry ships have adopted similar types of hull shape such as monohull, catamaran, hydrofoils, and any other hull form (Transit Cooperative Research Program, 2003).

In terms of propulsion installation, ship designers consider the functionality of the ferry. Therefore, most RoPax ferries have double ended structures to ease their operations when berthing. Each end is equipped with one or more propulsion systems. To ease its operation, propulsion types such as azimuth thrusters, and void Schneider, are also installed so the ship is easier to handle and manoeuvre (Dokkum, 2012).

According to its main function, a RoPax Ferry is required to have space to carry vehicles and or trains on board its deck. Roll-on/Roll-off shipping is usually reserved for larger cargo ships since it takes considerable space to deliver vehicles with this method and also requires enough vehicles to be moved at once for it to be financially feasible. The cardeck space can be an open space type or fully enclosed type. The selection of cardeck construction type depends on the route and type of operation. For example, a fully enclosed cardeck is designed for the ferry to protect its cars when it is transiting in open seas that have higher waves. Relevant to the function of the ramp door, all openings in the enclosed space deck should be watertight. The open space cardeck is normally for short distance ferries that are transiting coastal areas or engaging in short distance voyages.

The ferry cardeck, as its main cargo compartment, is measured by its carrying capacity in Line per Meter (LiM) (Dokkum, 2012). The cardeck is also specifically designed to support the weight of the vehicles and its cargo. Therefore, information on the details of the cargo and the vehicles is considered of importance for ferry operation.

Since it also carries passengers, the Ropax ferry ship provides accommodation space. The accommodation structure highly depends on the type, length, time and area of operation. For instance, short distance ferries only provide passenger space similar to waiting rooms; meanwhile, cruise-like ferries can provide comfortable cabins for passengers to stay in during lengthy operations.

2.2.2 Safety onboard ropax ferry

Since the ropax ferry ship is mixture like cargo (auto-carrier) vessel and passenger type ship, there are some parameters to indicate safety of its operation.

Stability

Stability is known as the main issue for ferry operation. The spacious and full length cardeck can create enormous effects when there are shifting cargoes or additional weight comes into effect such as from flooding. Flooding can create a stability phenomenon called free surface effect (FSE). The free surface effect worsens ship stability due to the large quantity of fluid moving to the direction in which the ship is heeling. The condition creates large heeling moment and resulted in a quick negative stability (reference).

There are a number of capsize cases indicating ferry vulnerability to FSE. Therefore, special regulations in SOLAS chapter II-1 on subdivision and damage stability were adopted to mitigate the issue. As general idea, the subdivision standard requires the ships to be able to survive if one watertight compartment is flooded.

In addition, the modern ro-ro ferry is installed with an anti-heeling system to allow water to automatically distribute between two opposing ballast tanks to keep the ship upright (Dokkum, 2012).

To prevent the flooding and reduce the risk of capsize, SOLAS requires all openings door/ramp door should be watertight. In addition, additional measures should be provided such as an inner door behind the bow door or visor to prevent water entering car deck - for example, through doors leading to other parts of the ship.

Following the higher possibility of the flooding, most of the Ro-ro ferries are installed with special drainage systems. For enclosed cardecks, SOLAS requires a system that allows drainage to be controlled by the crew from the bridge instead of operated directly in the engine room. On the other hand, an open space cardeck should be fitted with a sufficient number of scuppers to allow the water to freely discharge overboard.

Cargo securing system

Due to ship movement, unsecured or improperly secured vehicles onboard a ferry, could compromise ship stability and possibly damage other cargo. To secure the vehicle deck, there are securing points known as lashings that should comply with guidelines for Securing Arrangements for the Transport of Road Vehicles on Ro-Ro Ships under IMO resolution A.581 (14). The guidelines apply to Ro-Ro ships which carry road vehicles on either long or short international voyages in unsheltered waters and are applicable to: Road vehicles with an authorized total mass of vehicle and cargo between 3.5 and 40 t, Articulated road trains with an authorized total mass not more than 45 t.

Local rules such as Indonesian standard for minimum ferry service require certain space arrangements for cars to provide easy access for the crew during ship operations and emergency situations.

Fire protection

Ferry also considered vulnerable to fire accident. The level of complexity in fire was rising due to the cargo and passenger carried onboard.

In more specific, IMO adopted resolution A.327 (IX), concerning fire safety requirements for cargo ships. The resolution recommends the implementation of improved fire safety requirements in addition to those incorporated in SOLAS 60 and SOLAS 74 (which at that time had not entered into force).

In addition, SOLAS regulations specify the minimum protection for typical passenger ship to have levels of fire protection equivalent to machinery spaces (Transit Cooperative Research Program, 2003), that is:

- Must be limited by class A boundaries (in steel or equivalent material)
- Closed spaces to be protected by a fixed fire extinguishing system, typically CO2 in cargo ships and sprinklers (DeLuge system) in car ferries
- Smoke detection system
- Open cargo decks do not require a fixed fire extinguishing system
- Portable systems and hoses

Life saving appliance

RoPax ferries are also required to comply with standards for life saving appliances such as ensuring an adequate number of liferafts and lifejackets for crew and passengers that are ready to access during emergency situations. There are different applications of the requirement since some countries also developed non-SOLAS safety standard.

2.2.3 Berthing operation

The main idea of ferry terminal design is to provide access for passengers and vehicles to proceed from the ferry to access a mode of continued travel. The internal layout of international facilities should reflect this concern for the convenience of passengers and their vehicles by providing simple and direct passenger/vehicle flow routes through well designed facilities (Transit Cooperative Research Program, 2003).

The Transit Cooperative Research Program (2003) provides the general concept of the berthing operation for ferries. The vessel capacity of the berth, or loading area, is dependent upon two key components: the arrival service time and the departure service time. Arrival service time, given in seconds per vessel, is the sum of the vessel clearance time, plus the passenger disembarking time. Similarly, departure service time is the embarking time plus clearance time of the vessel to allow for other vessels to use the dock area. Disembarking and embarking time is a function of a number of factors, including passenger or auto demand, fare collection methods, and the design of the embarking and disembarking facilities, such as the dimensions of the gangways and walkways.

The vessel and loading design may also enable the embarking and disembarking times to be overlapped.

A. Passenger boarding operation

Passengers' travel time is the duration from leaving the origin to arrival at the destination. Design elements include docks, shelter, queuing areas, and fare collection. All of these elements should be arranged to provide safety and reliability and to reduce time as much as possible. For international ferry connections, some additional facilities such as custom clearance and immigration service might also be provided.

Above all, the main idea for a passenger manifest system in Ro-ro ferry operation is to identify the exact number of total passengers boarded. There should be sufficient identification since the ship is limited to a certain number passengers due to safety and comfort.

B. Vehicle loading operation

The process of vehicle loading and unloading is time consuming and hence demands proper loading facilities and circulation provisions at the terminal (Transit Cooperative Research Program, 2003).

To support its operation, some RoPax ferry ports are also equipped with specially built transport facilities known as movable bridges (MB). The MB can be adjusted to accommodate the tide of the water with the ship draught and allow vehicles easy access to and from its cargo deck. Docking configurations largely depend upon the vessel and the design parameters for capacity and overall travel time. Since there are no standard designs for ferry terminals (as there are standard highway designs), great care must be taken to configure terminals to work for the ferry system and the ferry vessels.

Bruzzone (2012) state that concerning safe and secure handling for the vehicle and its cargo loaded while they are transported onboard ferry, there should proper identification of the cargo and its weight. Therefore, the ferry terminal is ideally equipped with vehicle-cargo weighing facilities and cargo inspection facilities. The shipper is also required to provide detailed document declaration of its type and size. Hence, the ferry crew can set up proper handling for the concerned vehicles. For instance, reefer cargo is mostly not allowed to use its independent cooling system. Therefore, vehicles with reefer cargo should be located near an electrical power port provided onboard the ferry ship.

2.2.4 Operational pattern

In order to maintain its effective operation, some ferry operations are maintained on a daily basis. Most RoPax ferries are operated regularly under an assigned schedule. In some ferry ports, there is a strict time of port operation due to high berthing occupancy of the berth facilities.

Referring to operational patterns, ferry operation can be divided into the following types (Bruzzone, 2012):

- Direct connection to connect two ports and working similarly to a floating bridge.
- Multiple connections system: developed to connect more than two points of call within a group of islands.
- Coastal and shortcut ferry: coastal ferry established to provide access and short cut of two points within the coastal region that its access is blocked by different condition.

In addition, in terms of its service, a ferry can be also categorized into the following (Transit Cooperative Research Program, 2003):

- Transit (no vehicle access):
  - Ferry Urban consisting of scheduled service between points within a city or metropolitan area.
  - Ferry Intercity consisting of scheduled service between metropolitan areas.
- Highway
  - Ferry Essential consisting of scheduled service between points outside a metropolitan area or between metropolitan areas and providing vehicle access almost always in areas without direct roadway access.

2.3 Development of rules and regulations for domestic RoPax ferry operation

RoPax ferries are not subject to exemption from any regulations. In fact there are stricter regulations since they carry passengers and possibly dangerous cargo in addition to vehicles. Similarly, almost all regulations to improve the safety and effectiveness of Ro-ro transport are derived from near misses, incidents, and accidents in the past. For instance, the development of the international safety management (ISM) code was strongly attributed to the Herald of Free Enterprise accident.

In general, shipping regulations should includes technical design, construction parametric, repair, operations standard and system, standard for manning, training, environmental impact, security and regular inspections throughout a vessel's life. Adequate and thorough inspections should examine deeply the stability information, hulls condition, propulsion system and performance, states of other machinery, electrical systems, lifesaving appliances and arrangements, fire prevention and fire fighting systems, navigation systems and communications systems (Interferry, 2014)

The IMO conference in 1995 adopted numbers of amendments to SOLAS, based on proposition by member states and highlighted by the Panel of Experts on the safety of roll on – roll off passenger ships.

The most significant changes relate to the stability of ro-ro passenger ships stipulated in Chapter II-1 of the convention. The SOLAS 90 related to damage stability standard was extended to existing ships in accordance with an agreed phase-in programme.

A new regulation 8-2 was adopted under the convention during the conference. It contained special standard for ro-ro passenger ships carrying 400 passengers or more. This main objective of the additional regulation is to scrap ships built to a single compartment standard and ensure the concept of two main compartments so the ship can survive without capsizing when flooded following damage occurred.

Amendments also included changes to Chapter III, which related with life saving appliances and arrangements, including the addition regulation that requiring ro-ro passenger ships to be equipped with public address (PA) mechanism.

Other amendments were also made to Chapter IV on the radio communications; Chapter V on the safety of navigation that also including a special requirement that all ro-ro passenger ships should have an established working language - and Chapter

VI on carriage of cargoes. The IMO conference 1995 also adopted a resolution which permits regional arrangements to be made on special safety requirements for ro-ro passenger ships.

It is obvious that SOLAS, MARPOL, STCW and other international convention requirements should be fully satisfied and complied with by typical passenger ships as well as RoPax ferries that engage in international voyages. However, since most domestic ferries operate within inland waterways and/or coastal service, international regulation implementation is limited but does not prevent the shipowner or the ship operator from applying it.

For most domestic ferry operations in developing countries, financial constraints are the main issue for RoPax ferry operators to comply fully with SOLAS requirements. Therefore, to provide legal protection and ensure safety is maintained at a satisfactory level, most State maritime administrations have developed a standard operating procedure that is equal to international conventions or depends on the policy of the country itself. The typical regulation is commonly referred to as non-convention vessel standard or regulation. Therefore, following the conditions, stipulated standards for ferry operation can be different from country to country.

For instance, following the tragic accident of Estonia in 1994, the EU developed a comprehensive policy for regional ferry transport by issuing the Council Directive 98/18/EC dated 17 March 1998 on safety rules and standards for passenger ships as amended by Directive 2003/24/EC dated 14 April 2003. The rules apply to domestic and inland water way transport that also includes passenger ferry transport in the European region.

In the United States, U.S. Coast Guard approval is always required for the operation of for-hire passenger vessels. The Code of Federal Regulations (CFR) Title 46 contains regulatory requirements applicable to the design, construction, and operation of ferries operating in U.S. waters.

Other regions, under IMO technical assistance support, are encouraged to develop local rules on domestic ferry operation. Indonesia Government issued standard for

Non-Convention vessels in 2009. The standard was developed under joint cooperation between Directorate General of Sea Transportation and Australian Maritime Safety Authority. The standard is considered sufficient to provide alternative for Non-Convention vessel flying Indonesia Flag in complying the level of safety based on the capability of local operators.

2.4 Typical domestic RoPax ferry operation issues

2.4.1 Policy and operational issues

Lawson and Weisbrod (2005) stated that ferry transport is a key element of economic development for many nations due to their main reliance on ferries for the transport of people and goods—hence the critical importance of ferries also goes for jobs opportunity and as a catalyst of national economic growth (Lawson & Weisbrod, 2005). Lawson and Weisbrod also mentioned that the nations where high rates of fatality incident occur, ferry transport is indispensable to the lives of the local social community. Ferry transport main developed based on the geographic features, such as nations with island archipelagos, unbridgeable straits, riverine deltas, poor road transport, or a combination of these geographic features. Concerning the importance of ferry transportation as the basis of economic development, the lack of safety is economically devastating.

The fire onboard Egyptian flag passenger ferry El Salam Boccaccio 98 in the Red Sea in February 2006 indicated insufficient maintenance, out dated technology for onboard emergency response and insufficient crew capability during emergency situation strongly contributed to the large number of casualties. On the other side, unavailability of shore based emergency response also proved to allow the severer consequence of a large number of fatalities.

The investigation into the Capsize of Princess Ashika off Tonga in 2009 also indicated a lack of shore-based influence to overall safety contributed significantly to the accident. In addition, improper maintenance and lack of safety regulations were also found to contribute to the accident (TAIC, 2010).

There are numerous studies on accidents involving domestic RoPax ferries in developing countries. Following the studies, it is possible to find commonalities among the cases. In their research, Dalziel et.al (2012) identified the repeated causes of ferry incidents: (Dalziel & Weisbrod, 2013):

- Overloading
- Inadequate Vessel Design and Maintenance
- Sudden Hazardous Weather
- Human Error
- Lack of communication (alerting/location)
- Inadequate rescue response

Due to the distinct operation of RoPax ferries, from a shore based operation perspective, OSHA of the United States identified several factors that contribute to injuries and damage to property, including (OSHA, 2010):

- Lack of training
- Lack of awareness
- Fatigue
- Inattention
- Inadequate traffic controls
- Lack of training
- Lack of awareness
- Fatigue
- Inattention
- Inadequate traffic controls

In addition, following a thorough examination of a number of ferry accidents in different regions, Lawson et.al (2009) discussed a common approach to identify safety issues in ferry operations for developing countries. This was done in two main aspects of prevention and response, and post-event responsibilities for ferry safety in developing countries. The prevention and response focused on the regulatory approach, vessel design related to its fitness, and sufficiency in standard operating and emergency response procedures that cover both shipboard operation and shore based response (Table 2-1).

Table 2-1: prevention and response for ferry safety in developing countries. Source: Lawson & Weisbrod, 2005.

Function	*Issues/Area of Inquiry*
Prevention	
Regulatory Approach	Are the regulations adequate to the conditions? How does the rule making take place? How are rules communicated? How are regulations enforced? Is there any oversight in the implementation of the regulations?
Vessel Design	Are vessels designed properly for their purpose? What proportion of the fleet of vessels is certified? Are there penalties/obstacles for certification? Are these noncertified vessels long-after, after-market vessels? Are there penalties for noncertification? Is there a difference with respect to accident rates for long-after, after-market vessels? What and how rigorous is the certification process? What is the relationship between ferry fatalities and vessel certification? Are the vessels inappropriate or inadequately maintained and/or improperly operated?
Operational Standard	What is the accident record differential between certified/noncertified vessels with respect to operating standards? What is the accident record differential between vessels that are publicly or privately owned? Are there differences with respect to routes and type of service between public and private operations? How can registration/certification be encouraged by the industry, local government, or citizens groups?
Response	What type of training and drills are available for private or public crews? Is there a relationship between the record of training and drills and ferry fatalities? Is there a formal system in place for search and rescues? Have "safe havens" been identified in event of major storm and/or vessel damage?

Under post event responsibilities, the issues mainly relate to the reactive actions of related parties, including the investigation of the accident, documentation and records of the event, imposed penalties for any violation that resulted in the accident, and post incident victim support such as insurance support and compensation (Table 2-2).

Table 2-2: Post event responsibilities for States operating domestic ferry Source: Lawson & Weisbrod, 2005.

Function	*Issues/Area of Inquiry*
Investigation	What agency investigates ferry accidents? How are involved parties informed of results? Are accident investigation reports disseminated in a timely and well-publicized fashion so that operators and regulators can learn from them?
Documentation of accidents	Where, who, how and what if there isn't any? Is there an active press to track and continually publicize incidents and the role of government and industry in implementing safe conditions on ferries?
Sanctions	What is the record of sanctions to those who violate the safety rules? Consider that the innate sanction of loss of asset for owners is not a feedback mechanism because the vessel is already depreciated. What would be effective?
Insurance	Do vessels need to have insurance to operate legally? Is insurance available? Are liability coverage provisions enforced?
Victim support	Are victims given compensation, through an insurance system, which would have the effect of discouraging reckless behavior?

Obviously the issues of ferry safety in the developing world will remain if there are no proper actions taken by all parties. The international maritime and ferry communities are required to stand ready to offer their assistance and capacity-building know-how.

During a regional forum on domestic ferry safety held in Bali Indonesia on 6-7 December 2011, issues that take place in ferry operation were discussed. This was mainly focused on lack of enforcement, insufficient regulation, administration monitoring of fleet operation, lack of safety management and non-existence of a safety culture in every aspect of ferry operation (IMO, 2011).

2.4.2 RoPax safety issues from a technological perspective

From a technological perspective, IMO has identified significant issues based on an analysis of ferry mishap data (IMO, 2014).

1. The lack of internal bulkheads

The hull was divided into some watertight compartments so when one of the compartment breached, the ship will remain afloat. The watertight bulkheads structure will stop or delay the flooding, providing sufficient time for evacuation of the passengers and crew. Where the structure considered intact, it will stop ship to capsize at all. The main problem with Ro-ros is the length and spacious cardeck that nearly impossible to install internal bulkhead mainly due to operational reason. The huge vehicle decks make it possible for water to enter very rapidly and fire can also spread very quickly for the same reason.

2. Cargo access doors

Rampdoor considered as the weak point due to number of capsize accident the seawater inrushes from non watertight door. During the cargo operation, such doors can also be damaged or twisted.

3. Stability

Ro-ro stability has been studied since it is found too vulnerable with such condition such as movement of cargo on the vehicle deck. The sudden and rapid inrush of water following damage to the hull or failure of watertight doors can be even more serious. Lack of condition of freeing port can also be a significant factor to ship stability as it allows water accumulated in the spacious cardeck. In addition, larger upper water superstructure means that the ship can also be more influenced by wind and bad weather.

4. Low freeboards

To ease the vehicle loading operation, cargo access doors fitted on cargo-only ro-ros are normally designed close to the waterline. The issues appear when the ship was loaded in maximum or having excessive trim by stern or even waves which could result in a sudden inrush of water (if the door is open or the structure was not watertight). Subsequently, the condition could result in the list increasing and a possible capsizing of the ship.

5. Cargo stowage and securing

When the ship experience excessive heel angle, the cargo inside can easily shifted and break loose if it is not correctly stowed and secured. The tight operation schedule urge the ship crew to commenced the securing in timely manner. Proper securing equipments are required to support this condition. Tight arrangement of the vehicle should be highly considered to provide sufficient access to the ship crew when emergency situation developed such as fire or spillage dangerous cargo from the tipped over vehicle.

6. Life-saving appliances

The high structure of the ro-ros, including passenger ships, could create serious issues regarding LSA: as the life boat stowed higher, it can be difficult to launch, especially if the ship is heeling badly.

7. The crew

The tight schedule, monotonous and typical operation can affect the crew. The typical ship regular and scheduled operation in certain conditions allows the ship not to be manned with sufficient number of crew. However, the factors referred to above indicate that ro-ros are highly sophisticated ships which require very careful handling. The situation makes the ship exceptionally vulnerable to human error.

2.5 Conclusion

To summarise, ferry transport is considered as the most successful maritime transport due to its flexibility, punctuality, and ease to connect with other transport modes. Due to its nature of operation, domestic ferry regulation has been developed in a stricter way.

For developed countries, ferry transport has achieved a sufficient level of safety following its operational, technological and regulatory improvements. However, studies have identified that there are safety areas in need of consideration for ferry operation in developing countries.

The international community has expressed its concern by providing assistance and technical support to the concerned ferry transport stakeholders in developing countries.

3 Indonesian domestic RoPax ferry operation

The following chapter provides an overview of Indonesian domestic RoPax ferry operation including its historical development, statistical activity data, current fleet condition, current policy and general overview of challenges that currently exist.

3.1 Indonesian policy and regulation on Domestic RoPax ferry transport

For archipelagic countries, maritime transport plays a significant role in all aspects of the Nation's development. It provides connection and open access to all parts of the country. Since Indonesia's policy and concept of the oceans is not to divide the nation but to connect all islands, maritime transport is considered as the keeper of National integrity and the main support for the economic equality development program. In addition, maritime transport in Indonesia provides the opportunity to reach 5000 inhabited remote islands spread across the country.

The Ro-ro is considered the most appropriate transport mode for Indonesia since it provides flexibility, low fare, and affordable technology. The Ro-ro can also access inland waters that require low draft ships. On the other hand, coastal ferries in some areas in Indonesia also play a significant role in saving time and increasing regional interconnectivity.

3.1.1 Indonesia domestic ferry policy

The history records that during the end of the Dutch colonising era in the early 1900s, the first modernised ferry port in Indonesia was established to connect the railway line from Merak Port of Java Island to Bakauheni port of the southern part of Sumatera island (Rizal, 2011). Later, following increased traffic and vast development across the country, the ferry service shifted from only being a connection to rail transport to focusing on the transport of passengers and connecting other land transport modes.

The Indonesian government considers Ro-ro transport as an integral part of the road transport network. It provides opportunities to enhance the overall reliability of transport services since it is capable of connecting all islands. Thus, it supports national social and economic activity (DGLT, 2005).

According to the long term development plan issued by the ministry of Transportation of Indonesia, the nation's ferry transport policy mainly focuses on to the following agenda (MoT, 2008):

- Development for mass transport
- Connection between islands, working similarly to a bridge
- Even growth and distribution of regional development and reduction of cost disparity
- Support for national logistic distribution
- Maintenance of national political and social stability; even further, avoidance of national social gap and disintegration.

In addition, the Indonesian Shipping Act no. 17/2008 and Government Decree no. 22/2010 on water transportation stipulated clearly the main function of ferry transport:

- Ferry transport is a floating bridge that connects road transport and railway transport systems that have been divided by water to transport passengers and vehicles and their cargo.
- Ferry transport development is also directed to open and provide access to remote and under developed inhabited islands. Future plans also attempt to provide alternatives to saturated road transport.

To interpret the policy stated in the act, the Ministry of Transportation developed a national blueprint for ferry transportation in 2009. The blueprint comprises the stages of a plan for improving ferry transport services. This focused on three main strategies:

- Revitalisation of the existing ferry service focused on the port facility and fleet retrofits.

- Optimisation and capacity improvement of existing commercial ferry lanes including improvement to the capacity of ferry service based on the growth of transport demand for passengers, vehicle and cargo transport
- Development of new ferry service to connect remote islands

3.1.2 Indonesia domestic ferry route network

According to the national blueprint for ferry transport in Indonesia, ferry lanes are considered to integrate with other land transport systems and attempt to provide connections to every island in Indonesia. Therefore, the Indonesian government decided to focus the operation of the ferry lane into three main lanes known as North, Middle and South Belt (Figure 3-1).

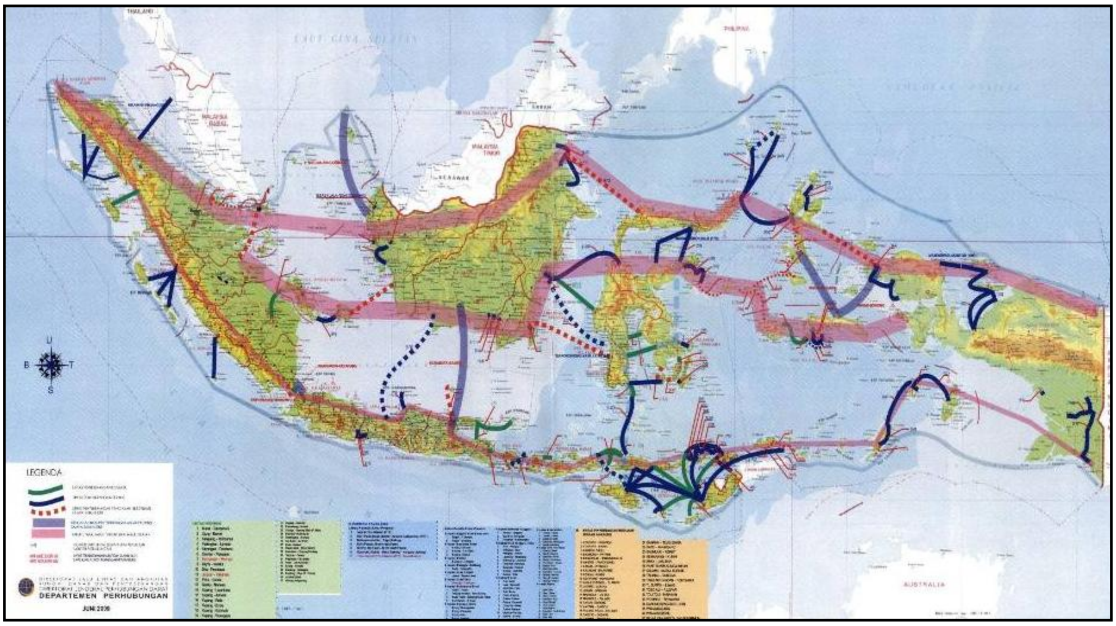


Figure 3-1: Indonesian domestic ferry transport lane system. Map obtained from DGST. Copyright 2009. Reprinted with permission

The north belt connects the road transport system of the northern part of Sumatera Island to the road transport system in the northern part of Kalimantan, North of Sulawesi and links the road transport network to the northern part of Papua Island. The middle belt provides connections for the road transport network from and to the middle part of Sumatera Island, Bangka Belitung, south to east coast road transport network of Kalimantan island, centre of Sulawesi, Seram Island and the west part of Papua. The South belt provides connections from and to Sumatera interstate highway network, Java island road network, Nusa Tenggara (lesser Sunda) islands, and the southern part of Papua province.

To integrate the three main belts and enhance transport network connectivity, the government also set up inter-connections through the long voyage ferry service.

In accordance with the Indonesian maritime transport policy stated above, the government continuously maintains ferry services throughout the country. According to the land transportation statistical data, there are a total of 217 ferry lanes across the country that are comprised of 48 commercial lanes and 169 lanes under the subsidiary of local municipalities or under the management of the central government as part of a pioneer service program. In terms of distance, the longest ferry lane covers 530 Nm (DGLT, 2014).

The ferry routes are serviced by 258 units RoPax ferry and 15 pioneer ships with total loading capacity of 50,460 passengers and 6,885 vehicles. Among the RoPax ferry numbers only 11% are owned and managed by the ferry authority and 88% of the total fleet is owned and operated by the private sector (DGLT, 2014).

To support ferry operation, in 2013, the Indonesian Government built 210 ferry ports across the nation. In detail, there were 34 ferry ports operated under the management of the state owned company, Indonesian Ferry, through a public-private partnership system, and 4 ports established under direct management of the directorate general of land transportation, via public service. In addition, the central government also supports local municipalities to operate 106 ports under a subsidiary support system, and in the meantime, there were another 66 ports in the process of construction (DGLT, 2014).

3.2 Indonesian RoPax ferry operation information

3.2.1 Productivity

With regard to transport productivity, Indonesia domestic ferry transport has achieved a significant outcome. In 2013, the domestic RoPax ferry transported a total of 62,036,587 passengers. The total transported passengers indicate a significant increment of 20% compared to the previous year of 2012, during which 58,673,855 passengers were transported (DGLT, 2014).

For 2013, the transport productivity data also indicates a significant increment. There were 7,713,925 motor cycle units transported by national ferry services. Compared to 2012, the number represents an increase of about 15%. The total number of vehicles transported also increased. In 2013, there were 7,443,459 units of different types of vehicle transported by ferry service. Vehicle transport activity increased by 30% in 2013 compared to data from 2012,

Table 3-1 presents the five busiest ferry services in Indonesia. In terms of passengers and cargo transported, the Merak-Bakauheni ferry lane is the most productive ferry service with 15 million passengers and 3 million vehicles transported. In terms of the number of trips, Ketapang – Gilimanuk ferry service is the busiest ferry service with 119,670 trips in 2013.

Table 3-1: Top 5 ferry lane productivity data in Indonesia year 2013. Data obtained from DGLT copyright 2014

Ferry lane	Trip	Pax	Motor	Vehicle
Merak - Bakauheni	63,680	18,597,804	587,873	3,317,524
Ketapang – Gilimanuk	167,230	14,204,920	1,431,310	2,204,577
Ujung - Kamal	34,245	6,620,924	1,561,671	199,179
Padangbai - Lembar	19,978	2,065,308	260,707	306,646
Kayangan - Pototano	25,301	2,636,174	324,725	295,874
Total	**310,434**	**44,125,130**	**4,166,286**	**6,323,800**

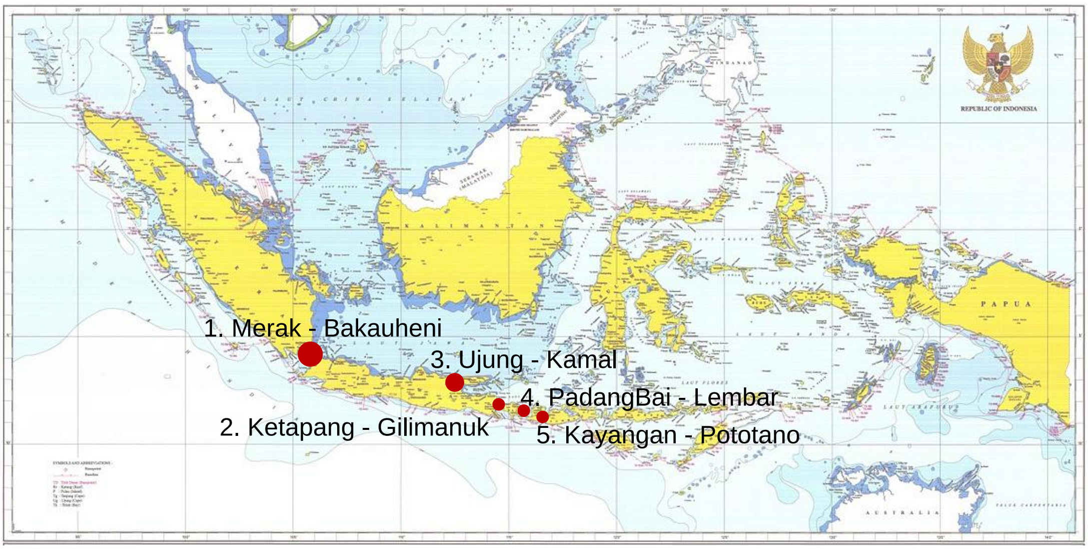


Figure 3-2: The top 5 busiest ferry service in Indonesia year 2013. Data DGLT copyright @2014. Reprinted with permission

3.2.2 Minimum standard for domestic ferry service

In order to standardise ferry operation, the government had issued standard operation for ferry transport service in Indonesia under Director General of Land Transportation decree no 73/AP005/DRJD2003 year 2003. This covers passenger service, vehicle loading operation, transit service and standard for schedule accomplishment.

The main features of the above standards are detailed as follows (DGLT, 2003):

- Ship service speed standard
  - Minimum service speed for economy class should be not less than 10 knots
  - Minimum service speed for non-economy class should be not less than 15 knots
  - Ship speed for short distance ferry route or less than 6 nautical miles can be adjusted accordingly
- Vehicle loading standards and procedure:
  - Maximum weight for the vehicle and its cargo shall not exceed 17.5 tonnes
  - Thus cardeck spaces shall also be constructed accordingly to withstand the above mentioned weight limit.

- The highest stack shall not exceed 2.5 metres for small cars, 3.8 metres for small lorries and 4.7 metres for container carrier lorries.
- The shortest distance between vehicles on the cardeck shall not exceed 60 cm for side end and 30 cm for both forward and after end.
- Securing lines for vehicles are required for ferries that transit routes with a probability of ship inclination up to 10 deg due to local sea state.
- The driver and passengers are not allowed to stay inside the car during the voyage. Open fire activity as such smoking is prohibited on the car deck. Any kind of machinery onboard vehicles shall be kept on while the ship is underway.

Director General of Land Transportation Decree no. 2681AP.005/DRJD/2006 regulates berth operation for ferry. The standard requires the ferry port operation divided into four main parts that is:

- Approaching time (15 minutes started from approaching area)
- Cargo operation time that divided into two Unloading time and Loading time (30 minutes)
- Departure preparation (15 minutes)

All the ship operators require to observed port operation time. This was developed to improve the port productivity and maintain the ferry operation schedule.

3.3 Identified challenges in Indonesian domestic ferry operation

As a typical developing country, Indonesia faces many challenges in its domestic ferry operation

3.3.1 Fleet condition

Domestic RoPax ferries in Indonesia are old. Data from DGLT (2014) indicates that the age of the ships varies from 1 year to 50 years. More than50% of the national ferry fleet is over 25 years old, whereas only 5% is under 5 years. To some extent, this condition could affect the efficiency of the overall operation. An older ship requires costly operation and longer time for maintenance. The lengthy time for maintenance also affects the ferry operation schedule. On some occasion, exemptions to the ferry conditions were issued by the relevant authority to the ferry ships, with the objective of fulfilling the transport demand during high peaks. Obviously this condition could increase the risk of operation since the maintenance schedule was not followed properly.

Indonesian ferry operation time is low. The average speed of operation was 8-9 knots. This condition does not comply with the ferry operation standard as mentioned above. Among the registered vessels, the highest speed RoPax ferry was only 15 knots and the lowest was 4 knots. This great disparity of speed has also influenced overall ferry service operation. For instance, the difference in speed could create congestion of ferry traffic in the waiting areas since they have to wait for slower ferries to be berthed by the port controller (NTSC, Investigation report into collision between Singapore registered gas carrier MV. Norgas Cathinka with Indonesia registered ropax ferry MV. Bahuga Jaya at Sunda Strait on 26 September 2012, 2013).

The Indonesian government has also attempted to revitalise the ferry fleet by ordering new ships annually (DGLT, 2005). However, since the newly built ships are only operated by the state owned Ferry Company the project will take time to sufficiently support the entire ferry fleet, considering the large coverage area and number of the ferry routes. In addition, the capacity of the private sector to acquire brand new vessels is limited. As a result, the private sector will continuously operate old ships as second hand priced ships are cheaper.

3.3.2 Effect of climate change in ferry operation

It is commonly known that tropical regions are facing issues of climate change more than other regions. One of the significant effects is change to sea state. Indonesian waters used to be relatively calm. However, recently storms have frequently approached and created significant sea states. The condition has caused rising concern for ferry operators and has affected the schedule. For instance, ferry authorities occasionally stop all ferry operations due to heavy weather.

Relevant to this issue, Indonesian ferry operation has also been affected by this situation. Data from DGLT indicates that most of the ferries servicing the long distance ferry routes are built with open space cardecks. Specifically, there is an issue when the sea state worsens, and the probability of seawater entering the cargo space is higher. This condition requires higher attention from ferry operators to conduct thorough inspections of the ships' structure, particularly of the stability related constructions such as bulkheads, scuppers and cargo securing systems.

The other issue relevant to the weather change is related to the suitability of the ferry design. Indonesian ferry fleet data indicates that most of the ferries operated were bought from Japan (DGLT, 2014). In Japan, the ferries serve ferry routes that are limited to the inner waterways or coastal ferries. This translates to the ferries being designed to operate in calm waters with a wave height not higher than 1.5 m.

3.3.3 Opening new ferry service

Until 2013, of the total ferry service lanes proposed in the national blue print for ferry transportation, there were still 29 ferry routes that were not yet fully operational. This condition occurred due to a lack of private sector interest in operating ferry routes. On the other hand, the government is still attempting to optimise the existing routes as its main priority.

The issues affect the sufficiency of the nation's fleet to accommodate transport demand. Compared to the transport demand across the country, the ferry port facilities are considered insufficient. The government has been limited by budget constraints to continuously provide proper infrastructure for ferry operation. (Alimoeso, 2009)

On the other hand, low maintenance is the major problem for ferry port facilities in Indonesia. Financial support mostly contributes to this condition. Some terminals do not have sufficient capacity to provide comfort of service to transport users.

3.3.4 Low tariff and competition with other transport modes

Indonesian ferry tariffs are low compared to similar ferry operations in the South East Asian region (Haryo, 2013).Haryo implies that from the consumer perspective, the government is concerned with the purchase power of the transport user. However, the local ferry operator needs to smartly manage the company to improve the quality of service with its current income state.

Current ferry transportation development implies that there is clear competition between ferry operators and road and air transport. For instance, there was a significant decrease in ferry productivity due to the establishment of a connecting bridge on the Ujung – Kamal ferry route (DGLT, 2014).

3.4 Conclusion

To summarise, domestic ferry transport plays a significant role in the nation's development effort. Taking the example of typical ferry operation in a developing country, ferry transport in Indonesia does not just provide safe, fast, comfortable, and environmentally friendly transport for the user, but it is also utilised and developed to maintain national integrity, thus providing opportunities for national development equality. Challenges as indicated above should be overcome to improve overall ferry performance such as safety itself.

Despite the success story of its productivity, statistical data shows that accidents and mishaps involving domestic RoPax ferries continue to occur despite some improvements and developments in every aspect of operation. NTSC maritime accident and incident data 2003 – 2013 indicates that very serious ferry accident occurred nearly every year. Most of the accidents have resulted in severe consequences, including loss of life and damage to property. Therefore, there should be a proper analysis to sufficiently identify the safety issues involved in its operation.

4 Assessing safety issues in domestic RoPax ferry operation

4.1 Overview

Safety has always been considered the main critical feature in domestic RoPax ferry operation. As described above, due to the nature of its operation, gaps and deficiencies in operation could lead to severe and catastrophic consequences. Safety systems are developed to prevent injury or loss of human life, damage to property and adverse consequences to the environment (Qureshi, 2008).

Maintaining the safety level in domestic ferry operation can be done in many ways but the main focus is on two factors: Preventive action and Reactive action. Preventive action is mostly related to any activity to mitigate risk involved in ship board operation such as design, procedure, inspection or any other hazard control method. On the other side, reactive action is any activity taken to reduce the severity of an accident by conducting investigations, search and rescue, or imposed penalties. Preventive action is critical to mitigate the risk of an incident developing into a greater harmful event. However, accidents themselves have proven that there are gaps in the safety system which are known as safety issues.

ATSB defines safety issues as safety factors that:

(a) can reasonably be regarded as having the potential to adversely affect the safety of future operations, and

(b) are a characteristic of an organisation or a system, rather than a characteristic of a specific individual, or characteristic of an operational environment at a specific point in time.

Safety issues in a maritime operation can be identified by analysing the previous mishaps and incidents/accidents. This can be done by analysing the statistical data, developing an accident causation model and investigating the mishaps. As a result, important information related to the causal factors can be unveiled to the interested parties to improve overall shipboard safety performance. On the other hand, it can also provide feedback to the designer (policy, procedure, tools) to stimulate validation and refinement of the system (Vassalos, et al., 2003).

To a further extent, Vassalos et al (2003) explains that the result of an analysis of safety issues in an accident also “pulls” together not only developing and updating the knowledge of accident model analysis tools but also provides comprehensive information on gaps in assessment of structural safety, survivability, passenger evacuation, seaworthiness and fire safety.

This chapter presents the systematic methodology utilised in this dissertation with the main objective of identifying safety issues in domestic RoPax ferry operation. Proper justification for the use of the SEMOMAP model is briefly explained by presenting the main concept, system workflow, methodology, and comparison with other models widely used for analysis of safety in the maritime field.

4.2 Concept of maritime transport accident/incident and need of investigation

The disaster of the Herald of Free Enterprise and many others Ro-ro passenger ship accidents remind maritime stakeholders how these accident bring great loss of life and damage to property and the environment.

Heinrich (1931) defined “accident” as a result of a chain of several undesired events, whilst the seriousness of the accident is a compound set of technical failures, operating errors, fundamental design errors, and management errors. The removal of any contributing links, or causes, may be sufficient to prevent accidents. This idea is considered as the basic concept for systemic investigation.

An accident is mostly a complex system that occurs through the accumulation of factors and failures. Reason (1999) in his accident model suggests that adverse events occur when multiple contributors, considered weaknesses in the established safety defence, align. Hollnagel (1998) emphasises the failure of barriers that are set up to prevent risk being carried out or a harmful event from taking place characterise the accident itself.

It is understood that even a small mishap should not be accepted in maritime operation. However, in the safety concern, an accident or incident is a learning opportunity to improve safety in maritime transportation.

4.2.1 Investigation into maritime casualty

Investigation into maritime casualties serves several purposes depending on the institution that conducts the investigation namely civil, criminal, administrative, or other.

Investigation into accidents/incidents is a natural approach to analyse the weaknesses or gaps in the overall transportation performance that led to the accidents. Traditionally, most accident investigations focused on the question of “who” instead of asking “how” and “why”. This condition derived from the public desire to simply blame and assign liability to a person or institution, thus considering the case concluded.

Investigations adopt a retrospective concept that can identify the gaps that led to the event, unlike during the design or development stage. The designer or policy maker can only foresee the likelihood of risk in the operation and fails to entirely identify weaknesses in their design or policy. Proper and comprehensive investigation looks into the development of an event and attempts to analyse its causal factors.

In terms of safety improvement, an investigation into a maritime casualty could be used to enhance safety by determining what happened, how it happened and why it happened. In addition, the information gained from the process of investigation can be used to improve safety of transport operation in view of (ATSB, 2008):

- Identifying safety issues that could adversely affect the safety of future operations, and encouraging or facilitating safety action by relevant organisations to address these issues.
- Providing information about the circumstances of the occurrence, and the factors involved in the development of the occurrence, to the transportation industry.

- Providing information for an occurrence database, which can then be combined with information from other occurrences and used for research and trend analysis purposes.

Under the international maritime regime, investigation is a key process to maintain and improve maritime safety performance. Investigation into casualty matters has been sufficiently described in the IMO's four pillars of SOLAS, MARPOL, STCW and MLC.

The International Maritime Organisation (IMO) under SOLAS has made casualty investigations mandatory by adopting IMO Resolution MSC. 255 (84) on the adoption of the code of the international standards and recommended practices for a safety investigation into a marine casualty or marine incident. The Amendment of SOLAS outlines a code for the investigation of marine casualties and incidents in an annex to Resolution A.849 (20) (27 November 1997). This document states the following:

> "The objective of any marine casualty investigation is to prevent similar casualties in the future. Investigations identify the circumstances of the casualty under investigation and establish the causes and contributing factors, by gathering and analysing information and drawing conclusions. Ideally, it is not the purpose of such investigations to determine liability, or apportion blame. However, the investigating authority should not refrain from fully reporting the causes because fault or liability may be inferred from its findings".

The code attempts to provide a common approach for member States to conduct safety investigations into marine casualties. The code mainly focuses on standard reporting, evidence collection, coordination and cooperation among different substantial interested States.

However, there are cases when an investigation itself is unable to provide comprehensive information; nonetheless, a systemic formal investigation is thoroughly conducted. Some examples show that an investigation report itself serves only to satisfy the public's hasty demand.

Wiegmann et.al (2002) discussed the cycle of the investigation process and how prevention efforts fail to stop accidents from occurring again. The outcome of the analysis underlined that each of the factors involved in the cycle is insufficient and incomprehensive in terms of providing information for the improvement of safety. Thus, any intervention or prevention program as a result of an accident analysis is considered insufficient. For instance, most accident investigations tend to focus on determining what happened instead of why it happened and are not supported by sufficient procedures. Insufficient database systems and lack of analysis of the data also take part in the ineffective prevention program (Wiegmann & Shappel, 2001).

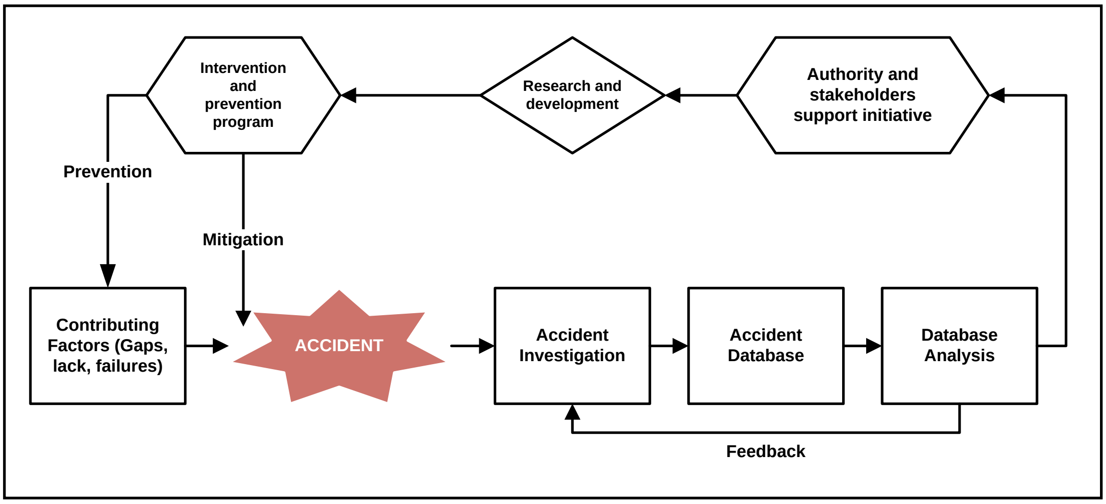


Figure 4-1: General process of investigation and preventing accident. The chart reproduced and adapted from a human error analysis of commercial aviation accidents using the human factors analysis and classification system by Wiegmann and Shappel. Copyright 2001

ATSB in 2008 conducted close scrutiny of the outcome of its investigation reports. The outcome of the analysis indicated that the method of analysis has been a neglected area in terms of standards, guidance and training of investigators in most organisations that conduct safety investigations, despite its importance, complexity, and reliance on investigators' judgements. The analysis results also pointed out that many investigators primarily used their experience and intuition in conducting analyses, which is not based on, or guided by, a structured process. Other issues appeared to be related to the limited time available for producing reports, meaning that the analysis process is normally conducted while the investigation report is being written. As a result, the writing process can become inefficient; supporting arguments for findings may be weak or not clearly presented, and important factors can be missed (ATSB, 2008).

Accordingly, it is necessary to enhance the factors of response cycles by improving the methods of the investigation and providing additional supportive analysis processes which then could identify the factors that might not be considered during the investigation process.

4.2.2 Accident causation models

An accident causation model is commonly a complex system that requires a sufficient level of knowledge so it can be used to determine the factor or issues that took place to increase risk of accident. Accident causation studies promise significant opportunity for those who are interested in developing the pertinent theory.

At present, theories of accident causation are conceptual in nature and, as such, are of limited use in preventing and controlling accidents. With such a diversity of theories, it will not be difficult to understand that there does not exist one single theory that is considered right or correct and is universally accepted.

In 1931, Heinrich introduced the first systemic approach known as the Domino model to analyse accidents in the industrial sector. The model was developed according to behaviour based safety which later identified that unsafe acts contributed majorly to workplace accidents (Heinrich, 1931).

Hollnagel (2004) reviewed the historical development of accident modelling based on traditional and modern approaches.

Traditional approach

Originally, the traditional accident causation model looked at the accident by its direct cause and attempted to view the entire event in a singular/one way order. There are two common approaches under the traditional model.

- Sequential/event based model

  The event based model was developed following the chain reaction concept, which explains an event in chronological order. The model highlights that an accident is caused by multiple events that occur one after another. It is a simple linear model that determines the causes as independent to every event in the main process. The model mostly focused on the failure and malfunction of the independent causes. The model suggests that prevention of accidents can be accomplished by eradicating one or more of the links so the event does not develop into an accident. The Domino theory by Heinrich (1931) (Figure 4-2) and Fault tree model are examples of event based models.

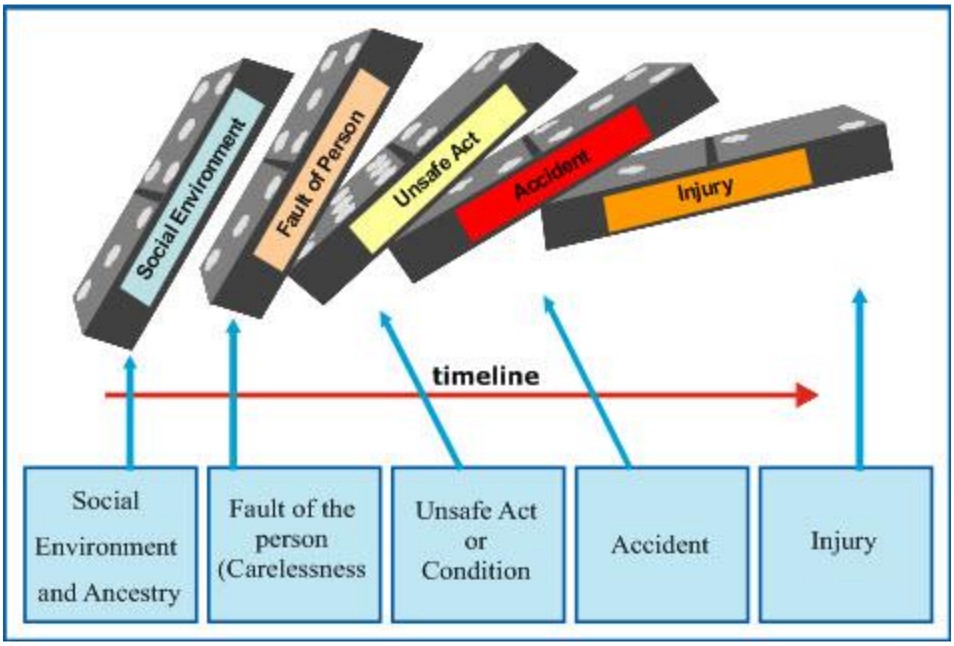


Figure 4-2: Domino theory model by Heinrich 1931. The figure taken from Heinrich: Industrial accident prevention. Copyright McGraw-Hil 1931.

- Epidemiological

The epidemiological accident model was originally based on biological research on the disease spread process. It attempts to identify the main cause of the disease by tracing back the entire cases or other event occurred randomly in the different circumstance. The epidemiological model identified that accidents (spread of disease) occur through the contribution of latent factors. Unlike the sequential model, the epidemiological model adopts a complex linear model that determines the cause as an interdependent factor. The concept sees the development of accidents due to errors in the safety defence/barrier that has been set up to prevent them.

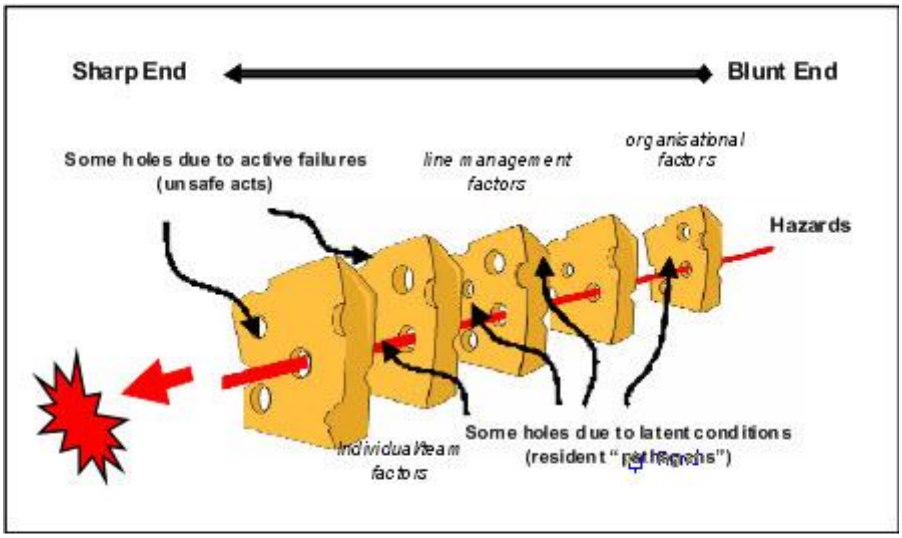


Figure 4-3: Swiss cheese model by James Reason (1997)

The generic barriers are commonly categorised into organisational factors, line management and precondition. The error of an individual factor (sharp end) is seen as an active failure, contributed to by previous misses and gaps in defence (blunt end). When all errors in each defence align, an accident occurs. The model made it possible to identify which safety defence was not working by observing the functionality of the barriers when the accident occurred. Hence, the prevention action is focused on strengthening the defence/barrier. The Swiss cheese model of James Reason is the prominent model in the epidemiological system.

Modern approach

Systemic models

Systemic models developed due to known insufficiency in the traditional approach. The systemic model sees the system as a whole as a contributor to the accident. The model adopts a non-linear model concept where all factors involved couple and interact coincidentally in a specific time (Hollnagel, 2004). The systemic models observe accidents as emergent phenomena that arise due to the complex interactions between system components that may lead to the degraded performance of the system, resulting in the accident. The tightness of the component coupling is one of the indicators to determine the health of the system.

In the systemic models, the system is seen as an entity of dynamic interaction among the components (technical, human, organisational and management) which was set up independently to support and maintain the operation of the system in achieving the goal. Leveson (2004) stated that accidents are treated as the result of flawed processes involving interactions among people, social and organisational structures, engineering activities, and physical and software system components.

Some examples of the accident causation model using the systemic concept are TRACEr of Kirwan and Shorrock (2001), STAMP of Leveson (2003), CREAM of Hollnagel (1998).

Qureshi (2008) argued that traditional accident modelling approaches are not adequate to analyse accidents that occur in modern sociotechnical systems, where accident causation is not the result of an individual component failure or human error.

The Swiss cheese model is also a useful method to provide a comprehensive overview of an accident by considering it via a generic group of categories. The Eurocontrol Experimental Centre (2006) mentioned that the model can be used for heuristic communication models, framework of accident analysis and basis of measurement. However, some scholars dispute the effectiveness of the models in explaining the interrelation of the factors in every stage of the models. Shappel and

Wiegman (2000) stated that Reason's 'Swiss cheese' model of accident causation had a few details on how to apply it in a real-world setting but never clearly mentioned the definition of the 'holes in the cheese'.

To some extent, systemic models are able to provide a comprehensive picture of the factor/component correlation in a complex socio-technical system. However, the systemic model requires extra effort to properly identify the multi non-linear relations.

Obviously, there is no "best" accident causation model that applies to all kinds of accidents. The description above does not attempt to define which accident model is the most appropriate; instead, it provides an overview of models applicable to certain conditions of events, with the similar main objective of acquiring information that can be a useful reference for determining the factors that affect the safety performance of a system.

4.3 The SEMOMAP

4.3.1 General concept and development

The sequential model of the maritime process (SEMOMAP) was originally developed by Schroeder under his PhD research thesis in 2003. The concept of the model adopts the sequential process, which mainly focuses on the overall accident process but also on analysing critical events at every stage of accident development (Schroeder, 2004). It also focuses on the question as to why some accidents result in total loss, whereas others can be mitigated to prevent, up to a certain point, greater consequences. This was deemed necessary since the model can be used to a further extent to analyse the possibility of an event in shipboard operation before it actually occurs and determine which factors are associated with higher risk of operation.

The approach of SEMOMAP is based on the Model of Human Recovery and Human Error Management developed by Van Der Schaaf in 1992.

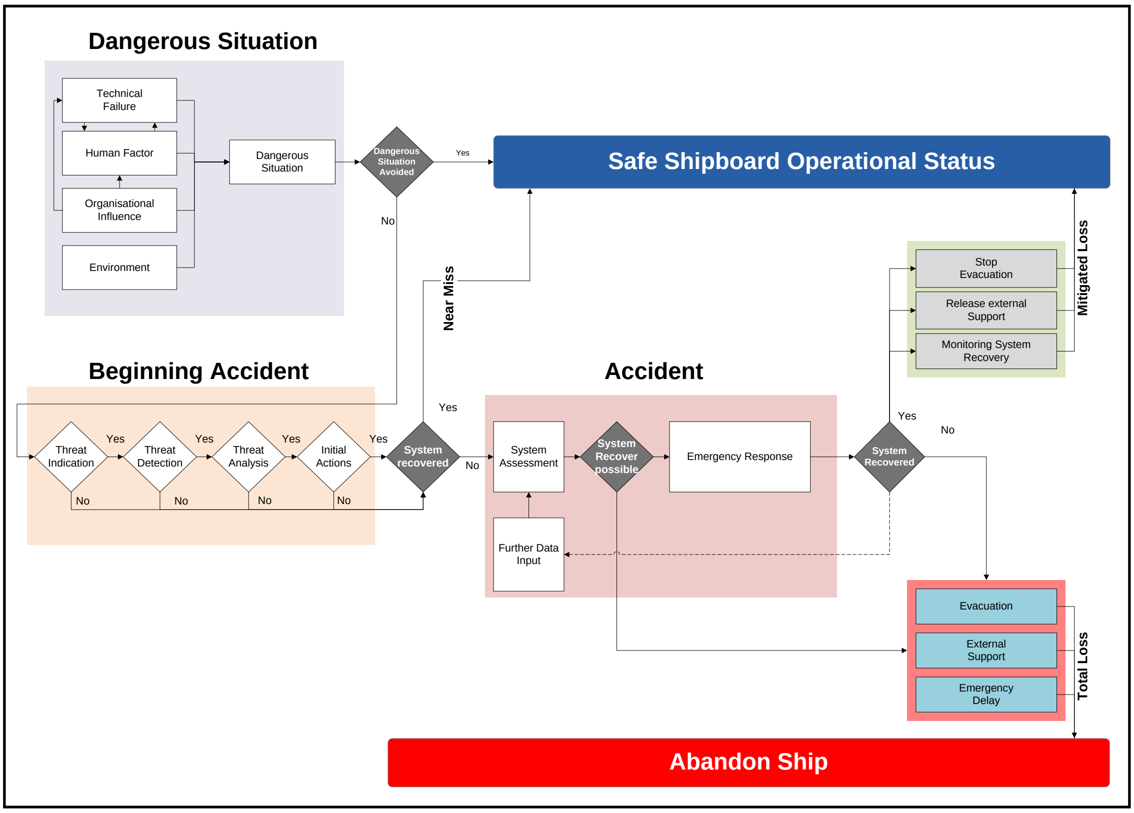


Figure 4-4: SEMOMAP v1 workflow by Schroder (2003)

In 2014, the model was developed to accommodate broader applicability, resulting in SEMOMAP v2 (Schroeder et al, 2014). Adopting the concept in the previous version, the SEMOMAP v2 generalises an accident into four main stages: Contributory stage, development of risk of accident, called "beginning of accident", the accident itself and the evacuation stage (Figure 4-5).

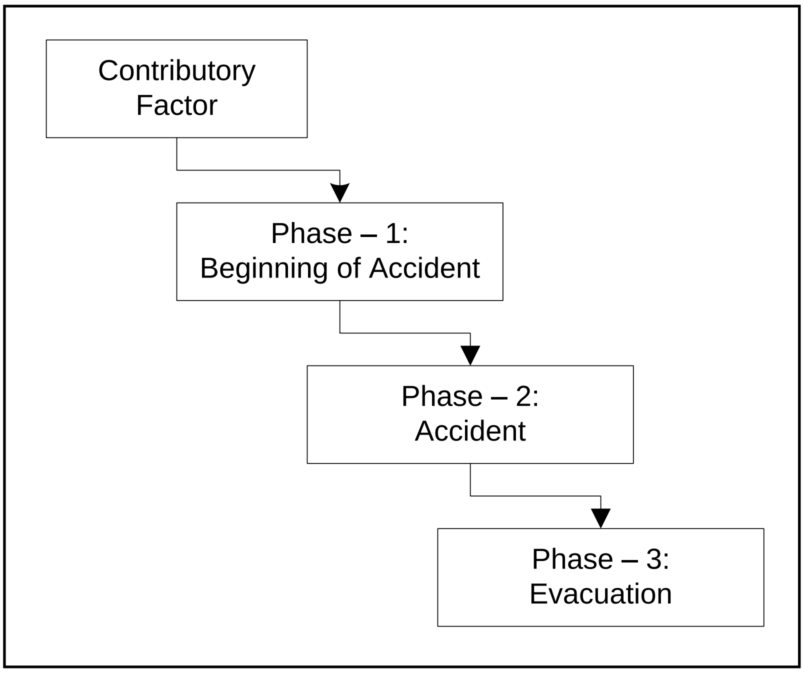


Figure 4-5: SEMOMAP concept for accident/incident development

Each stage is developed into more detailed sub-stages by adopting a number of independent taxonomies that are considered appropriate.

Under phase-0 of the Contributory factor, SEMOMAP attempts to identify the factor responsible for affecting the degrading performance of shipborne operation. The phase also describes the event where improper systemic factors take place and lead to a higher risk of accident/incident. The phase utilises an improved HFACS taxonomy to sufficiently assess each possible factor in the perspective of shipboard operation.

The SEMOMAP considers that the identified factors could influence different aspects of ship operation, mainly focused on two main elements, human and technical. Under each element, the SEMOMAP defines the list of subjects as follows:

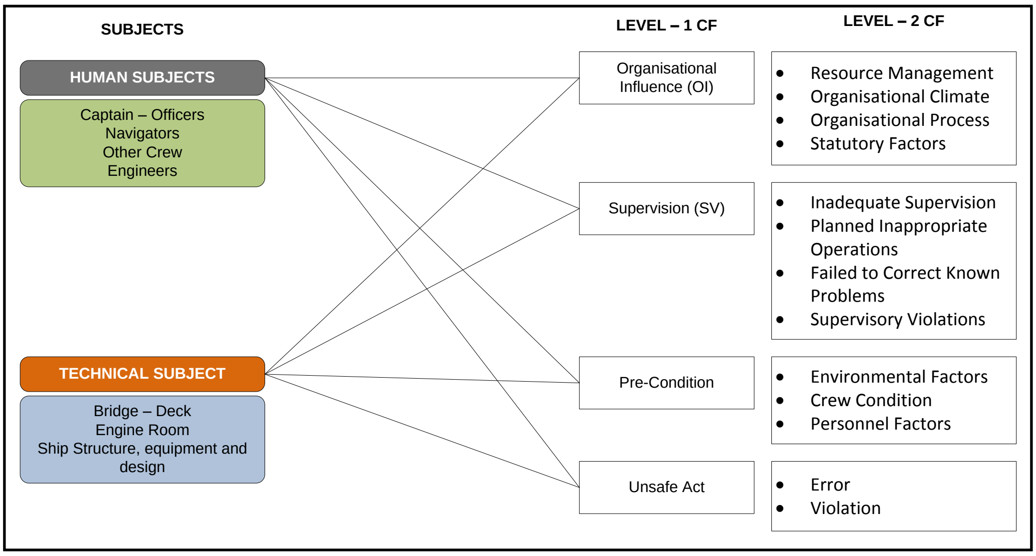


Figure 4-6: Scope of analysis under CF phase of SEMOMAP

Under the CF phase, the SEMOMAP categorises the actions taken by the human subjects. Under SRK models of Rasmussen (1999), the SEMOMAP categorises the action into two types of error and violation. As shown in Figure 4-6, within each level there are numerous specific types of contributing safety factors. Details of the taxonomy used for SEMOMAP under phase CF can be seen in Appendix-3

During phase-1 to phase-3, the SEMOMAP sees the process as an action of the shipboard element to react with the current state of the operation. SEMOMAP utilises the concept of Simple Model of Cognition developed by Hollnagel in 1998 as well as the model of information processing by Wickens (1992). Both models generate similar concepts on how human as operator reacts/behaves in complex situations as well shipboard operation. Both models incorporate the information processing stage which later results in decisions and action taken.

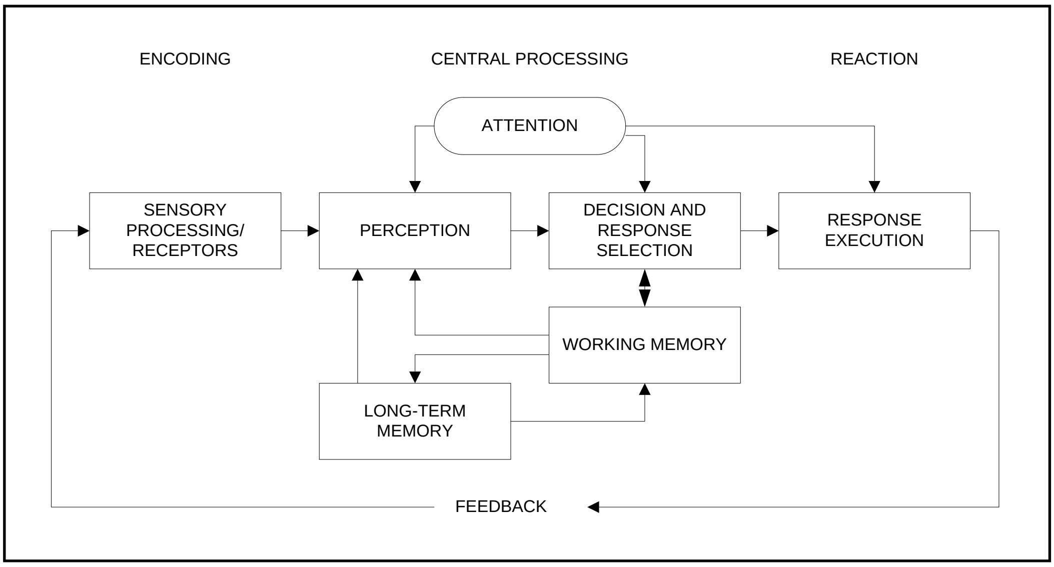


Figure 4-7: Wickens' model of information processing (1994)

Wickens provides a detailed concept of cognition by adding memory based action and information processing events to the cognitive process.

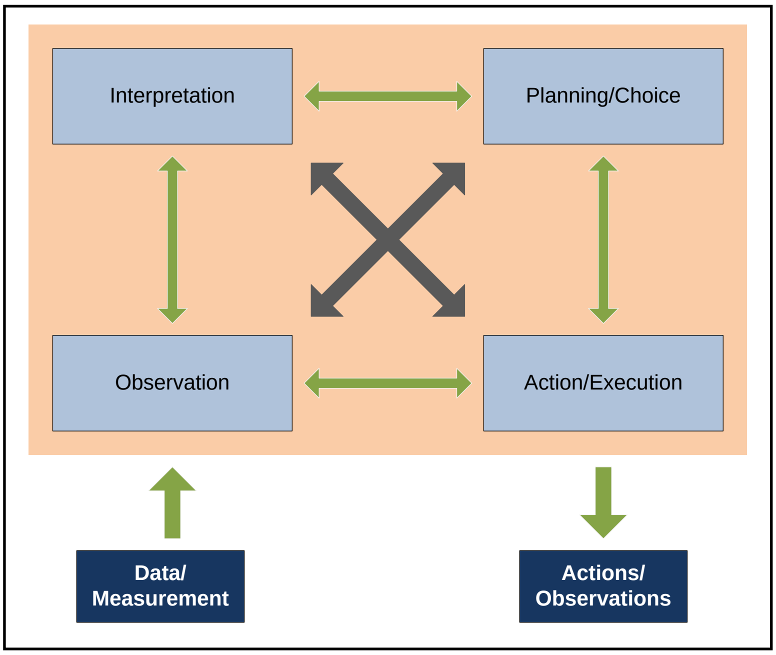


Figure 4-8: Simple Model of Cognition by Hollnagel (1998)

According to Hollnagel, human performance in critical situations would generally complete four main steps of observation, interpretation, planning/selection of action and, lastly, executing the action selected.

From the cognitive process models above, SEMOMAP extends the process and modifies the models of human cognitive process into four steps of accident assessment process: indication - detection - analysis – action/preventive measure.

The cognition models describe all action taken onboard prior to or post event based on the perspective of the subject involved during the cognition process. It also recognises that the party involved during the cognition process could be from anywhere such as onboard or ashore or even offboard (other ships). This can also originate from the human aspect or equipment aspect.

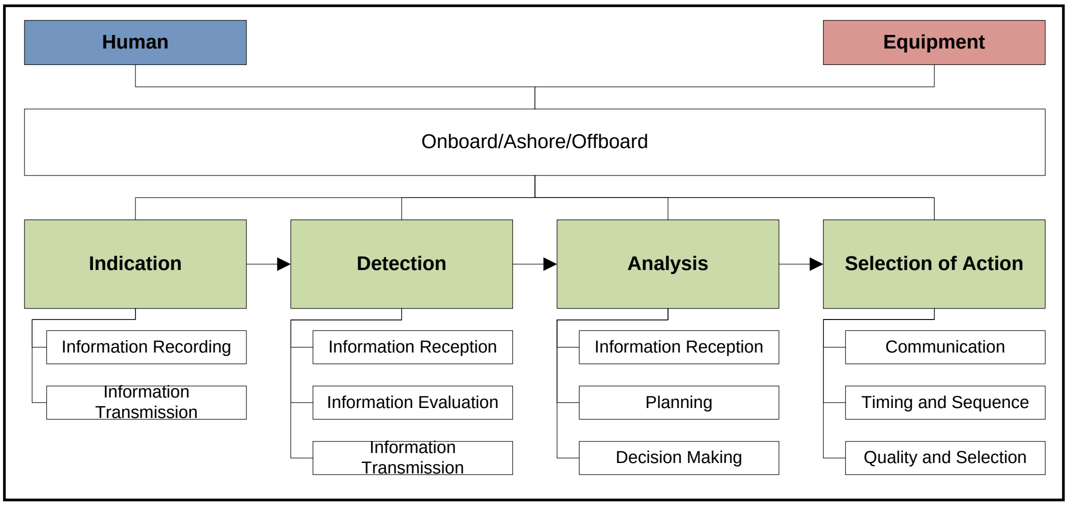


Figure 4-9: Cognition model under SEMOMAP

During the indication stage, SEMOMAP identifies gaps that might take place and assesses whether information is recorded and thus transmitted properly. When there is a failure during the main cognitive process, the SEMOMAP model also makes it possible to identify the source of the failure which can be human failure or equipment failure. Additionally, by utilising the Error Mode under the TRACEr model, the SEMOMAP model makes it possible to identify the contributing factors that affect the cognitive process.

During the detection stage, the SEMOMAP considers the information transmission process as the key point in determining the success of the process. The information transmitted from the previous stage is the main reference during the detection process. Overall, the assessment process during the detection stage involves information reception, evaluation process and information transmission. The activity could involve humans or equipment installed either onboard or ashore. The SEMOMAP also assesses the error/failure for each sub-stage by utilising Error Mode under the TRACEr model.

Analysis of the threat is the main activity in the cognitive process. It differs with regard to outcome, either successfully anticipating the threat or increasing the risk in shipboard operation. The analysis process involves information reception, setting up planning and decision making. The analysis of the information is possibly conducted by shipboard personnel or other sources. The key ingredient for the success of this stage is the information transmitted from the previous stage and also the capability of the subjects involved. Similar to the previous stage, SEMOMAP observes error and failure during the entire process, using the possible features listed in the human reliability assessment under the TRACEr model.

Selection of action is the final step under the cognitive process. The SEMOMAP differentiates the action based on the risk of each type of accident. To analyse the success of cognitive process under the selection of action stage, SEMOMAP divides the cognitive process into three main sub-stages: communication process, timing and sequence, and quality and selection. Each sub-stage is reviewed from the perspectives of human and equipment failure. Each failure is also observed by each of the contributing factors to determine the root causal factor.

4.3.2 Taxonomy involved

As explained in the previous section, two major taxonomies are utilised to support the main process of SEMOMAP model. The following section provides brief information about both HFACS and TRACEr model.

HFACS

Shappel and Wiegmann developed the Human Factors Analysis and Classification System (HFACS) in 2000. The model is developed based on the sequential or chain-of-events theory of accident causation and was derived from Reason's (1990) accident causation model. It was originally developed for use within the United

States military, both to guide investigations when determining why an accident or incident occurred, and to analyse accident data.

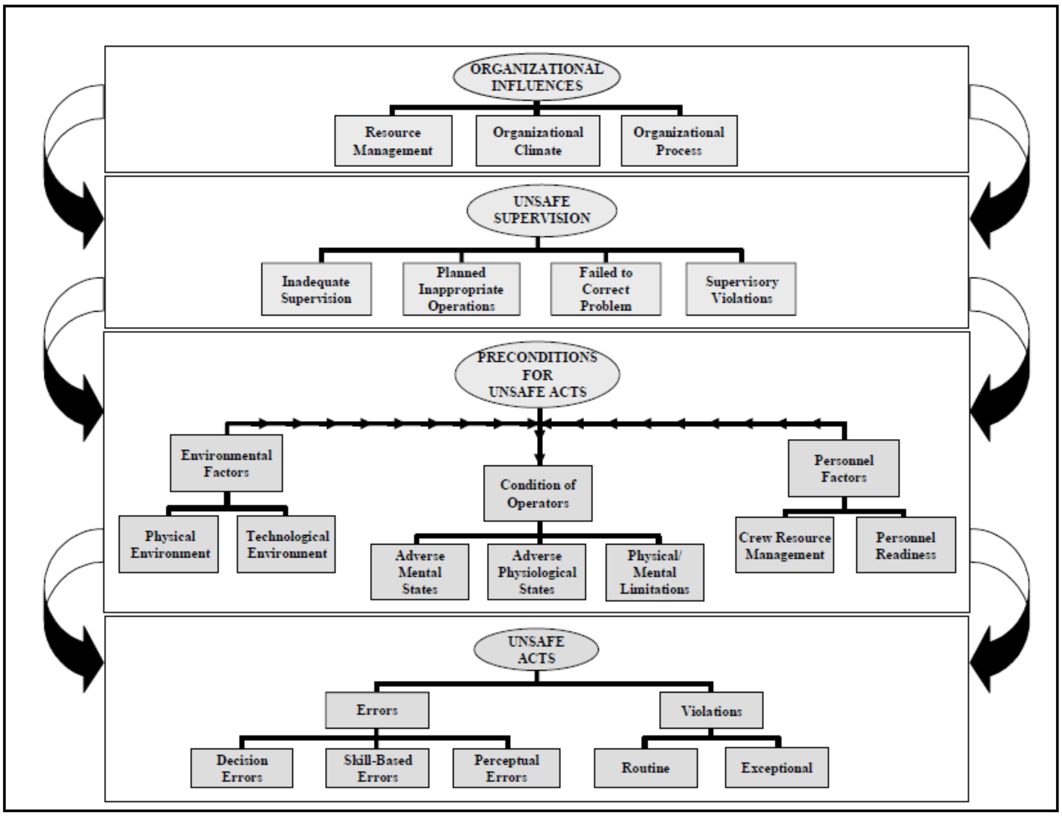


Figure 4-10: HFACS framework by Shappel and Wiegmann (2000)

The HFACS classification system focused on four hierarchical levels, (under the SEMOMAP so called Level-1):

1) Organisational influences:

Under organisational influence, originally HFACS provide three main categories of Level-2 *including resource management*, *organisational climate* and *organisational process*. For further detail, the taxonomy expanded each factor under level-2 into detail factor of Level-3. The SEMOMAP extended the detail of taxonomy into level-4 for each factor under level-3, with further detail can be found in the Appendix-3

2) Unsafe supervision

Under supervision, HFACS expand the category into four sub-categories of Level-2 namely *Failed to Correct Known Problems*, *Inadequate Supervision*, *Planned*

Inappropriate Operations and *Supervisory Violations*. Under factors level-2, the SEMOMAP extend the factors into marine related factors of Level-3. Level- 4 of each factor is also developed with further detail can be found in the Appendix-3.

3) Preconditions for unsafe acts

Under precondition, HFACS taxonomy divided into three different categories of: environmental factors, Crew Conditions and Personal factors.

4) Unsafe acts of operators.

HFACS categories the unsafe act into two main factors of Error and Violation. Under Errors type, HFSC adopt SRK models of human error developed by James Reason and divided the factor into Skill-based, Rule Based and Knowledge based Error. For Violation type, there are two sub-categories namely Exceptional and Routine Violation

For every level of HFACS, causal categories were developed that identify the active and latent failures that occur. Theoretically, there should be at least one failure occur at each level and resulted in adverse condition.

HFACS was originally developed to assess human performance in the aviation industry. Schroeder et al (2011) modified the HFACS taxonomy to be applicable to research in the maritime sector, more specifically to analyse explosions and fires in the machinery space (Schroeder, Baldauf, & Ghirxi, 2011). The modification mainly focused on the fifth level on top of organisational influence. The term "statutory" was added in order to observe the influence of safety regulations in shipping. Full details of the taxonomy used, including its definition for SEMOMAP models, can be found in Appendix-3.

TRACEr

The technique for the retrospective and predictive analysis of cognitive error (TRACEr) was developed by Kirwan and Shorrock in 2000. The model is based on the Human Factor Information Processing paradigm, but draws extensively from a range of Human Factors and error causation models. It was based on a task analysis of the controller activities via Hierarchical Task Analysis. TRACEr contains a number of flowcharts to help the analyst determine what errors could occur, what their causes might be, and their relative recovery likelihood.

The original TRACEr has a modular structure, comprising eight taxonomies or classification schemes. There are three main types of taxonomy: those describing the context within which the error occurred (Shorrock & Kirwan, 2002). Table 4-1 below indicates classified human error by TRACEr.

Table 4-1: Generation of TRACEr Internal Error Model. The tables reproduced from Development and application of a human error identification tool for air traffic control by Steven T. Shorrock and Barry Kirwan. Copyright (2002).

Cognitive Domain	Cognitive Function	Relevant Keywords	Example IEM
Perception	Vision / Hearing → Detection	None, late, incorrect	Late detection
	Identification	None, late, incorrect	Misidentification
	Recognition/ Comparison	None, late, incorrect	Hearback error
Memory	Recall perceptual information	None, incorrect	Forget temporary information
	Previous actions	None, incorrect	Forget previous actions
	Immediate/current action	None, incorrect	Forget to perform action
	Prospective memory	None, incorrect	Prospective memory failure
	Stored information (procedural and declarative knowledge)	None, incorrect	Misrecall stored information
Judgement, Planning and Decision Making	Judgement	Incorrect	Misprojection
	Planning	None, too little, incorrect	Underplan
	Decision Making	None, late, incorrect	Incorrect decision
Action Execution	Timing	Early, late, long, short	Action too early
	Positioning	Too much, too little, incorrect, wrong direction	Positioning error: overshoot
	Selection	Incorrect	Typing error
	Communication	None, unclear, incorrect	Unclear information transmitted

The SEMOMAP adopted the TRACEr taxonomy to identify operator-machine interaction and suggests that incidents are often triggered by cognitive and psychological error by the operator. The operator is furthermore influenced in his performance by external and internal factors.

From the human failure taxonomy above, SEMOMAP adopted every phase of cognition. Details of the taxonomy can be found in Appendix-3

4.3.3 SEMOMAP System methodology

Along with the objectives in this dissertation, the following section provides a general overview of how to utilise the SEMOMAP model.

Phase-0: Contributory factors (CF)

As explained above, the SEMOMAP begins with CF as its initial step. In compliance with the concept of HFACS, the first step under the phase is to focus on and identify which human and/or technical element plays a significant role and is mostly affected by the deficiencies and gaps in the contributory factor(s) in the four main groups. Each factor in detail in the Level-4 taxonomy is reviewed and selected in accordance with the information provided in the investigation reports.

The model's workflow can be seen in the Appendix-1.

Phase-1: beginning of accident

The beginning of accident phase under SEMOMAP attempts to explain in detail how the shipboard or shore side reacted to the presence of risk in the ship operation. The SEMOMAP uses the term "Threat" to indicate the important factors that affect the risk of ship operation.

As some issues were not resolved during the initial stage, the shipboard operation is subsequently led to the possible risk of accident/incident. SEMOMAP categorises risk of accident/incident into four main sections: Navigational risk, Onboard Incident and Entire Vessel risk. Under each main category, the details are as follow:

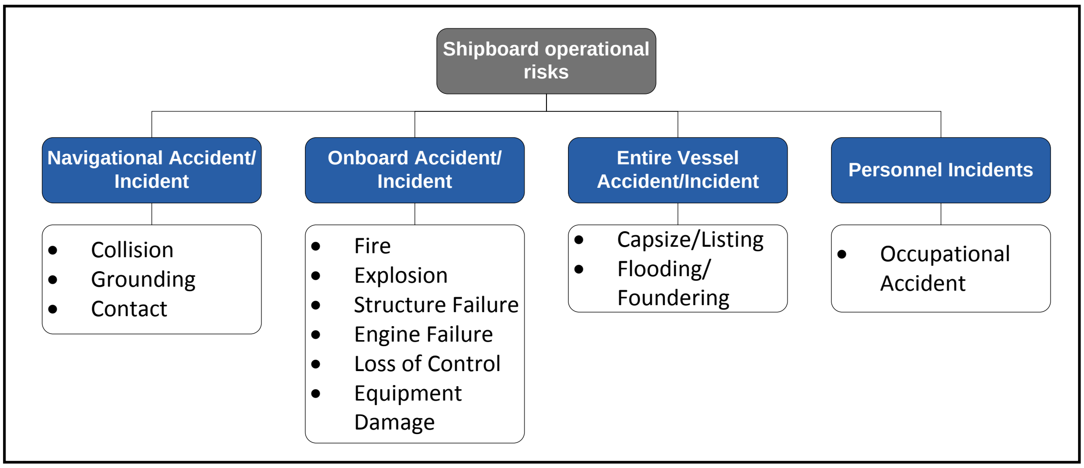


Figure 4-11: shipboard operational risk category under SEMOMAP v2

By adopting the cognitive process, the SEMOMAP amends the process under phase-1 into following order.

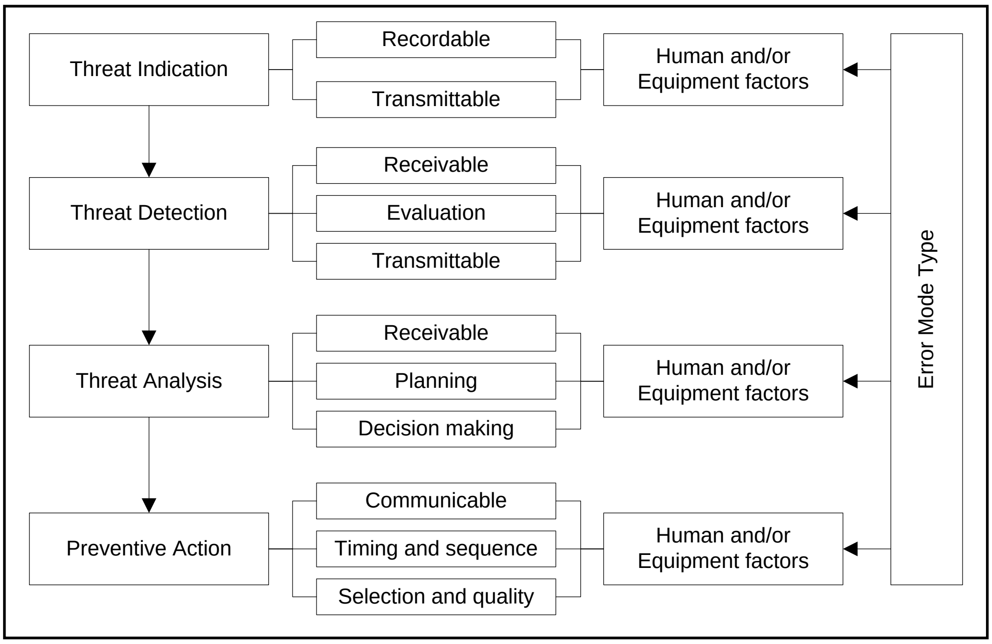


Figure 4-12: Cognitive process under phase-1 beginning of accident of SEMOMAP v2 model.

Indication of the threat could come from a variety of sources, either onboard ship, including ship equipment, different types of sensors; or ashore, including warning information from a shore-based agency. Each of the involved indicators is reviewed and analysed to find out whether the process was successful or failed. The process continues following the cognitive process as one type of iteration.

In most of accidents, there could be a series of events that occur concurrently, leading to failure, which results in the escalation of risk. The SEMOMAP model makes it possible to analyse each of the events by looping the event until all the processes are either resolved or continue to develop into the event of an accident.

Phase-2: Accident Phase

Phase-2 is as a result of improper or insufficient preventive action taken by the shipboard parties to mitigate the risk. Similar to Phase-1, SEMOMAP defines the event's progress based on the cognitive process workflow.

Since the threat was not properly mitigated and has become an accident, the SEMOMAP changes the term "threat term" to "health system". This is to define the state of the shipboard operation after the main event of the accident/incident occurs. The concept is that the crew would initiate efforts to reduce the consequences after the accident by reviewing and assessing overall or partially affected ship components.

Phase-2: Accident Phase

The phase-2 is as a result of improper or insufficient preventive action taken by the shipboard party to mitigate the risk. Similarly like Phase-1, SEMOMAP define the event progress based on the cognitive process workflow.

Since the threat was not properly mitigated and has considerably been change into accident, the SEMOMAP change the threat term in to "health system". This to define the state of the shipboard operation after the main event of accident/incident occurred. The concept is the crew would start initiate their effort to reduce the consequence after the accident by reviewing and assessing overall or partial ship affected component.

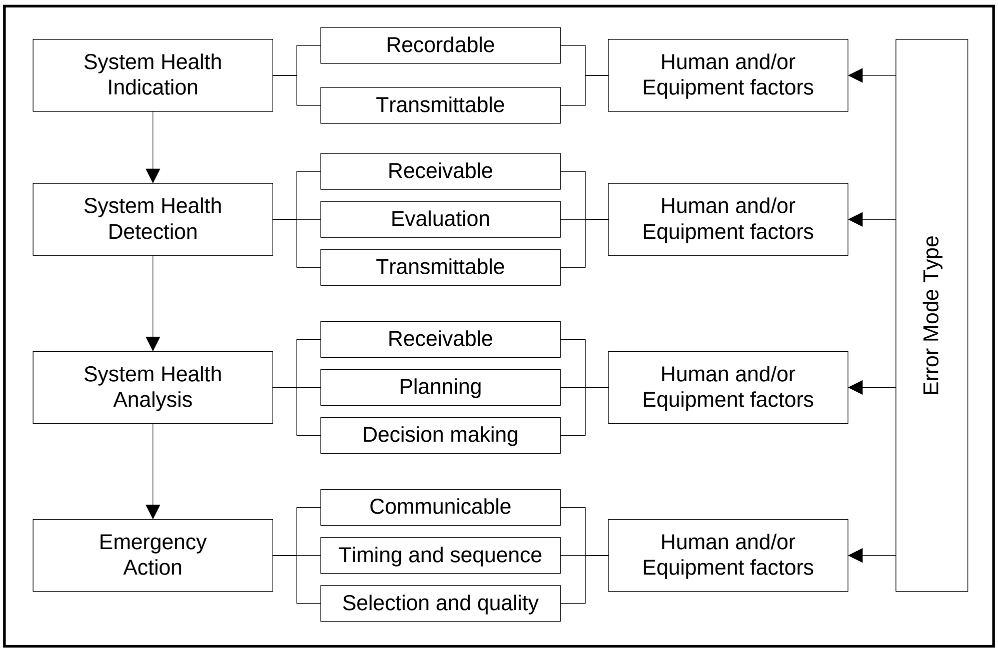


Figure 4-13: Cognitive process under phase-2 of SEMOMAP v2 model

Similar to the cognitive process during phase-1, the SEMOMAP provides tools to assess failure during each stage. Under phase-2, the action considerably related to mitigating the consequences after the accident happens. When the event is not properly assessed and evaluated, the event later could develop into initiation of the evacuation process.

Phase-3: Evacuation Phase

SEMOMAP considers phase-3 as a consequence of unsuccessful mitigation effort during phase-2. The events occurring are seen as a continuation of the previous action taken under the emergency stage. During this stage, the shipborne operation is focused on the operation to reduce the consequences caused by the event in phase-2. Most of the resources are used to either evacuate the personnel and/or continue the action to reduce the consequences, while the evacuation process is underway. Therefore, the SEMOMAP model is slightly modified from the two previous stages.

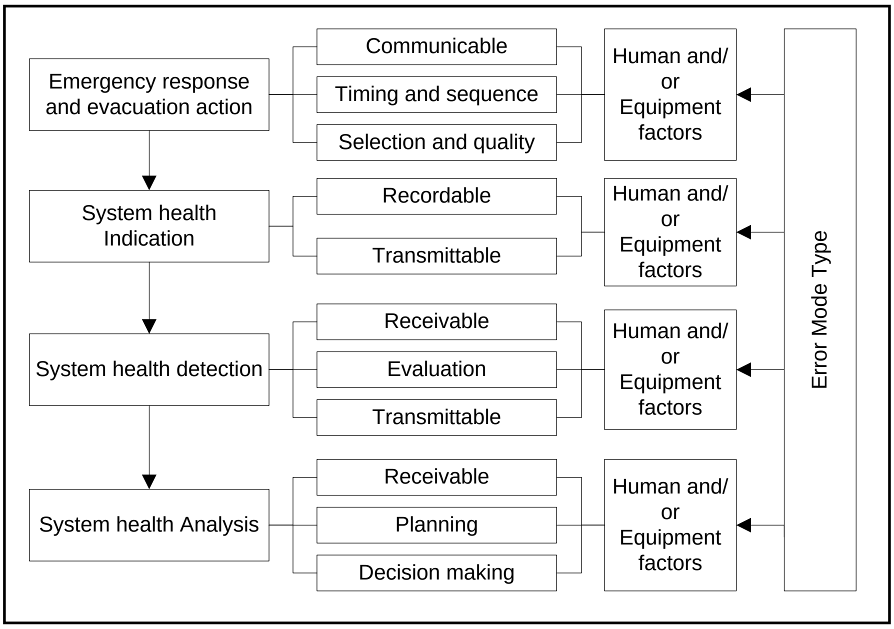


Figure 4-14: Cognitive process under phase-3 of SEMOMAP v2 model

Like two previous phases, the model attempts to identify and analyse the failure/error source that takes place during the process of evacuation.

In detail, the complete workflow SEMOMAP analysis process can be found in Appendix-2.

4.4 Methodology to utilise the model

After determining the proper accident causation models of SEMOMAP, the dissertation used selected investigation reports issued by a formal investigative body in Indonesia. Following the objective of the dissertation, the selection will only review cases related to the operation of domestic RoPax ferries. The selected reports comprise the factual information, accident chronology, findings and recommendations.

The coding is conducted based on the available information in the report by the writer. Graphical breakdown and results are only shown for levels 1 to 4a of the taxonomy. Level 4b and 5 have not been analysed graphically, as they are reliant and dependant on coder reliability –i.e. – different people might disagree with the taxonomy options selected for level 4b and 5; instead, however, levels 4b and 5 are described and discussed very broadly and subjectively.

It is acknowledged that in comparison with the model, some information in the investigation reports could have been unavailable for various reasons. Additional supporting information is subject to obtained in order to support the analysis in the accident causation model of SEMOMAP.

Obviously, the correct interpretation of the writer is of importance to sufficiently select factors under each phase. In addition, ideally it requires the work of groups comprised of experts in every aspect of shipborne operation to sufficiently interpret the information listed in the investigation reports. Therefore, in order to have proper results, the SEMOMAP system requires comprehensive knowledge of the users in the sense of the investigation process, concept of accident process, human factor analysis, and maritime operation. In this thesis, however, the report was single-handedly coded by the writer. Therefore, to ensure the validity and accuracy of the SEMOMAP result, background of the writer is necessary to mention.

The writer has background and knowledge in naval architecture and ship engineering. He also has extensive experience in marine casualty investigation and has attended formal one year comprehensive training in ATSB. In addition, the writer was also involved in most of the investigations of the cases used in this thesis and contributed in producing the investigation reports.

Following the outcome of the SEMOMAP analysis, the dissertation attempts to identify which safety factors are considered dominant in every stage of the accident. This is done by observing the cases based on the nature of the accidents: fire, sinking/capsize and collision.

In particular for collision cases, the coding mainly focused on crew behaviour and performance on the Ropax ferry instead of covering all the involved ship behaviours.

4.5 Conclusion

Obviously, accident causation model analyses and formal investigations are two separate methods but they have the same paramount objective of identifying gaps and weaknesses in maritime operation that lead to accidents and propose improvements to the system to prevent recurrence in the future. For this reason, applying both methods could create a more comprehensive outcome. Therefore, the need to analyse investigation reports by adopting a proper accident causation model is of utmost importance.

The SEMOMAP is considered an appropriate model to analyse the safety issues in typical ship board accident/incidents such as events involving domestic ferries. The SEMOMAP has been successfully developed to provide a clear picture of how an accident develops from a small event into a greater consequence/s. The model is thoroughly integrated with adequate prescriptive established taxonomies to understand complex situations in a temporal event.

5 Model Results

5.1 Domestic RoPax ferry accident investigation reports 2003 – 2013

The dissertation reviews and utilises sixteen investigation reports related to domestic ferry accidents/incidents in Indonesia issued by the NTSC during the period of 2003 – 2013 as the main references. The selected cases were considered to provide sufficient information to view the issues in domestic ferry operation. The variety of consequences among the selected accidents also made it possible to conduct benchmarking between two different cases with two different outcomes. Most of the selected cases are high profile due to their contributing factors and the consequences resulting from the accidents.

In terms of the nature of the accidents, the selected cases comprise 8 fire accidents, 5 sinking/capsize cases and 3 collision cases.

Under IMO category for occurrence categorisation (IMO, 2008), there are 11 cases of very serious marine casualty, 3 cases of serious marine casualty and 2 cases of less serious marine casualty. In the case of fire accidents, the selected cases can be categorized by the location where the fire started. There are 3 cases in the engine room and 5 cases in the cardeck/accommodation space.

Following the ferry service types of short and long distance ferry routes, the selected cases were categorised into 5 cases occurring on short distance ferry services and 11 cases occurring on long distance ferry services. Figure 5-1 below indicates the location where the accidents occurred.

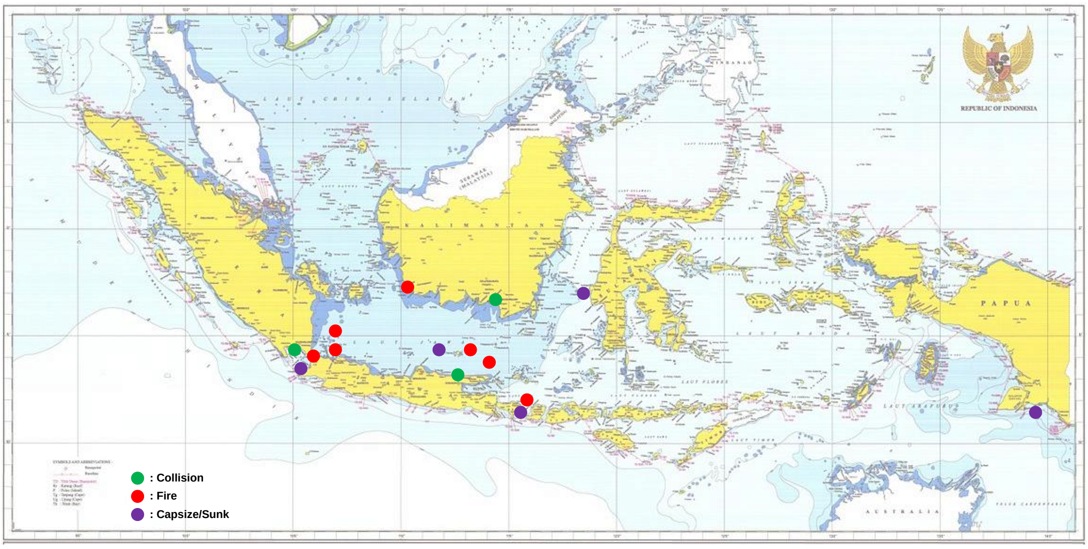


Figure 5-1: Selected accident case by its location and nature of the accident

Overall ship data can also be distinguished by age and ship size at the time of the accident. With regard to the ships' age at the time of the accident, the average age for involved ships is 23 years old, where the youngest ship in the population is 10 years old and the oldest ship is 40 years old. In terms of the ship size, the involved ships were comprised of 4 ships with size less than 1000 GT, 8 ships between 1000 GT to 5000 GT and 4 ships above 5000 GT.

Information related to all selected investigation reports used in this dissertation can be seen in Appendix 4.

The selected cases were thoroughly reviewed in accordance with the workflow in the SEMOMAP v2 models. Under Phase-0: Contributory Factor, the model identified the issues that occurred and contributed significantly to the development of the increased risk of accident. Under phases 1, 2 and 3, the model focused on personnel performance and their interaction with the system and surroundings. In Phase-1, the SEMOMAP models identified how the crew reacted to the existing risk and analysed the gaps and misses in their performance which later increased the risk of accident. Phase-2 and phase-3 examine the related parties' performance to reduce or prevent further consequences after the accident occurred.

In order to provide sufficient overview of the outcome of the model to the selected cases, analysis results are divided by the nature of the accident: fire, sinking/capsize and collision.

5.2 SEMOMAP result for Fire category accident

Under the SEMOMAP model, the analysis result focused on the affected human and technical factors as described in the previous chapter. The SEMOMAP identified parties based on the interaction of the factors according to the HFACS. Since each of the contributory factors interacts differently in each element, the outcome of the result is divided into two main components of contribution: Human element interaction and technical element interaction

5.2.1 Identified contributory factors for Fire category accidents

Factors affecting human element under fire category accidents

From a review of 8 fire accident cases, SEMOMAP records 592 interactions between 9 major human element subjects and 24 factors under level 3 of the HFACS system. The human element includes the captain and navigational officers, ordinary seaman and engine department officers.

Under the category of *Organisational Influence*, the results indicate that the *factor of poor equipment/facility resources* (25%) had the highest effect on human performance during the fire accidents, whereas the factor of *lack of oversight* under organisational process (27%) contributed to the behaviour of the human element and increased risk of fire in ferry operation.

With regard to the *Supervision* issue, there were 183 interactions of the factors, in which *Planned Inappropriate Operation* (36%) is considered as the most significant factor. *Poor Shipborne Operation* is the second factor that influences human performance in relation to risk of fire accident.

Under the *Preconditions* category, *poor crew interaction* (30%) under *personnel factors* is found to influence human performance in relation to risk of fire. On the other hand, *poor technological environment* (29%) also contributed highly to the presence of risk of fire onboard the ferry ship.

All the factors above were later found to contribute to the presence of unsafe acts where *skill based error* (38%) was mostly identified and increased the risk of fire accident, whereas *exceptional violation* was also be found to contribute significantly to the presence of fire risk in ferry operation. Further details of the recorded interaction among each factor are shown in Table 5-1 below.

Table 5-1: Identified factors under HFACS level 2 that influence the Human Element performance for fire type accidents

Factors L1	Factors L2	Factors L3	Total Identified Factors
Organisational Influences (i)	Resource Management	Lack of Human Resources	30
		Poor Equipment/Facility Resources	44
	Organisational Climate	Disorganised Structure	1
		Poor Work Culture	21
	Organisational Process	Poorly Designed Operations	9
		Inappropriate Procedures	9
		Lack of Oversight	29
	Statutory Factors	Poor International/ National Standards	10
		Inadequate Flag State Implementation	22
Supervision (ii)	Inadequate Supervision	Poor Shipborne and Shore Supervision	48
	Planned Inappropriate Operations	Poor Shipborne Operations	60
	Failed to Correct Known Problems	Shipborne Related Shortcomings	52
	Supervisory Violations	Shipborne Violations	9
Preconditions (iii)	Environmental Factors	Poor Physical Environment	14
		Poor Technological Environment	53
	Crew Condition	Negative Cognitive Factors	20
		Poor Physiological State	2
	Personnel Factors	Poor Crew Interaction	55
		Poor Personal Readiness	41
Unsafe Acts (iv)	Errors	Skill-based errors	24
		Decision and judgement errors	14
		Perceptual errors	4
	Violations	Routine	4
		Exceptional	17
		Total	592

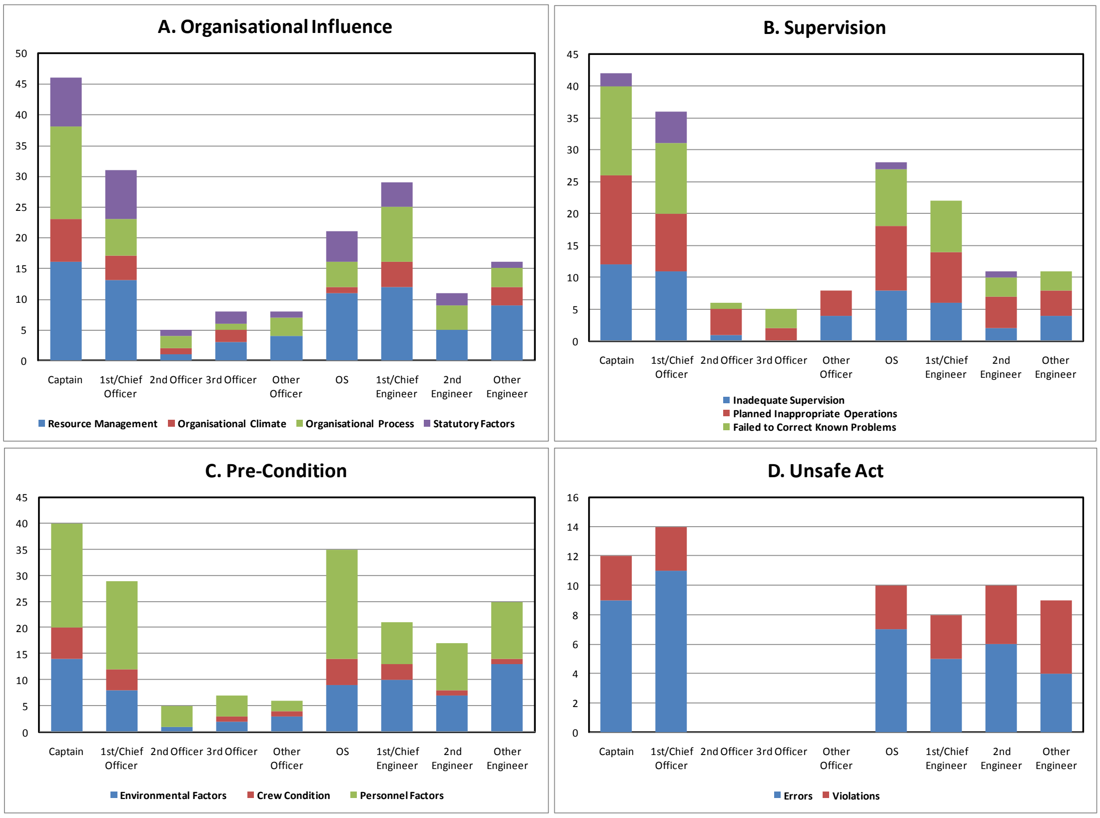


Figure 5-2: identified HFACS level-2 factors that influenced each involved **Human** performance in the fire category accident

The Figure 5-2 above indicates that among 8 human elements identified as the most affected and playing a major role in the presence of risk of fire accident, the Captain is the most affected human element due to misses and gaps in the systemic process. 1st/chief officer and Chief Engineer are in the second position and play a significant role under the same circumstance.

Under organisational influence, the SEMOMAP identified lack of human resources such as *training* and *selection* as the factor that most influences the insufficient performance of the Captain. Similarly, the chief officer and chief engineer are identified as being affected by such conditions (Figure 5-2 A).

Under the supervision category, the factor of *Planned Inappropriate Operations* is the key factor that contributed to the deficient performance of the captain, chief officer, chief engineer and ordinary seaman, whereas the factor of *Failed to Correct Known Problem* was another significant issue in supervision affecting the same human element (Figure 5-2B).

Factors affecting technical elements under fire category accidents

The SEMOMAP records five main elements that played significant roles during the fire accidents. These include alarm panels and systems, main engine, ballast water pumps, separators and other technical elements (covers fire fighting equipment for both fixed system and portable extinguishers). Deficiency in the technical element performance is contributed to by 23 factors under HFACS level-3 with a total of 171 interactions.

Under the *organisational influence* category, the factor of *poor equipment/facility resources* (35%) such as *engineer support* and failure to *correct known design flaws contributes* most significantly to the performance of the technical element. The *factor of lack of oversight* such as *failure to monitor and check resources to ensure safe work environment* is also known to influence the performance of the technical element and contributed to the increased risk of fire in the Roro ferry operation. The factor of *inadequate flag state implementation* (17%) is the next factor that significantly influenced the condition of the technical element. This was mostly from *lack of class and statutory surveys*.

Under the *Supervision* category, the factor of *shipborne related short comings* (39%) is known to be the most influential factor to the technical element and includes the factor of *failed to correct safety hazard*. Another factor that also contributes significantly to the issues in the technical element is *poor shipborne operations* (36%). This includes the factor of lack of risk assessment and limited recent experience shown by the crew.

Poor technological environment (71%) under the *Precondition* category is another factor that is influential to the weakness of the technical element condition. This covers mainly the factors of faulty equipment, in*correct modification to the manufacturer's procedures* and issues on *control and switches*.

It is interesting to note that human behaviour also contributed to the degrading performance of the technical element. *Judgement errors* under unsafe act/behaviour were found to affect the technical element performance.

Table 5-2: Identified factors under HFACS level 2 that influence the Technical Element performance for fire category accident

Factors			Total Identified Factors
L1	**L2**	**L3**	
Organisational Influences (i)	Resource Management	Lack of Human Resources	7
		Poor Technological Resources	3
		Poor Equipment/Facility Resources	30
	Organisational Climate	Inadequate Policies	1
		Poor Work Culture	5
	Organisational Process	Poorly Designed Operations	4
		Inappropriate Procedures	5
		Lack of Oversight	14
	Statutory Factors	Poor International/ National Standards	4
		Inadequate Flag State Implementation	12
Supervision (ii)	Inadequate Supervision	Poor Shipborne and Shore Supervision	6
	Planned Inappropriate Operations	Poor Shipborne Operations	12
	Failed to Correct Known Problems	Shipborne Related Shortcomings	13
	Supervisory Violations	Shipborne Violations	2
Preconditions (iii)	Environmental Factors	Poor Physical Environment	5
		Poor Technological Environment	32
	Crew Condition	Negative Cognitive Factors	1
	Personnel Factors	Poor Crew Interaction	2
		Poor Personal Readiness	5
Unsafe Acts (iv)	Errors	Skill-based errors	2
		Decision and judgement errors	3
	Violations	Routine	1
		Exceptional	2
		Total	171

The SEMOMAP also records that other elements such as fire fighting equipment were the most affected technical elements due to gaps and misses in the systemic process, whereas the main engine is the 2nd most affected technical element. The main issues in the fire fighting system stemmed mostly from factors of *resource management*, *planned inappropriate operations* and *environmental factors*. Inadequacy in the main engine performance was found to be affected by issues in *resource management, planned inappropriate operations* and *environmental factors*. On the other hand, some errors in handling the main engine were also found to contribute to degrading performance of the main engine (Figure 5-3).

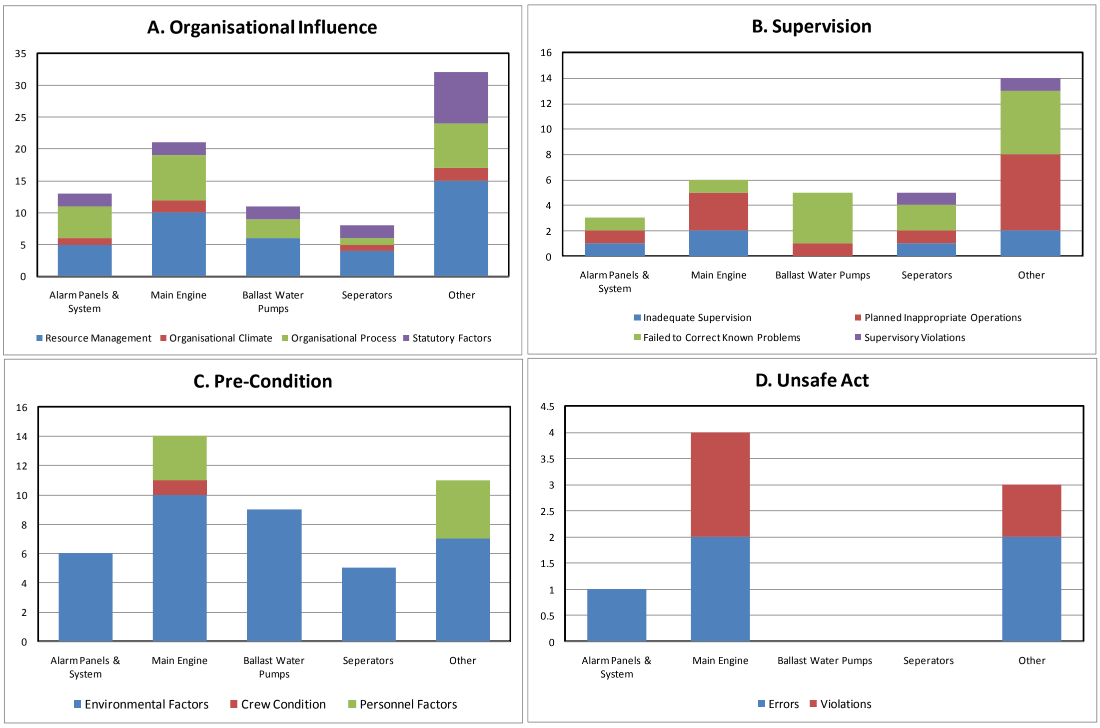
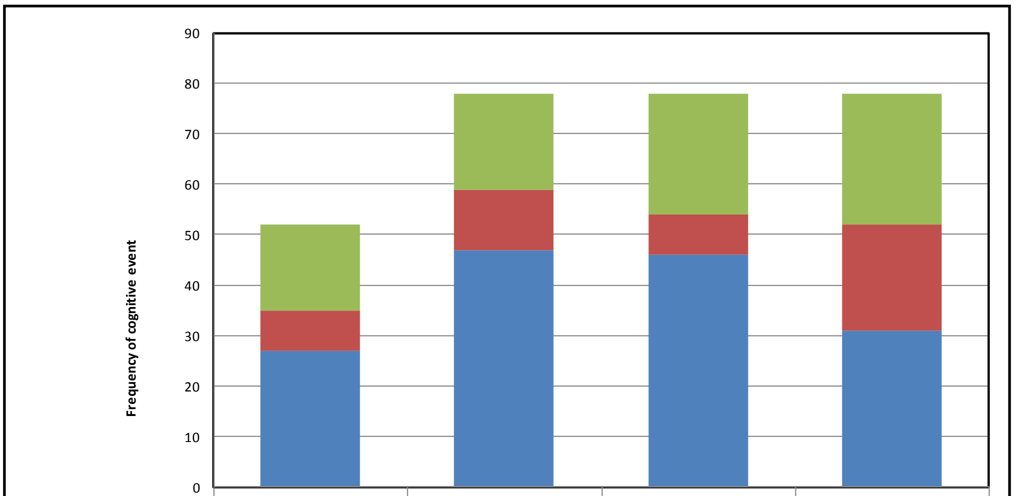


Figure 5-3: Influence of Contributory factors to the involved technical element for fire type accident

5.2.2 Phase-1 result for fire category accidents

Since the SEMOMAP adopts cognitive processes to overview the element of behaviour while assessing the risk of accident, the outcome of the model is categorized by the nature of accident and based on each phase and each stage of: Indication-detection-analysis-action. The outcome focuses on the particular stage that had the most issues and influences to mitigate the risk of fire accident.

From 8 fire cases reviewed, the SEMOMAP recorded 78 events of accident assessment process during phase-1 (Figure 5-4). The risk of fire was identified to escalate since there were failures in every step of the cognitive process. During the indication stage, failure was identified mostly during the transmission process, which involved human as the indicator. During the detection stage, the failure mostly took place in the evaluation stage, where it comes from human failure such as ignoring the threat or omitted action.



	Threat Indication	Threat Detection	Threat Analysis	Threat Prevention Action
Not Applicable	17	19	24	26
Applicable but Not Successful	8	12	8	21
Applicable	27	47	46	31

Figure 5-4: frequency of fail (red block) /safe (blue block) accident assessment process under phase-1 of fire type accident

During the threat analysis stage, failure mostly occurred when setting up a plan to handle the presence of risk of fire. The issues mostly resulted from human failure as a result of insufficient planning due to confusion, distractions, forgetting long term training and lack of vigilance to the situation.

For the fire category, the data indicates the most of the failures occurred during the threat prevention action with most of the failures caused by lack of human performance such as action taken too late due to lack of vigilance and situational awareness. There are 5 actions most frequently taken to prevent fire such as cutting off oxygen supply, reducing heat, and shutting down the engine, but there is also evidence to mention that there was no action taken to prevent fire from developing. Failure in human performance was also found in the inappropriate action taken during the selection and quality stage. During this crucial stage, most of the evidence shows that the crew provided too little action to prevent the fire from spreading. Detailed particulars for phase-1 can be found in Table 0-74, Appendix-5.

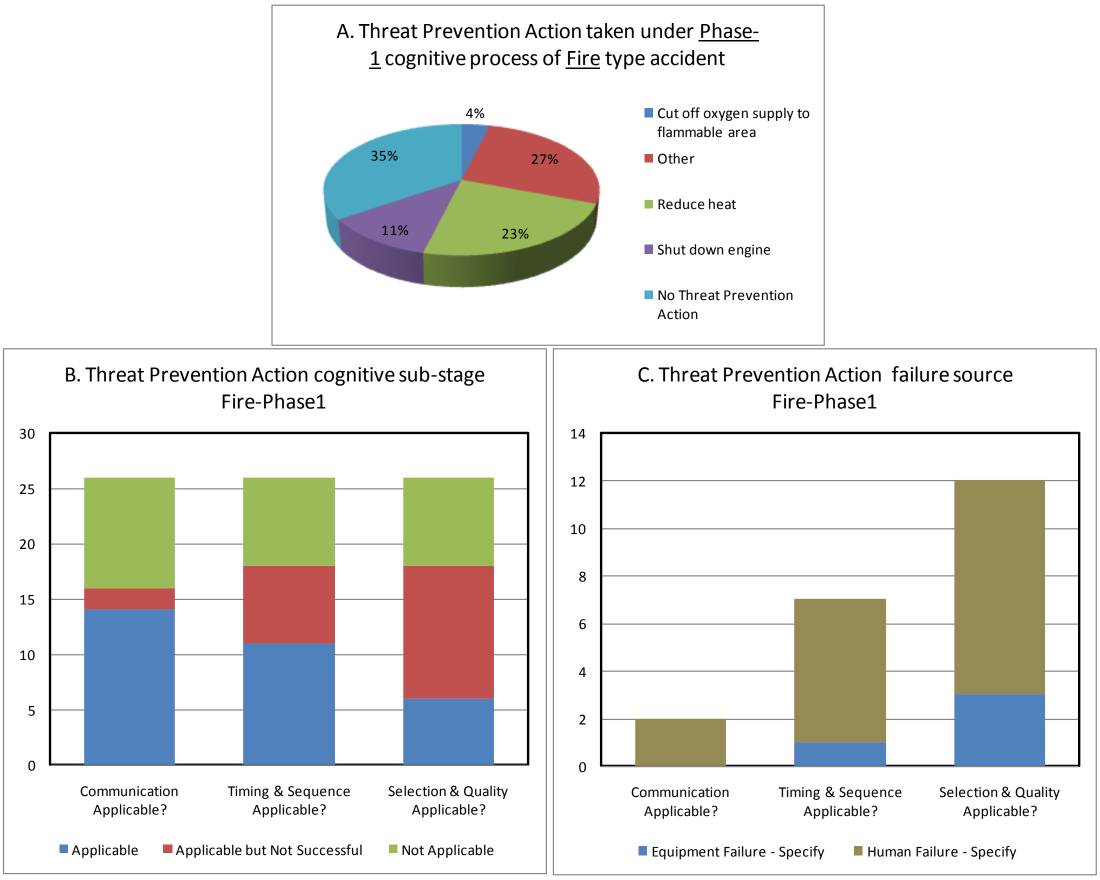


Figure 5-5: Threat prevention action data for fire category accident

5.2.3 Phase-2 result for fire category accidents

Under phase 2, SEMOMAP recorded 84 events of accident assessment process from the total reviewed fire cases. The data shows that since the accidents occurred most of the indications have become obvious. However, the issues later took place at the next stage of cognition.

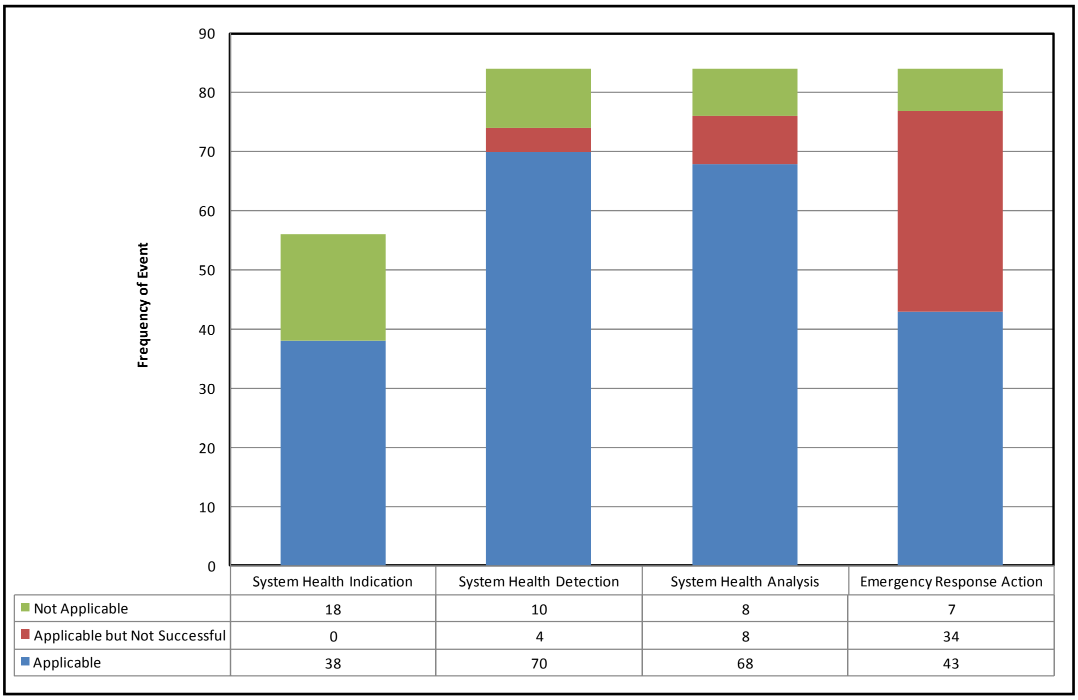


Figure 5-6: frequency of fail (red block) /safe (blue block) accident assessment process under phase-2 of fire type accident

During the system health detection, the issues are found to totally come from human failure as a result of factor of confusion, fail to see the information and forget long-term training. Time pressure also found influencing the analysis process.

Similarly to the system health indication, the human failure is also identified as the most factors resulting in the fall of the analysis process. The condition takes place during planning and decision making. This was mainly caused by factors of confusion, distraction, forget long-term training, lack of vigilance and other factors.

During the system health detection, the issues are found to result completely from human failures as a result of factors of confusion, failure to see the information and forgetting long-term training. Time pressure was also found to be an influence in the analysis process.

Similarly to the system health indication, human failure was also identified as the top factor resulting in the fall of the analysis process, specifically during planning and decision making. This was mainly caused by factors of confusion, distraction, forgetting long-term training, lack of vigilance and other factors.

During phase-2 in fire type accidents, there were 7 actions commonly taken: fire fighting (57%), other action (25%) and shutting down the engine (4%). However, failures also occurred during the action taken to handle the emergency situation. The data shows that from the total 84 events during the cognition process under this phase, 40% were found to be caused by human failure (76%) and equipment failure (24%) (See Figure 5-7). The issues mainly took places in timing and sequences, and also during selection and quality. Under timing and sequence, the evidence shows that most of action taken was too late, mostly as a result of confusion, distraction, forgetting long-term training and time pressure. On the other hand, too little action taken was found to be the major factor under human failure that caused the fire accident to continue to develop.

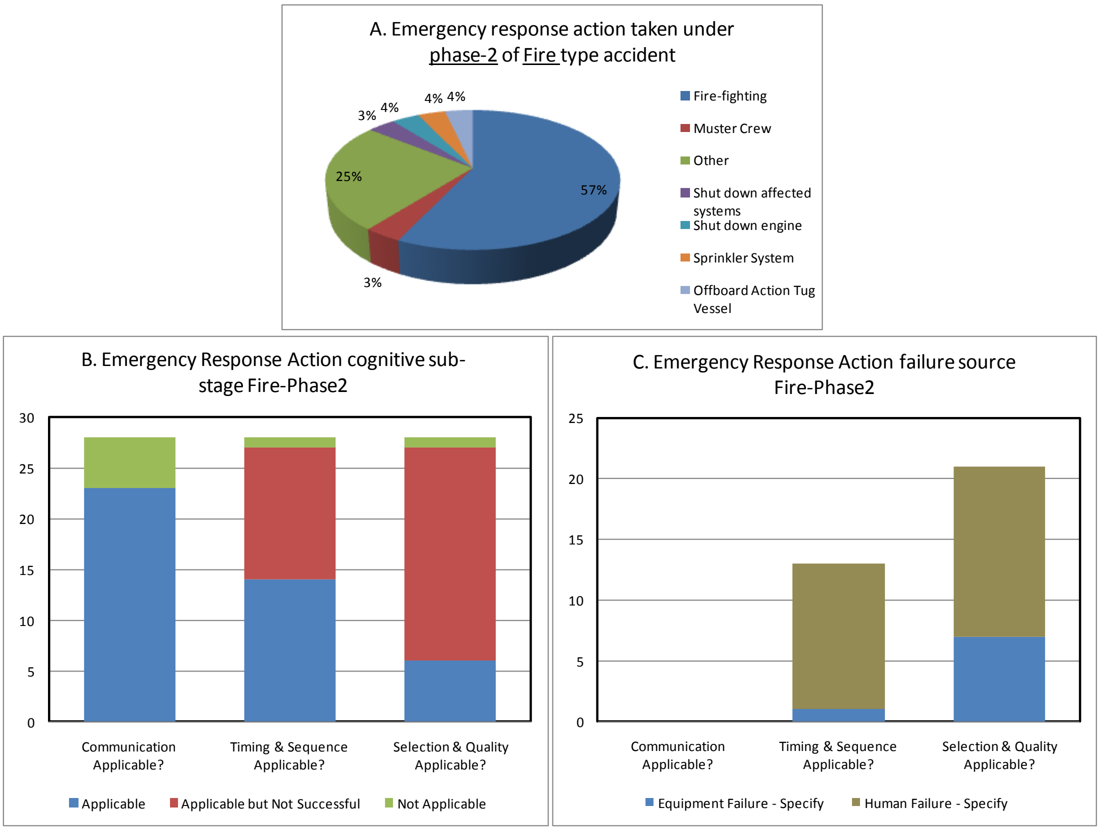
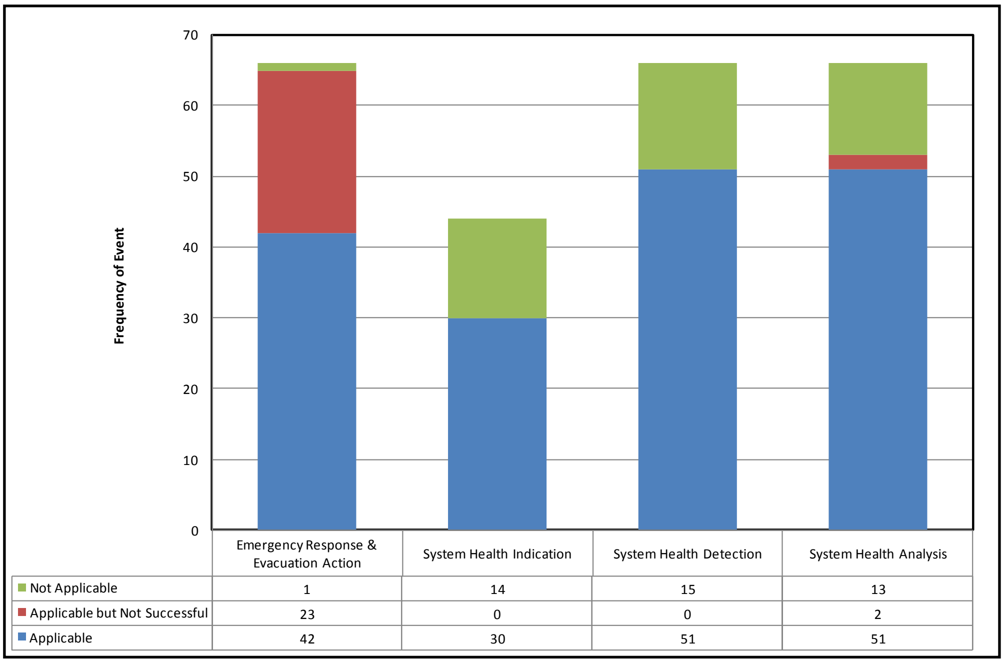


Figure 5-7: Detailed particulars for emergency response under phase-2 in fire type accident

From the 8 fire cases reviewed, 2 cases indicating proper situation handling during phase-2 that was able to mitigate the event, preventing is from developing into further consequences..

5.2.4 Phase-3 results for fire category accidents

In phase-3 for fire type accidents, the SEMOMAP recorded 66 events of cognition (see appendix-5, Table 0-74). The data shows that failure occurred continuously during the emergency situation and evacuation process.



	Emergency Response & Evacuation Action	System Health Indication	System Health Detection	System Health Analysis
Not Applicable	1	14	15	13
Applicable but Not Successful	23	0	0	2
Applicable	42	30	51	51

Figure 5-8: frequency of fail (red block) /safe (blue block) accident assessment process under phase-3 of fire type accident

From 23 failures identified in phase-3, 74% were caused by human failure which mostly occurred under selection and quality factors and timing and sequence factors (Figure 5-9).

The factors of action too little and action too late were the main human factors that took place in the failure, and were contributed to by the conditions of confusion, distraction, forgetting long-term training and procedure, and tunnel vision..

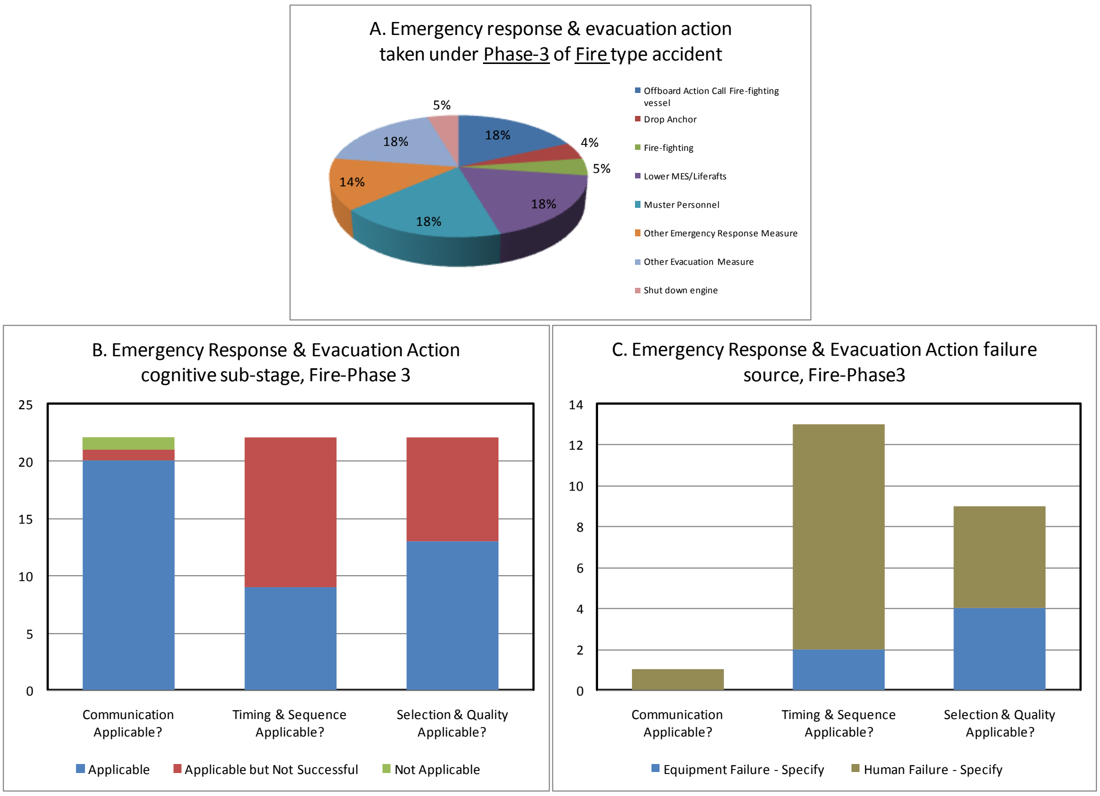


Figure 5-9: Detailed information for emergency response and evacuation action under phase-3 for fire type accident.

From the 8 cases reviewed, there are 2 cases that showed the event was mitigated up to phase-2, whereas the other 6 cases developed up to phase-3. For the cases developed up to phase-3, the final consequences of the cases were also varied. SEMOMAP records 4 cases of severe loss with casualty/s, 1 case with severe loss without casualty and 1 case of total loss without casualty.

5.3 SEMOMAP results for Capsize/Listing category accidents

5.3.1 Identified contributory factors for Capsize/Listing type accidents

Factors affecting human element under Capsize/Listing category accidents

From the 5 capsize cases reviewed, SEMOMAP recorded 26 factors of HFACS level 3, affecting 5 main human element performances (Table 5-3).

Under the *Organisational Influence* category, factors of *lack of human resources* and *poor equipment/facility resources* were the two main factors that contributed to the failure of the human element performance, increasing the risk of operation particularly for risk of capsize accident. The SEMOMAP also recorded the factors of *lack of training* and *lack of safety value* as the two most influential issues for crew performance in responding to the risk of capsize.

Table 5-3: Identified factors under HFACS level 2 that influence the Human Element performance for Capsize/Listing type accident

Factors			Total Identified Factor
L1	**L2**	**L3**	
Organisational Influences (i)	Resource Management	Lack of Human Resources	18
		Poor Technological Resources	1
		Poor Equipment/ Facility Resources	17
	Organisational Climate	Disorganised Structure	3
		Inadequate Policies	9
		Poor Work Culture	8
	Organisational Process	Poorly Designed Operations	13
		Inappropriate Procedures	3
		Lack of Oversight	13
	Statutory Factors	Poor International/ National Standards	5
		Inadequate Flag State Implementation	5
Supervision (ii)	Inadequate Supervision	Poor Shipborne and Shore Supervision	17
	Planned Inappropriate Operations	Poor Shipborne Operations	23
	Failed to Correct Known Problems	Shipborne Related Shortcomings	19
	Supervisory Violations	Shipborne Violations	5
Preconditions (iii)	Environmental Factors	Poor Physical Environment	12
		Poor Technological Environment	10
	Crew Condition	Negative Cognitive Factors	18
		Poor Physiological State	2
	Personnel Factors	Poor Crew Interaction	22
		Poor Personal Readiness	15
Unsafe Acts (iv)	Errors	Skill-based errors	17
		Decision and judgement errors	14
		Perceptual errors	3
	Violations	Routine	3
		Exceptional	7
		Total	282

Under the *Supervision* category, the selected cases indicated issues of *poor Shipborne operations* as the most affecting factor to crew performance, whereas the factor of *Shipborne related shortcomings* was the second most influencing factor.

More specifically, the factors of *lack of formal risk assessment* and *loss of supervisory situational awareness* are common issues that affect human element performance in terms of risk of capsize/listing accidents.

Poor ship movements and manoeuvres under environmental factors are the most common issues under the *Preconditions* category. From the perspective of the human factor issue, pattern of *poor risk judgment* is considered the second most influential factor related to human performance onboard ferry ships.

Under the unsafe act category, the data identifies *skill based error* factors such as *poor technique/seamanship* and *inadvertent use of equipment* as two common errors shown by the human element

The chart below indicates the human elements most affected by the gaps and misses in the system. Based on the reviewed cases, SEMOMAP recorded the captain, chief officer, helmsman, AB and bosun as the most affected human elements during capsize/listing type accidents. The data shows that under *organisational influence*, the master's performance was mostly affected by the factors of *resource management* and *organisational process*, whereas the chief officer, responsible for cargo preparation and management, was affected mostly by *personnel factors* under the supervision category (Figure 5-10).

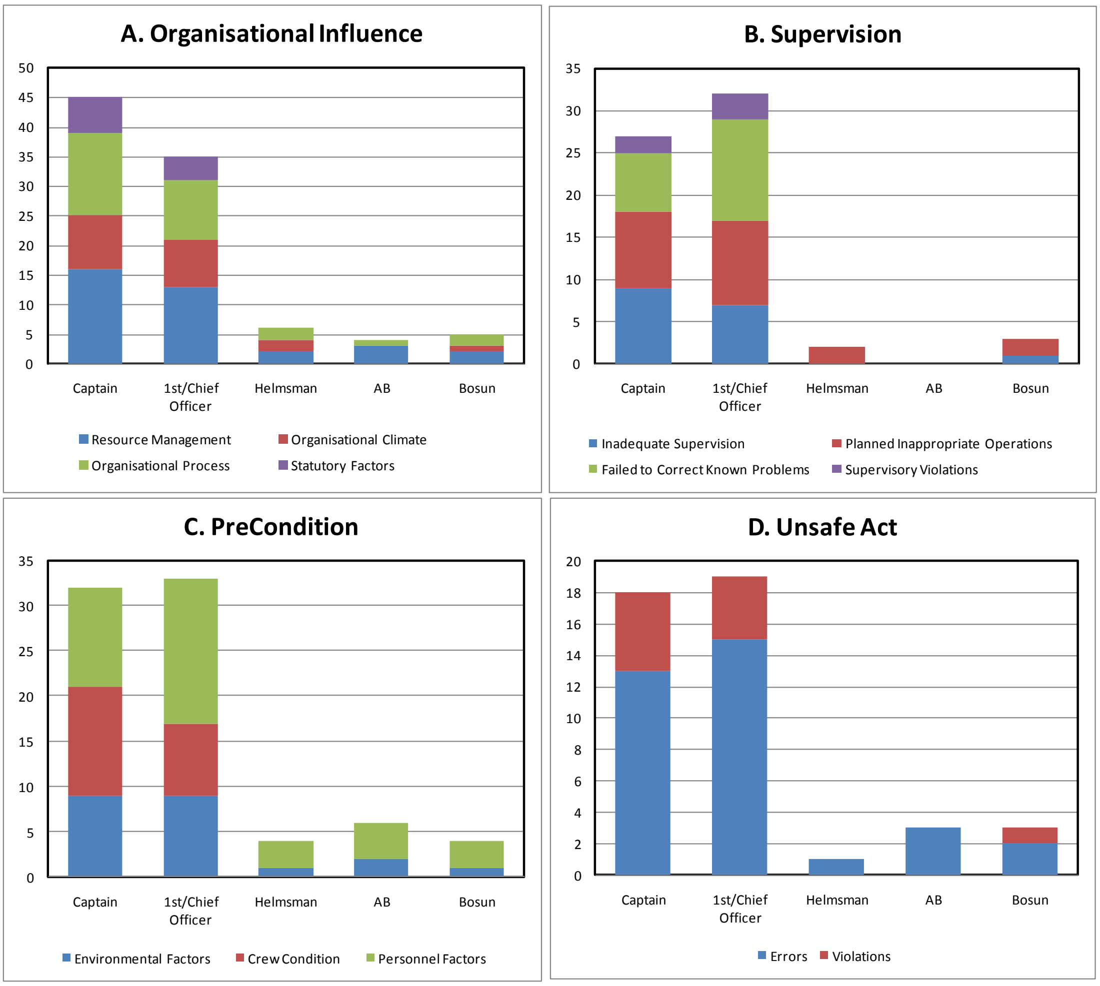


Figure 5-10: identified HFACS level-2 factors that influenced each involved Human performance in the capsize/listing type accident

Factors affecting technical element under Capsize/Listing category accidents

From the review of the 5 cases of Ropax ferry capsize/listing, SEMOMAP identified the 7 technical elements most involved and affected by the issues at the systemic level. The SEMOMAP also recorded 133 interactions of the 17 HFACS level-3 factors with the involved technical elements.

Table 5-4: Contributory factor influencing technical element for capsize/listing type accident

Factors			Total Identified Factor
L1	L2	L3	
Organisational Influences (i)	Resource Management	Lack of Human Resources	3
		Poor Technological Resources	7
		Poor Equipment/Facility Resources	28
	Organisational Climate	Poor Work Culture	9
	Organisational Process	Poorly Designed Operations	6
		Inappropriate Procedures	1
		Lack of Oversight	10
	Statutory Factors	Poor International/ National Standards	5
		Inadequate Flag State Implementation	12
Supervision (ii)	Inadequate Supervision	Poor Shipborne and Shore Supervision	5
	Planned Inappropriate Operations	Poor Shipborne Operations	9
	Failed to Correct Known Problems	Shipborne Related Shortcomings	7
	Supervisory Violations	Shipborne Violations	1
Preconditions (iii)	Environmental Factors	Poor Physical Environment	5
		Poor Technological Environment	22
	Personnel Factors	Poor Personal Readiness	1
Unsafe Acts (iv)	Violations	Exceptional	2
		Total	133

As regards *organisational influence*, the factor of *poor equipment/facility resources* under *resource management* was the most influential aspect to the degrading performance of the technical element. This factor mostly affects hull condition and other technical elements such as scupper/freeing port in the car deck, and watertight openings (ramps, doors). Factors of *inadequate flag state implementation* such as *class and statutory survey* were considered as the second most influential factor to the performance of involved technical element.

Under the *supervision* category, the factor of *poor Shipborne operations* was identified as affecting the technical element, whereas the factor of *Shipborne related shortcomings* was the second influential factor (Figure 5-11 A). The factors mostly influence the technical elements of hull, steering equipment and other types as mentioned in the previous paragraph.

The factor of *poor technological environment* was identified as the most influencing factor to the degrading performance of the involved technical element. More specifically, faulty equipment was the factor that mostly took place in the hull, steering equipment, and freeing port in the car deck, thus increasing the risk of capsize/listing in Ropax ferry operation.

Unsafe acts were also found to influence the degrading performance of the technical element. The data indicates that factors of *exceeding limits of system* and *unauthorised to operate beyond design criteria* under *exceptional violation* type were the two factors that took place in the capsize/listing type accidents.

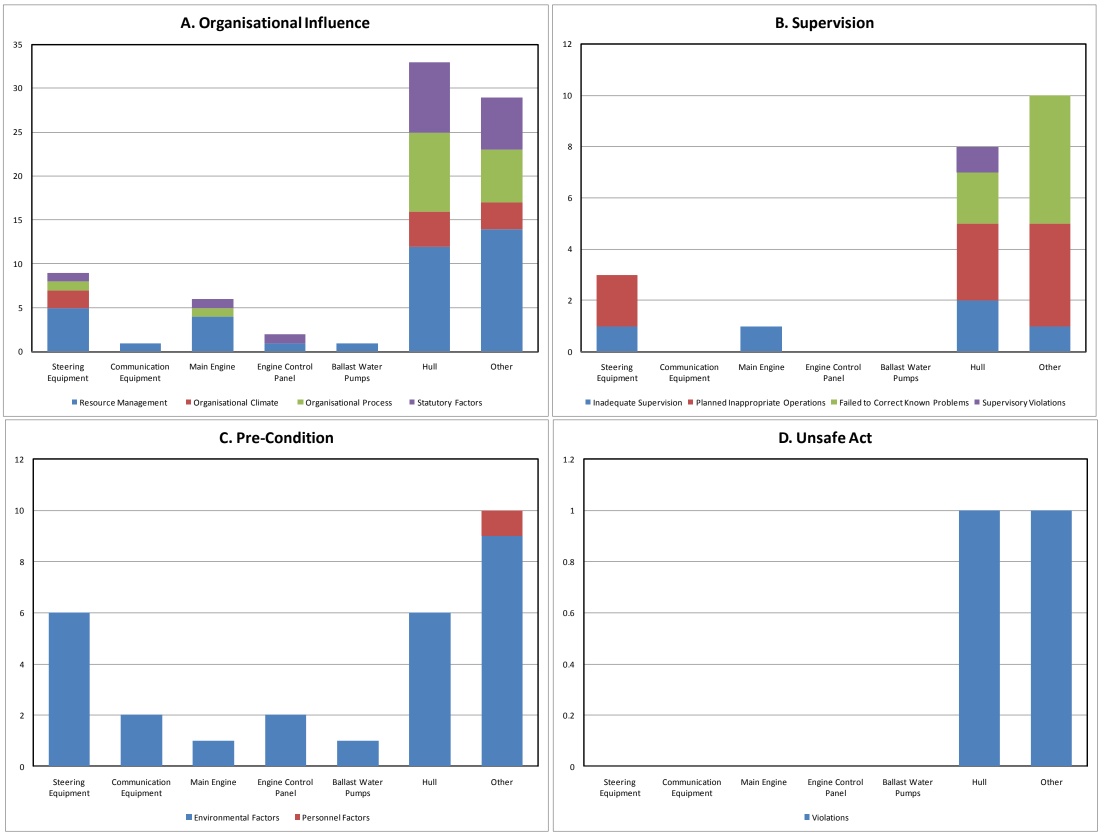


Figure 5-11: Identified HFACS level-2 factors that influenced each involved technical performance in the capsize/listing type accident

5.3.2 Phase-1 result for the Capsize/Listing type accidents

From the review of 5 Ropax ferry capsize accidents, SEMOMAP recorded 90 cognitive processes. During phase-1 for capsize/listing type accident, failure was found in every stage of the cognitive process, but mostly took place during the last step of threat prevention action (Figure 5-12).

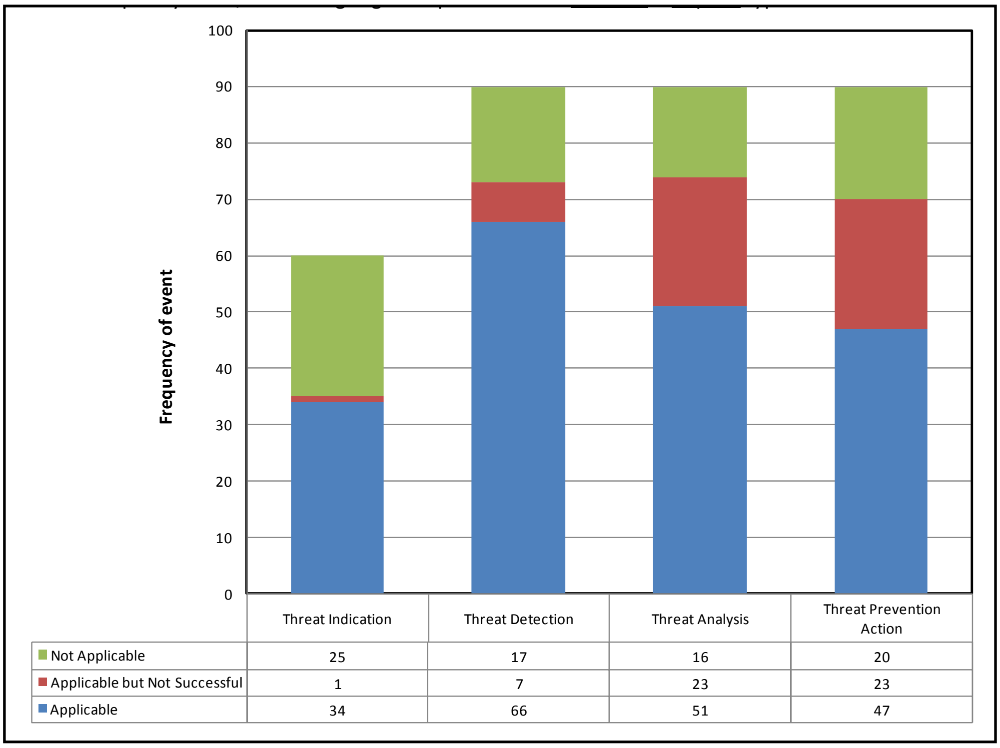


Figure 5-12: frequency of fail (red-block) and safe (blue-block) of accident assessment process under phase-1 for capsize/listing type accident

During phase-1 of capsize/listing type accident, human failure is identified as the main factor compared to equipment failure. From 54 failures that increased the risk of capsize in ferry operation during phase-1, 93% came from human failure, whereas 7 % came from equipment failure.

Under phase-1, human failure took place more during threat analysis and threat prevention action. There are 4 main subjects involved in the stage including: master (83%), officer on watch (7%) and other crew (Figure 5-13 A). During threat analysis, failures occurred during the setting up planning and decision making process, such as failure in planning and decision making or partial/unclear planning. The factors that influenced failure in decision were mostly those of expectation bias, desire for harmony, lack of vigilance and time pressure.

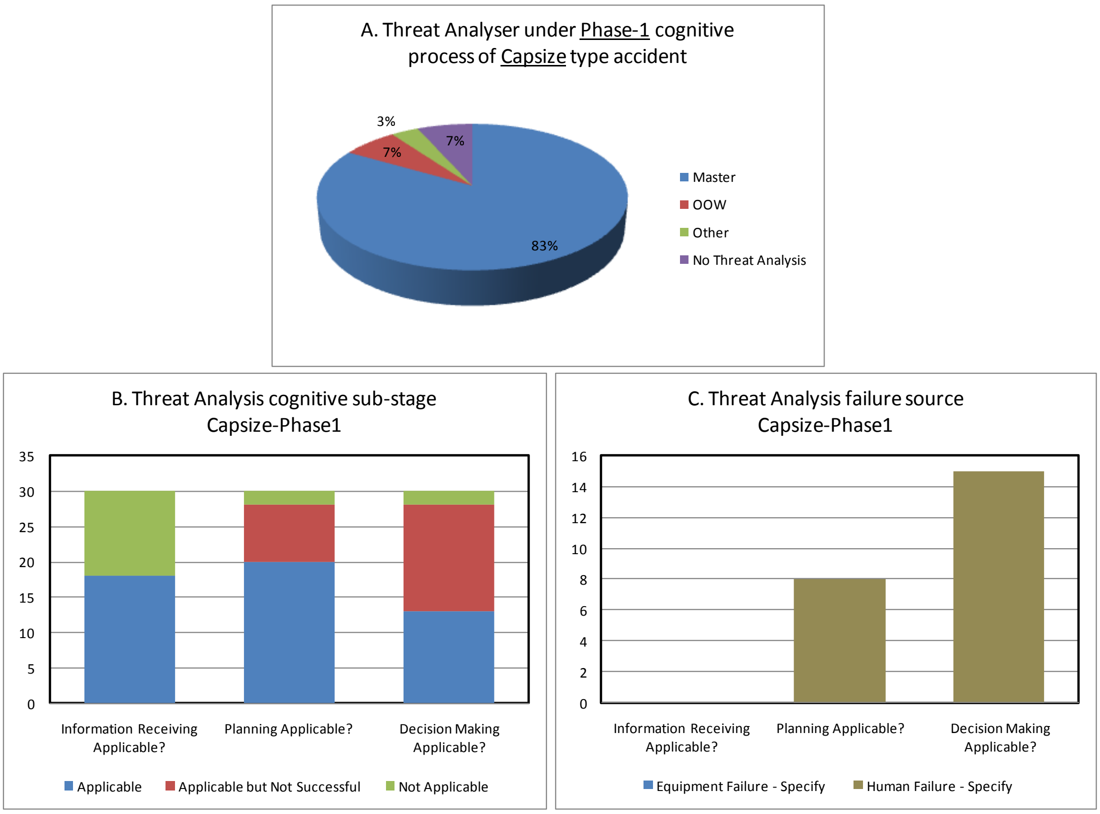


Figure 5-13: detailed information on the threat analysis action under phase-1 for capsize/listing type accident

The SEMOMAP records four main actions taken to prevent capsize from occurring: altering speed, stabilising and securing cargo and other actions such as reduce stop ship movement, and pumping out flooding (Figure 5-14 A). However, failures occurred during this stage. Most of the failures identified took place due to timing and sequence (action too late), and selection and quality (action too little). For human failure, causal factors were confusion, forgetting long-term training, time pressure, and lack of vigilance.

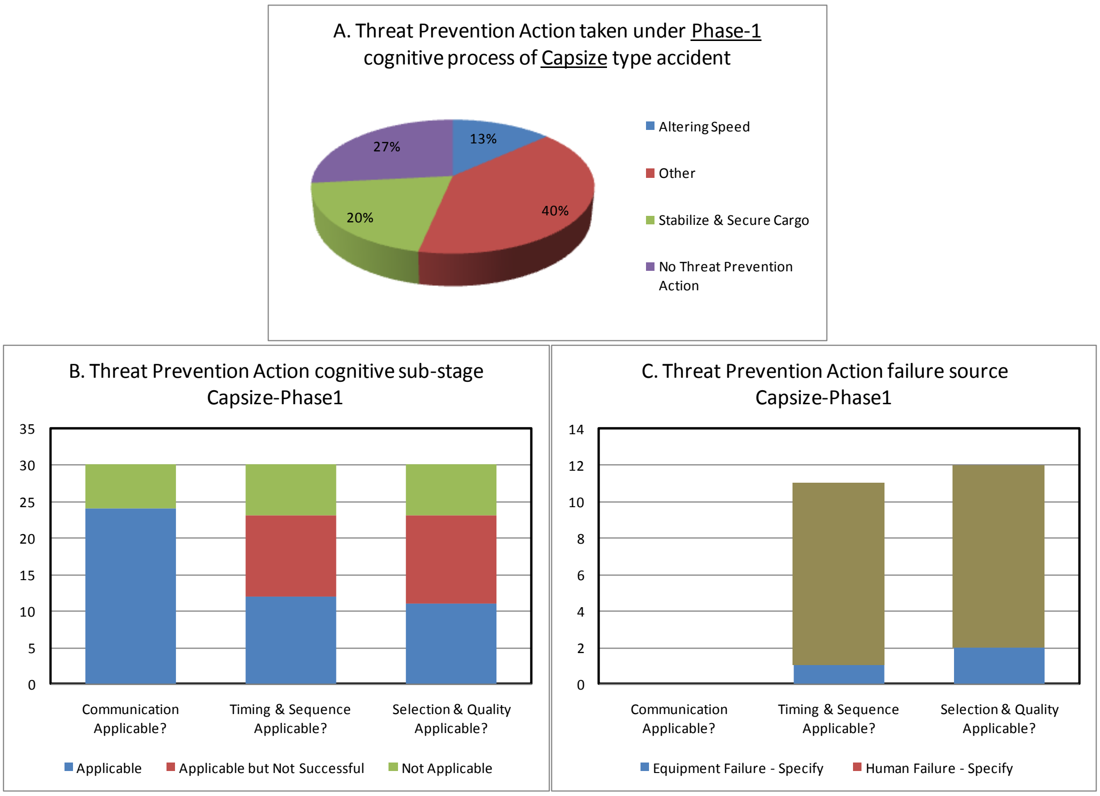
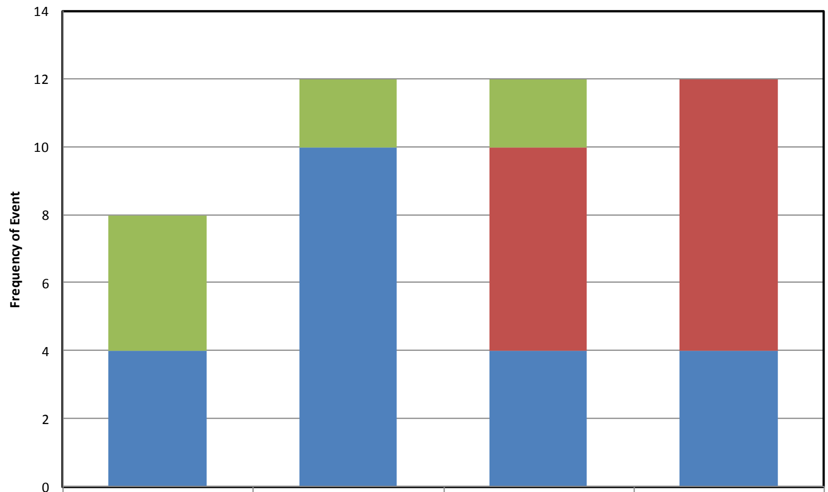


Figure 5-14: Detailed information on the threat prevention action under phase-1 for capsize/listing type accident

5.3.3 Phase-2 result for the Capsize/Listing type accidents

During phase-2 for the 5 cases of capsize/listing Ropax ferry, SEMOMAP recorded 12 events of cognitive process.

From the observed cases, the first two steps of cognition (system health indication and system health detection) successfully responded to the situation by providing proper detection of the potential system health issue after the accident took place. However, the data shows that failures during the accident assessment process under system health analysis occurred. The failures were observed mostly from humans, whereas equipment contributed less during that stage. The Master is known to take all responsibility during the analysis process; however, the data indicates that failures mostly occurred during the decision making stages. This was caused by factors of confusion, distraction, and lack of vigilance and, since the accident had started, time pressure existed as well.



	System Health Indication	System Health Detection	System Health Analysis	Emergency Response Action
Not Applicable	4	2	2	0
Applicable but Not Successful	0	0	6	8
Applicable	4	10	4	4

Figure 5-15: frequency of fail (red-block) and safe (blue-block) of accident assessment process under phase-2 for capsize/listing type accident

Failure in taking emergency response action was also observed. Altering speed is the most common action taken by the crew after becoming aware of compromised stability. However, the issues existed not just in the timing and sequence (such as action too late), but also in its selection and quality (action too little). Human failure is identified to contribute to the failure during the stage of action taking (Figure 5-16 C). The common human factors that influence failure are mostly confusion, lack of vigilance, and distraction.

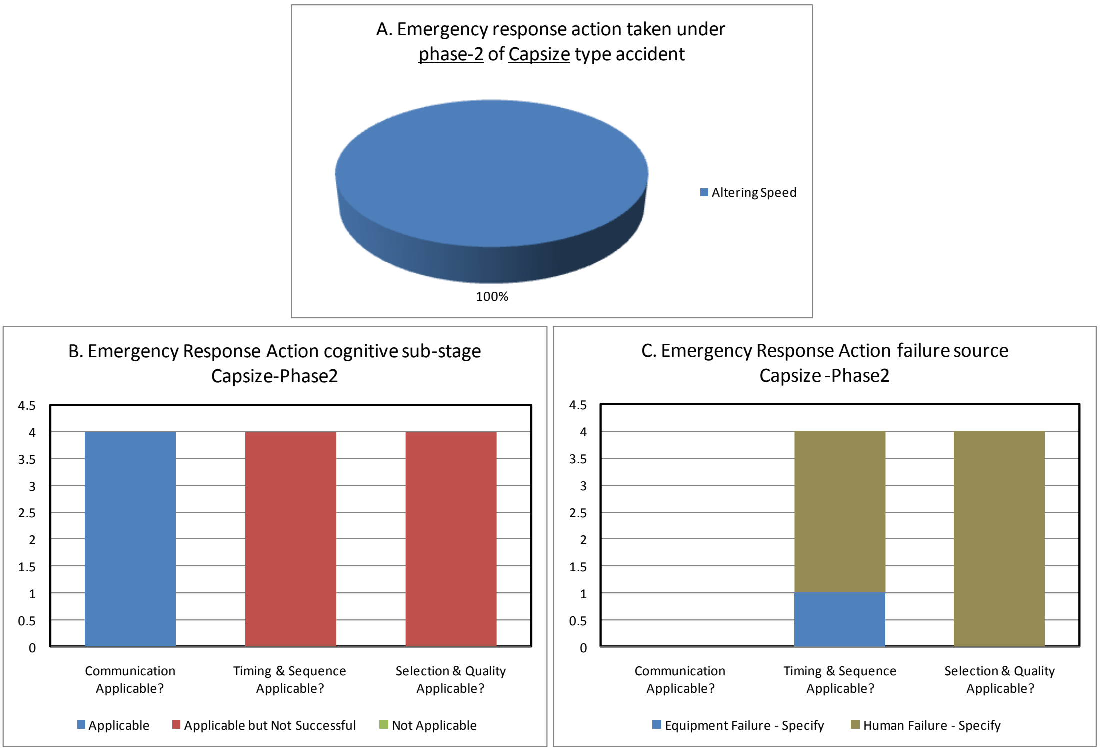
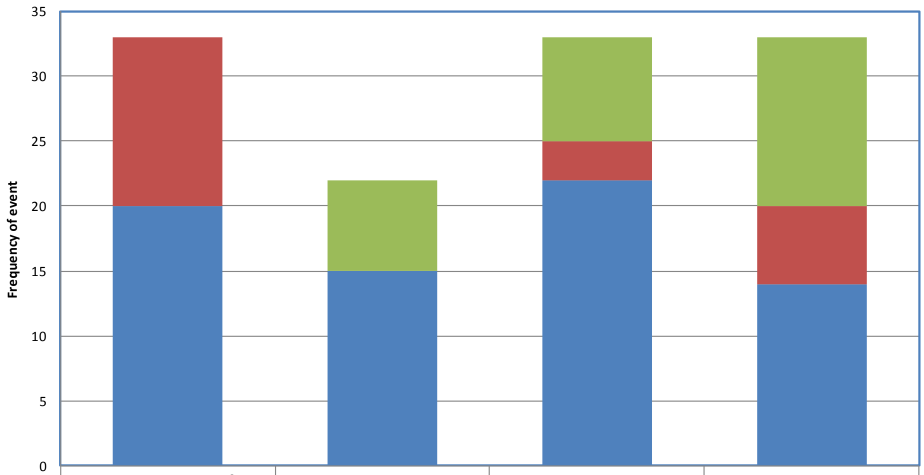


Figure 5-16: Detailed information on the emergency response action under phase-2 for capsize/listing type accident

Up to phase-2, the accident data shows no proper mitigation action taken by the related parties. Hence, most of the cases reviewed continued to the next phase of the accident.

5.3.4 Phase-3 result for the Capsize/Listing type accidents

From the 5 cases of Ropax ferry capsize/listing accidents, SEMOMAP recorded 33 event of accident assessment process to deal with the emergency situation. The data compiled shows that emergency response was taken mostly by the muster personnel, lowering MES (marine emergency system)/liferafts and call for SAR services. From the data compiled, failure during the phase continued to occur. Failures observed mostly during stage of emergency response and evacuation action (Figure 5-17). This condition is considered to influence the process of evacuation, whether successful or causing more loss of life.



	Emergency Response & Evacuation Action	System Health Indication	System Health Detection	System Health Analysis
FALSEFALSE	0	7	8	13
TRUEFALSE	13	0	3	6
TRUETRUE	20	15	22	14

Figure 5-17: frequency of fail (red-block) and safe (blue-block) of accident assessment process under phase-3 for capsize/listing type accident

Failures were identified mainly during the process of evacuation itself. SEMOMAP records factors of timing and sequence, and selection and quality as still the most common issues. Failure was also observed to take place during the stage of analysis, specifically during the planning and decision making process. Human failure was also the source of failure that resulted in the overall problem in the evacuation stage (Figure 5-18). The human factors that commonly existed and affected the failure were delay in planning and taking decisions, due to factors of confusion, expectation bias, time pressure and distraction.

From the reviewed cases, due to insufficient effort and mitigation of the issues, all cases resulted in total loss with casualty/s.

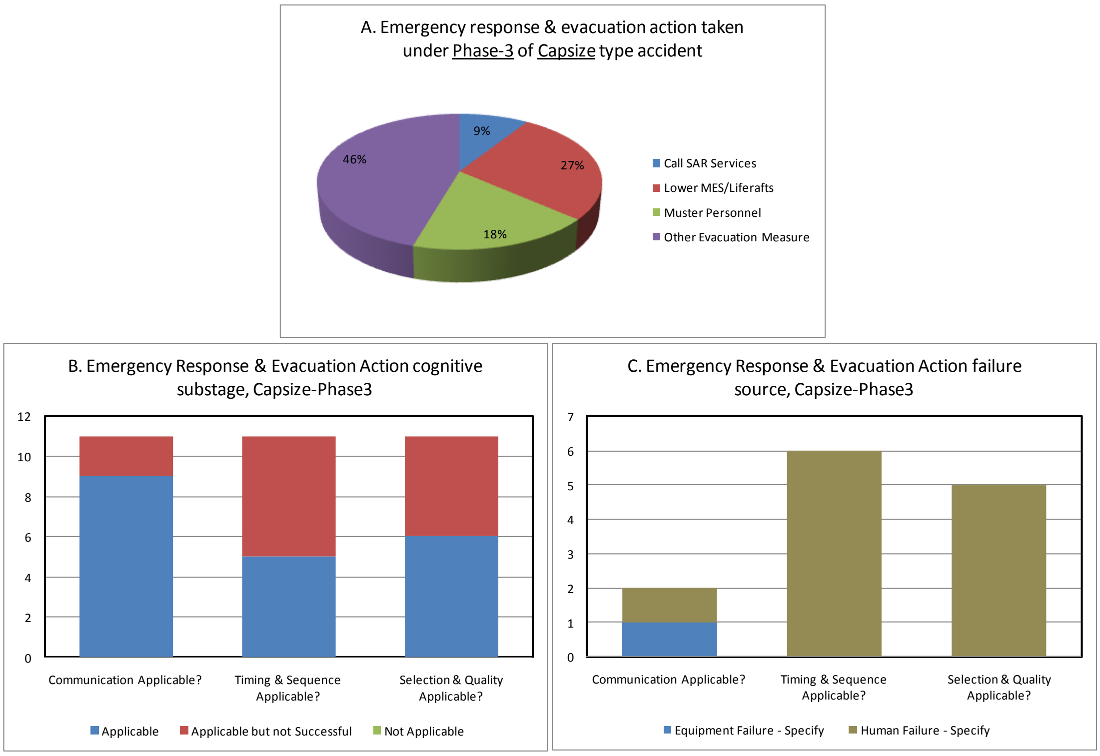


Figure 5-18: Detailed information on the emergency response and evacuation action under phase-3 for capsize/listing type accident

5.4 SEMOMAP results for Collision type accidents

5.4.1 Identified contributory factors for collision type accidents

Factors affecting human element under Collision category accidents

For the 3 cases of ropax ferry involved collision accidents, SEMOMAP recorded 188 interactions between 5 human elements involved in the collision accident with 26 factors of HFACS level-3. In particular, for collision type accidents, Pilot is another human element present as a support during the navigational process.

Under the organisational influence category, factors under resource management are the most influential for crew performance in handling the risk of collision. Lack of human resources (in terms of training and manning), and presence of poor equipment/facility resources are found to be the most common issues affecting crew behaviour when dealing with risk of collision (Figure 5-19A). The captain, the officer on watch and helmsman are the common human elements affected.

Under the supervision category, the factor of Shipborne related shortcomings is known to develop risk of collision and affect crew performance when handling this kind of situation. The most identified factor that took place was failure to identify corrective action and failure to correct inappropriate/risky behaviour. The issues affected the captain, chief officer, OOW, helmsman and pilot (Figure 5-19 B).

Table 5-5: Identified factors under HFACS level 2 that influence the Human Element performance for Capsize/Listing type accident

Factors			Total Identified Factors
L1	L2	L3	
Organisational Influences (i)	Resource Management	Lack of Human Resources	5
		Poor Technological Resources	3
		Poor Equipment/Facility Resources	6
	Organisational Climate	Disorganised Structure	2
		Inadequate Policies	1
		Poor Work Culture	6
	Organisational Process	Poorly Designed Operations	3
		Lack of Oversight	11
	Statutory Factors	Poor International/ National Standards	4
		Inadequate Flag State Implementation	6
Supervision (ii)	Inadequate Supervision	Poor Shipborne and Shore Supervision	12
	Planned Inappropriate Operations	Poor Shipborne Operations	13
	Failed to Correct Known Problems	Shipborne Related Shortcomings	23
	Supervisory Violations	Shipborne Violations	2
Preconditions (iii)	Environmental Factors	Poor Physical Environment	10
		Poor Technological Environment	5
	Crew Condition	Negative Cognitive Factors	7
		Poor Physiological State	1
	Personnel Factors	Poor Crew Interaction	23
		Poor Personal Readiness	10
Unsafe Acts (iv)	Errors	Skill-based errors	14
		Decision and judgement errors	10
		Perceptual errors	6
	Violations	Routine	1
		Exceptional	4
		Total	188

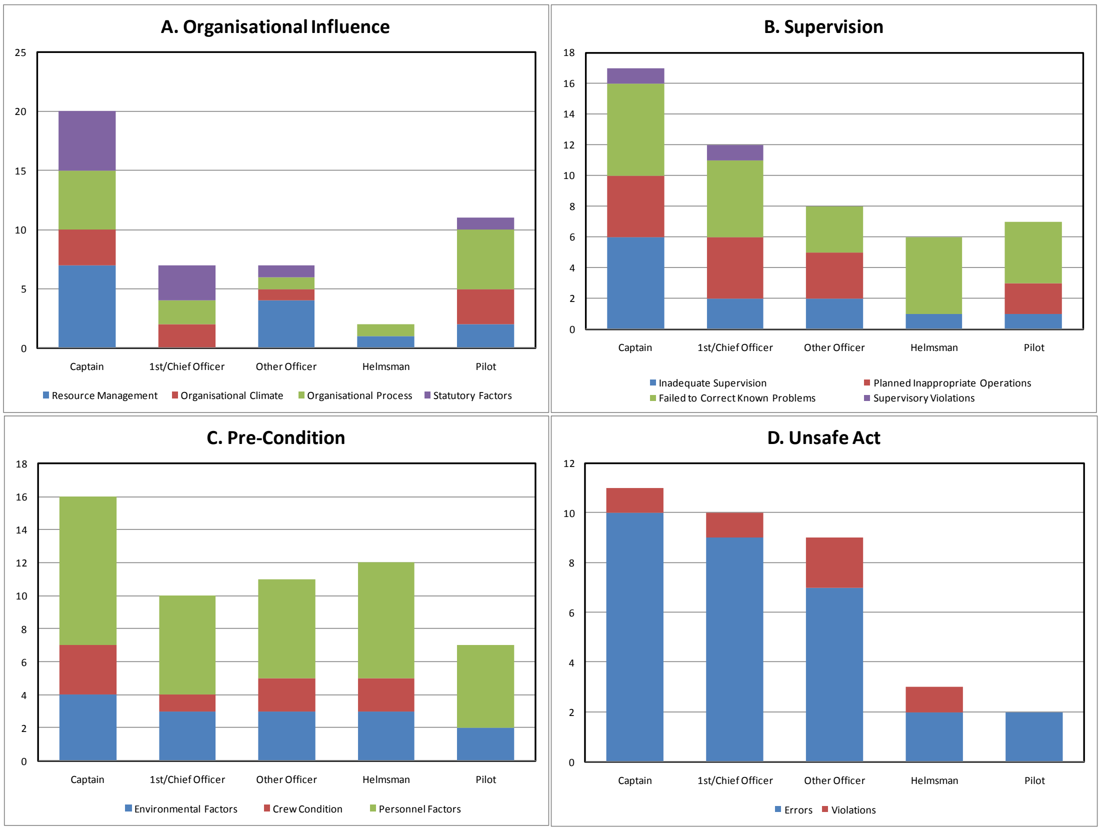


Figure 5-19: identified HFACS level-2 factors that influenced each involved human performance in the collision type accident

Under the precondition category, personal factors are identified as common issues in the escalation of risk of collision. Most of the factors are poor crew interaction and poor personal readiness to handle the risk of collision. Another significant factor is lack of cross-monitoring performance mainly indicated during the critical stage of operation and the risk of collision becoming prominent. The factors were identified to affect all involved human elements as mentioned in the previous paragraph. The environment factor as well as ship movement and manoeuvres are other significant factors that influence crew performance in handling risk of collision.

Under the unsafe act category, the errors are the prominent factors observed, whereas some violations were also identified during the handling of risk of collision. Poor techniques/seamanship is the obvious factor under skill based error shown by the crew when handling risk of collision. The data also identified perceptual errors as another symptom of error by the crew.

Factors affecting technical element under Collision type accidents

From the 3 cases of Ropax ferry collision, SEMOMAP recorded 15 interactions between two technical elements with 10 factors of HFACS level-3. The hull and main engine are the technical elements that were most involved during the risk of collision.

Under *organisational influence*, *poor equipment/facility resources* as well as organisational climates are the two common issues in Ropax ferry operation that increase risk of collision (Table 5-6). More specifically, Lack of *engineer support, issues in acquisition policies/ design process, Failure to correct known design flaws* under resource management is identified to influence the technical element such as ship hull and main engine.

Under the *supervision* category, two factors of *poor shipborne operations* and *shipborne related shortcomings* are found to affect the condition of the hull and main engine which later increased the risk of collision.

Table 5-6: Identified factors under HFACS level 2 that influence the Human Element performance for Capsize/Listing type accident

<table>
<tr><th colspan="3">Factors</th><th rowspan="2">Total Identified Factors</th></tr>
<tr><th>L1</th><th>L2</th><th>L3</th></tr>
<tr><td rowspan="6">Organisational Influences (i)</td><td rowspan="2">Resource Management</td><td>Poor Technological Resources</td><td>1</td></tr>
<tr><td>Poor Equipment/Facility Resources</td><td>3</td></tr>
<tr><td rowspan="2">Organisational Climate</td><td>Poor Work Culture</td><td>1</td></tr>
<tr><td>Lack of Oversight</td><td>2</td></tr>
<tr><td rowspan="2">Statutory Factors</td><td>Poor International/National Standards</td><td>1</td></tr>
<tr><td>Inadequate Flag State Implementation</td><td>1</td></tr>
<tr><td rowspan="2">Supervision (ii)</td><td>Planned Inappropriate Operations</td><td>Poor Shipborne Operations</td><td>1</td></tr>
<tr><td>Failed to Correct Known Problems</td><td>Shipborne Related Shortcomings</td><td>1</td></tr>
<tr><td rowspan="2">Preconditions (iii)</td><td rowspan="2">Environmental Factors</td><td>Poor Physical Environment</td><td>2</td></tr>
<tr><td>Poor Technological Environment</td><td>2</td></tr>
<tr><td></td><td></td><td>Total</td><td>15</td></tr>
</table>

Factors of *poor physical environment* and *poor technological environment*, such as ship movement and faulty equipment, were also identified to contribute significantly to the degrading performance of hull and main engine.

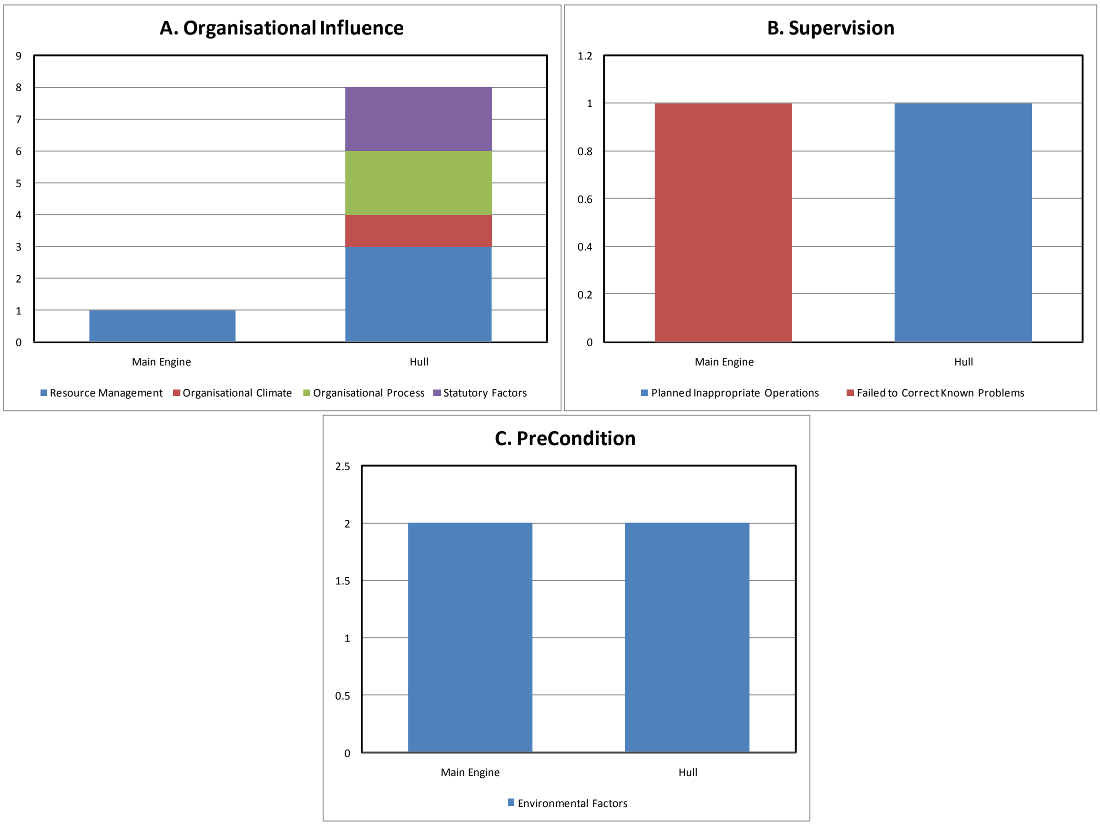
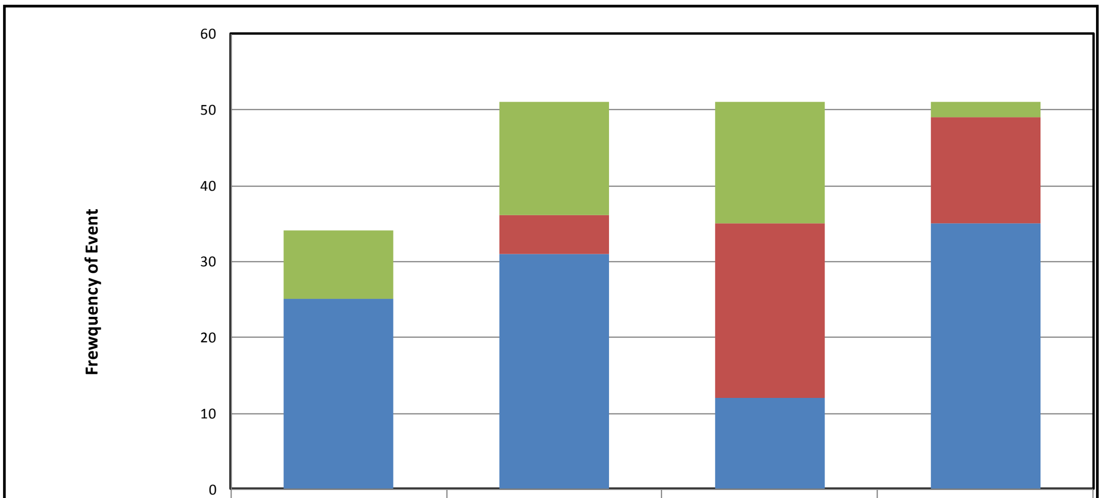


Figure 5-20: identified HFACS level-2 factors that influenced each involved technical performance in the collision type accident

5.4.2 Phase-1 result for the collision type accidents

Following the review of the sequence of events for 3 cases of Ropax ferry collision, SEMOMAP recorded 51 cognition processes (Figure 5-21).



	Threat Indication	Threat Detection	Threat Analysis	Threat Prevention Action
Not Applicable	9	15	16	2
Applicable but Not Successful	0	5	23	14
Applicable	25	31	12	35

Figure 5-21: frequency of fail (red-block) and safe (blue-block) of accident assessment process under phase-1 for collision type accident

There are five common components identified to indicate risk of collision, which are AIS, Lookout, and other equipment such as radar and Sea chart. The SEMOMAP result shows that there was no failure of indication of risk of collision by all relevant and available means.

However, failure in handling risk of collision was mostly identified during the stage of analysis of the threat of collision. Under this stage, most of the failures were observed to take place during the planning and decision making process. These were identified as human failures, including mistakes and delays in planning and making decisions. More specifically, human factors such as confusion, distractions, forgetting long term training and procedures, and lack of vigilance are identified as the common issues involved in the failure of the cognitive process.

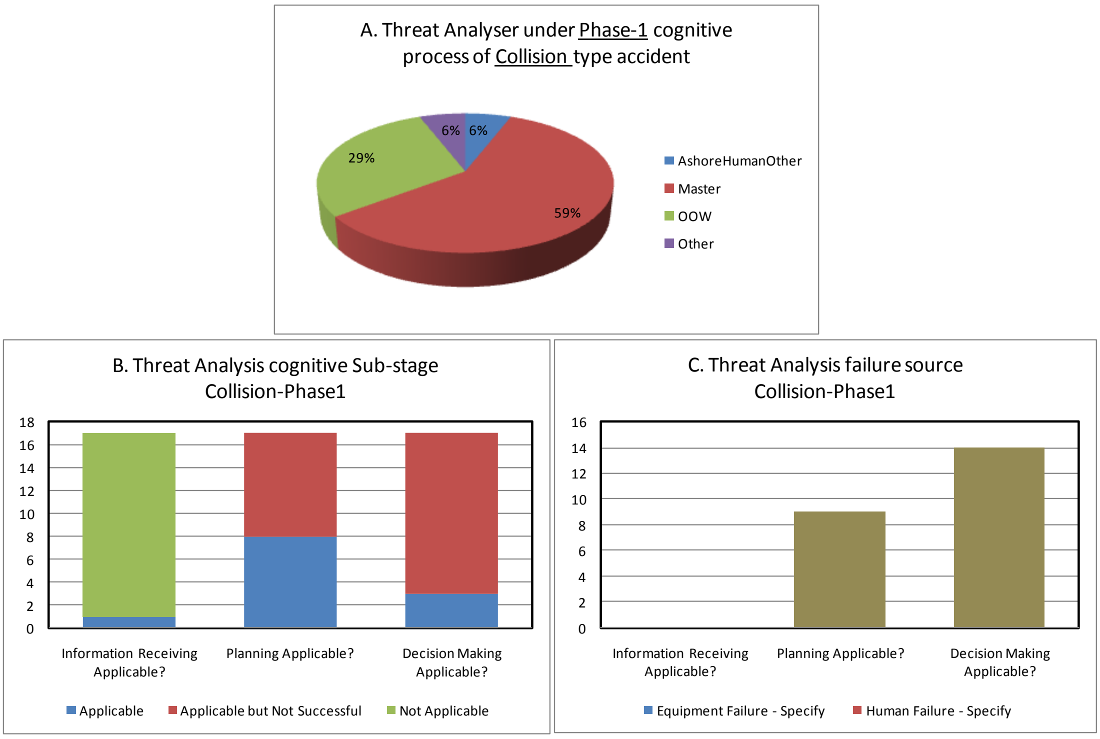


Figure 5-22: detailed information on the threat analysis under phase-1 for collision type accident

Failures during this stage of analysis contributed to the failure to take preventive action. The SEMOMAP recorded 6 common actions taken to prevent the risk of collision from developing. On the shipboard side, reverse thrust, steering and manoeuvring, and altering speed were the common actions taken; meanwhile, on the offboard side, other vessels took actions such as altering course and altering speed. However, failures were indicated mostly under timing and sequence and also under selection and quality. Under timing and sequence, action too late is the common problem indicated by crew performance to deal with the risk of collision. This was mainly caused by human factors of distraction, expectation bias and forgetting long-term training. The human factors were mainly the result of desire for harmony, discrimination failure, distraction and forgetting long-term training and procedure.

The data indicates that due to improper handling at every stage of cognition to the risk of collision, the events later developed into accidents

5.4.3 Phase-2 result for the collision type accidents

During phase-2, SEMOMAP recorded a total of 27 cognition processes from 3 collision cases observed (Figure 5-23).

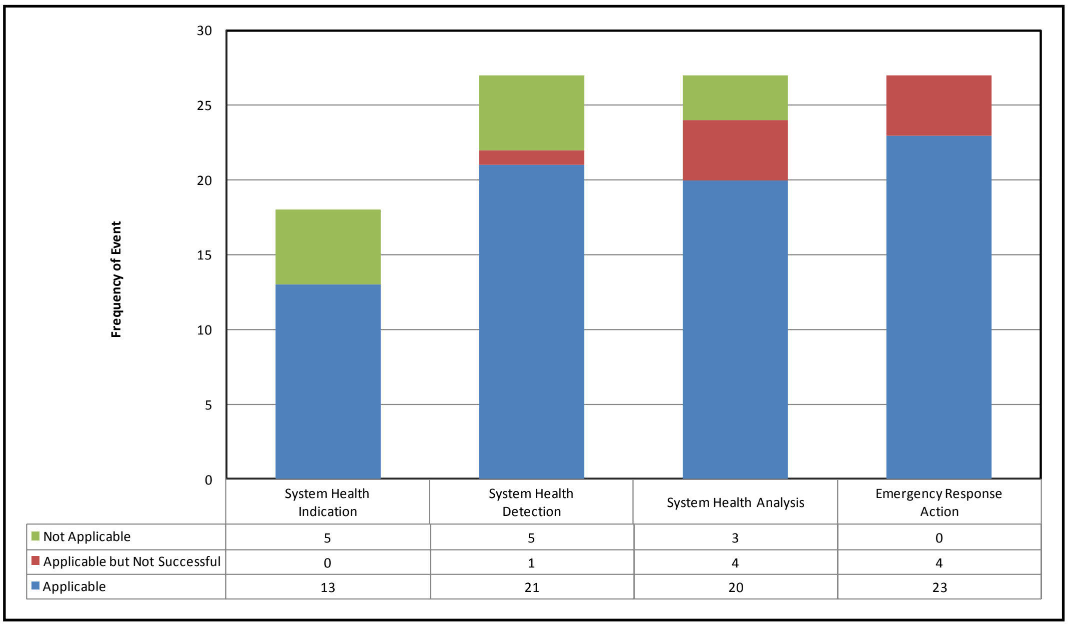


Figure 5-23: frequency of fail (red-block) and safe (blue-block) of accident assessment process under phase-2 for collision type accident

Since the collision become obvious, all indicative measures showed sufficient information to determine the status of the ship after the accident. All related indicators such as hull damage sensor, stability indicator, the crew and even passengers themselves were involved in the stage. However, the failures came to exist during the next step of cognition.

During the system health detection stage, failures were observed mainly during the evaluation stage where the human was the main source of the issues. Typical causes of human failures were factors of confusion, distraction, forgetting long-term training, tunnel vision and expectation bias. Other crew as a common source of system health detection shows the factor of confusion as the common human factor in place.

Improper handling of events after the collision worsened the situation by other failures that happened during system health analysis. The master was identified as the major human element during this stage. The data shows that most of the failures occurred during the planning and decision making process. Key factors were delay in planning and decision, commonly due to human factors of distraction, discrimination failure, and expectation bias.

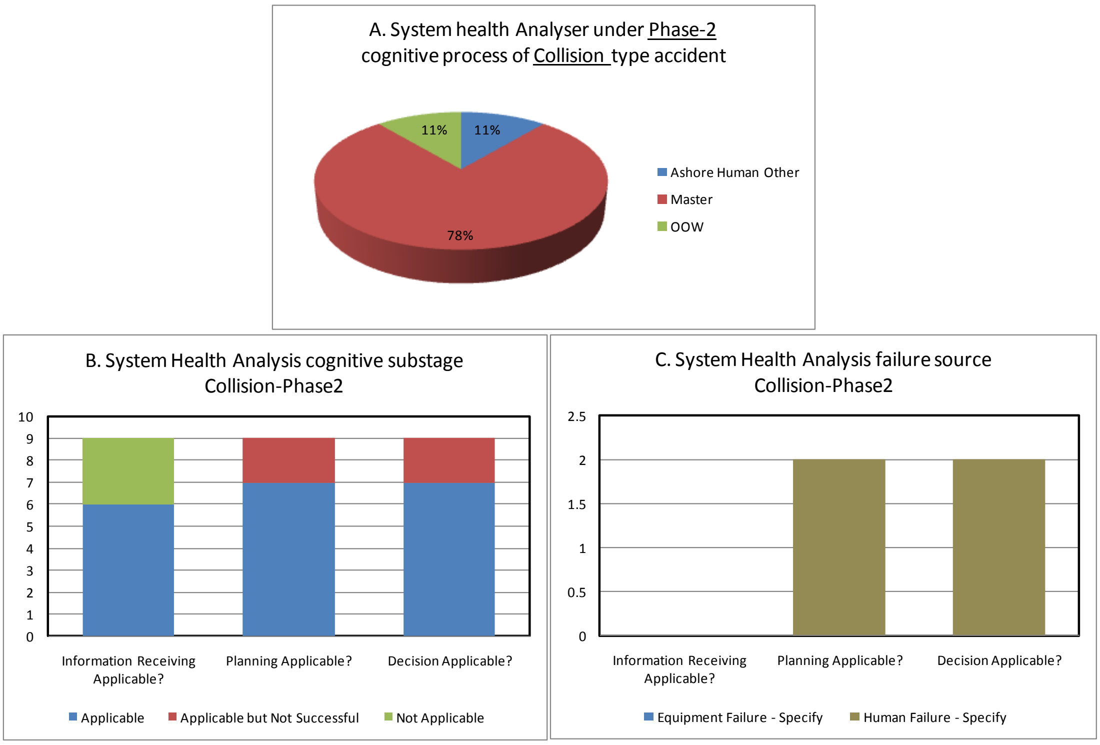


Figure 5-24: detailed information on the system health analysis under phase-2 for collision type accident

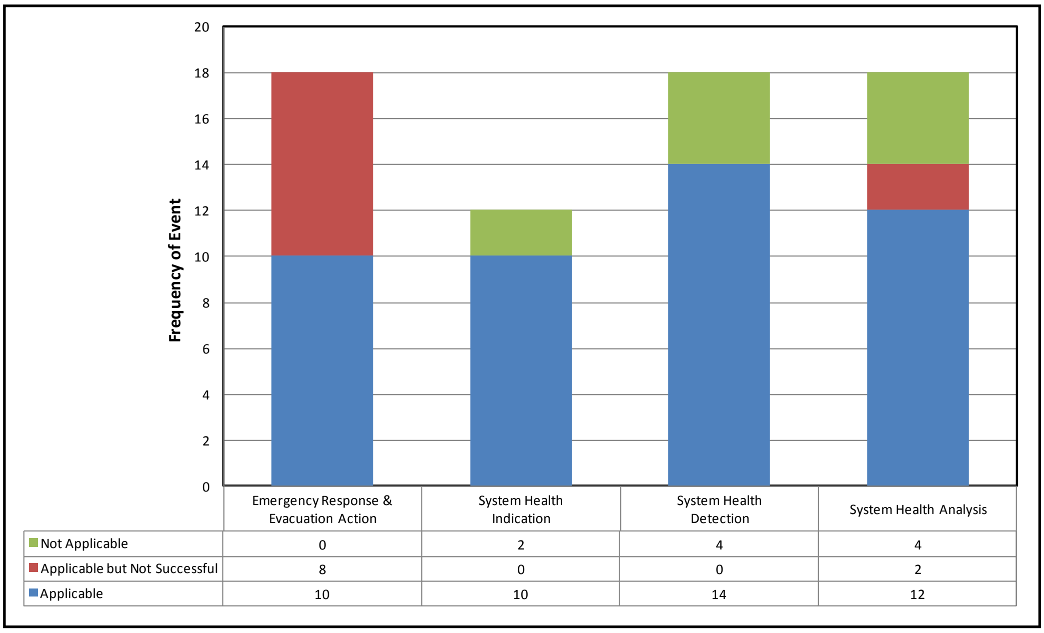
Even though errors and failures took place at every stage of the cognitive process, not all collisions ended up with severe consequences. The SEMOMAP recorded 1 case that concluded with mitigated loss but, unfortunately, with casualty as a result.

From the cases of Ropax ferry collision, it was also observed that the event of collision is a trigger for development of other events. For instance, 1 case of collision resulted in the over heeling of the ferry that allowed seawater ingress to the cardeck and later the event of capsize developed. Another case shows that fire broke out after the event of collision. Hence the subsequent evacuation effort was related to the fire accident.

During the emergency response under phase-2 for collision cases, SEMOMAP identified 6 common actions taken namely: contained hull damaged, stability and secure cargo, sprinkler system, and fire fighting. Failures were observed during the process which mostly occurred under timing and sequence factor (action too late), and quality and selection (action too little). The failure data shows that the failures came from common human factors such as confusion, distraction, forgetting long-term training and procedure.

5.4.4 Phase-3 result to the collision type accident

Since the outcome of phase-2 varies due to different development of accidents, the data also provides different information of response. For instance, as one collision did not result in severe consequences, no further phase was developed. However, in the other cases, failures were observed to occur in different stages of cognition during phase-3



	Emergency Response & Evacuation Action	System Health Indication	System Health Detection	System Health Analysis
Not Applicable	0	2	4	4
Applicable but Not Successful	8	0	0	2
Applicable	10	10	14	12

Figure 5-25: frequency of fail (red-block) and safe (blue-block) of accident assessment process under phase-3 for collision type accident

SEMOMAP recorded 6 common emergency actions taken during the evacuation process such as call SAR service, muster personnel and lower MES/liferaft. However, as fire was also found to develop after collision, of fire fighting was also performed during the phase.

During the emergency response, failure was observed to occur. Failures were identified during all cognitive processes of the emergency process: communication, timing and sequence, and selection and quality (Figure 5-26 C). From the cases reviewed, the human is identified as the sole source of the failures, which were due to factors of confusion, distraction, forgetting long-term training and procedures and other factor such as being overwhelmed due to the panic situation of passengers.

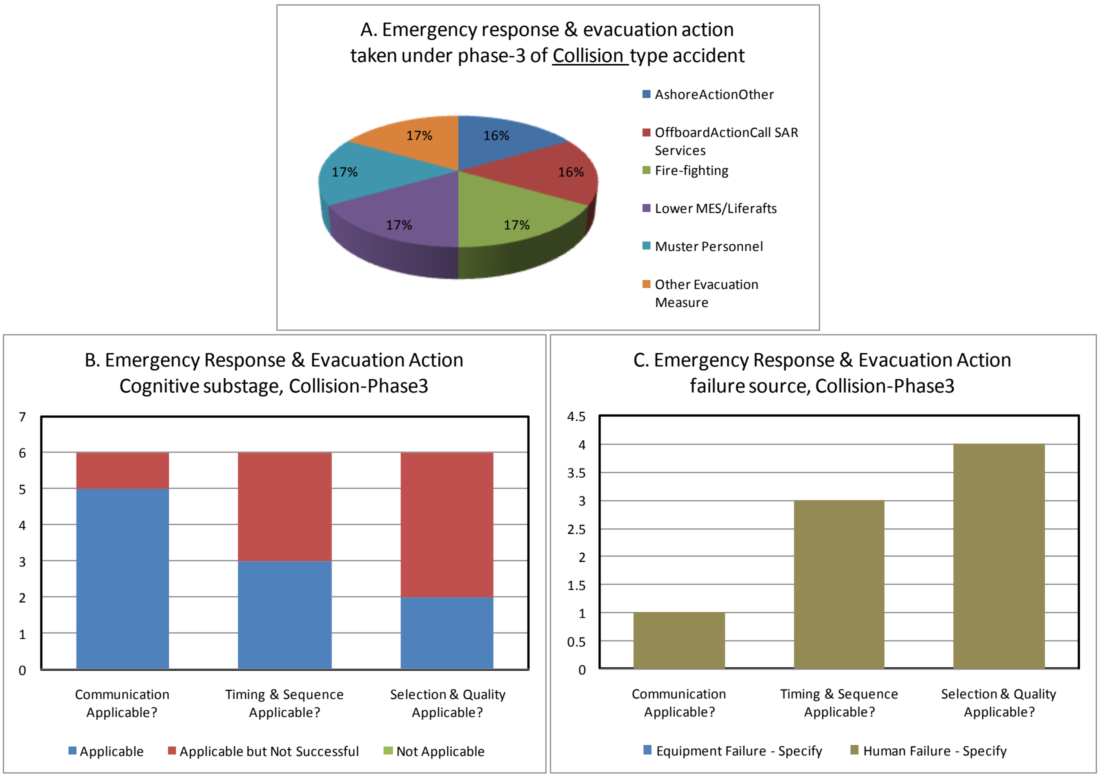


Figure 5-26: detailed information on the emergency response and evacuation action under phase-3 for collision type accident

Failures were also observed during the system health analysis stage which mainly took place during the planning and decision making stage. Human is observed as the main source of failure. The captain takes a major role in analysing the situation during the emergency stage as the captain is the person in charge when the situation becomes worse. From the cases reviewed, delay in decision making contributed to the failure of the evacuation process. In addition, common factors that influenced the failure of the master were confusion, expectation bias, and forgetting long term training and procedure

Of the SEMOMAP records for the two cases that developed into phase-3, one case developed into severe loss and the other concluded with an event of total loss. Unfortunately, both cases resulted in a number of casualties.

5.5 Conclusion

The results of the SEMOMAP are too comprehensive to describe individually. However, detailed results of SEMOMAP to all cases are provided in the appendix. From the SEMOMAP data above, failure in every phase of accidents influences the next process of cognition and results in greater consequences. While the data identifies human failure as the main source of failure due to common human factors, equipment also contributed significantly.

Most of the failures were found to occur during the most critical stages of the cognition process such as analysis and action taking to prevent or mitigate the issues. In more detail, planning and decision is the area where most failures occurred.

In summary, the table below provides the different outcomes for the reviewed cases.

Table 5-7: list of reviewed cases based on its nature of the accident and the final outcome

No	Type of Accident	No of cases	End result of the case	Location of accident
1	Fire	8	4 severe loss with casualty/s 2 mitigated loss without casualty 1 severe loss without casualty 1 total loss without casualty	3 Engine room 5 Cardeck/Acc space
2	Capsize	5	5 Total loss with casualty	
3	Collision	3	1 mitigated loss 1 total loss with casualty 1 severe loss with casualty	

6 Discussion and analysis of the SEMOMAP result

The previous chapter provided an overview of the results of the SEMOMAP to the selected cases of domestic ropax ferry accidents. However, it would be meaningless without any proper interpretation of the information. Thus, the following section provides cross relation information and analyses the information to achieve a comprehensive outcome.

Referring to the objectives of the dissertation stated earlier, the interpretation of the SEMOMAP outcome focused on the identification of major systemic issues under HFACS category, identification to typical sources of failure that contributed to the accidents, the shipborne performance in handling and mitigating the consequences, and comparison with other analysis results issued by another organisation..

6.1 Identified major systemic issues and their influence on the shipboard element

Reason's SCM recognises systemic issues as the latent factors that increase the risk of accident in the operation system. Therefore, accident prevention or even safety improvement programs should consider the contributory factor as the first target instead of focusing on the sharp end (operator).

Following the outcome of the SEMOMAP, the contributory factors for accidents involving domestic ropax ferries were identified. However, to avoid lengthy discussion due to fine details and too many different categories, this dissertation only focuses on explaining the most frequent factors.

Since the ropax ferry has a typical operation, the discussion generalises the result of the contributory factor by combining all recorded events and analyses to identify the influence pattern of the factors on human and technical shipborne operation elements.

6.1.1 Organisational influence

Organisational influence is considered the first barrier where the risk should be mitigated. The SEMOMAP results highlight a stronger relationship between the factors under HFACS mostly affecting the Captain, the chief officer and chief engineer.

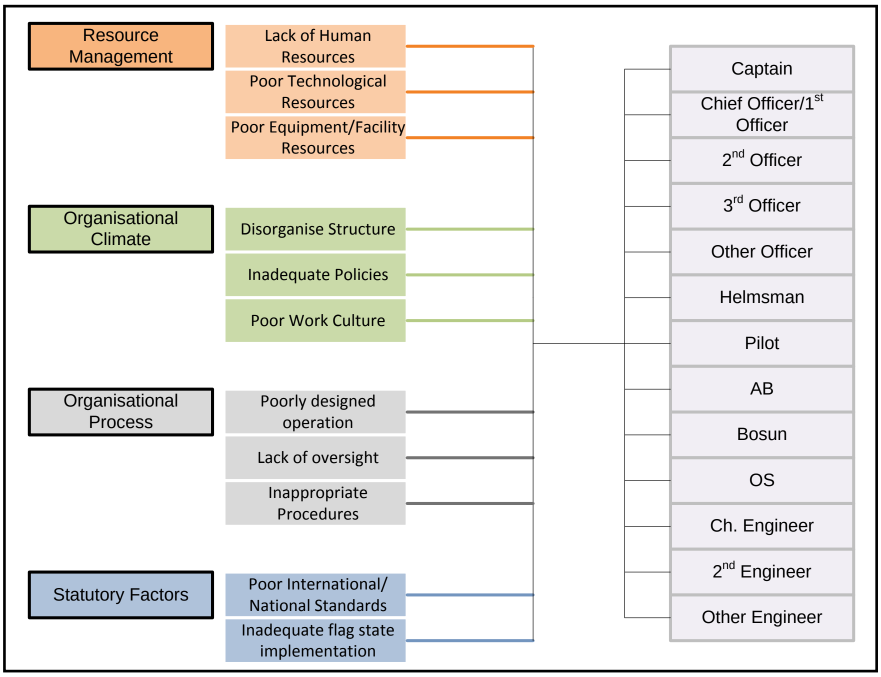


Figure 6-1: illustration to the relationship between human element with identified HFACS factor Level-3 under Organisational influence category

Under organisation influence, poor equipment/facility resources are considered to be the most influencing factors, while lack of human resource and lack of oversight are the other factors identified as affecting human element performance. For instance, poor equipment was observed mostly in the fire type category, where there was a lack of sufficient engineer supports and there was no backup from the organisational side to correct design flaws. In more detail, during fire Case No. 6 (refer to Table 0-73), the installation of non-marine use cables had resulted in higher risk of electrical malfunction. The company was not able to supply adequate parts for engineers to maintain the safe operation of ship electricity (NTSCb, 2007). Another pertinent example of poor equipment was found in the case of capsizes. In most of the cases of capsize, improper water freeing port was the biggest technical faulty identified during the course of the investigation since accumulated water in the car deck is an obvious factor affecting ship stability. The freeing port issues were mostly connected to lack of maintenance, and failure to observe the condition regularly.

In terms of lack of human resources, the issues mostly took place due to lack of training. The strongest relations were indicated in the fire accidents. In fire accidents, most of the investigation reports indicate that either regular basis training or even single training was not sufficiently provided to the crew. Ferry operation is well-known for its heavy and tight schedule. The investigation also established that even when training was found to be regularly held, it was not sufficient to provide crew with real time conditions. This was evidenced during fire fighting operations, when most of the crew failed to put out the fire in time. Another indication shows that, due to lack of training, most of the crew forget how to perform properly in emergency situations and allow the passengers to react on their own behalf. Lack of control of passengers is another indication of low competency of the crew due to insufficient training provided by the ship management.

Another factor that is considered of importance is the statutory factors. Substantial evidence indicated that lack of implementation of the safety regulation has contributed indirectly but significant to the risk of accident. For instance, lack of inspection of cargo onboard vehicles during the loading process has resulted in dangerous cargo entering unnoticed. Investigations into the accidents identified this issue took place in most of cases of fire, in which the fire started from a vehicle.

The factor of lack of oversight is another significant issue influencing the shipborne elements. The issues are mainly related to the factors of no proper monitoring, checking of resources climate and processes to ensure safe work environment. For instance, a common issue in domestic ropax ferry operation is tightness of schedule. The ferry operation authority provides limited time for berth operations as stipulated in standards for port ferry operation. The standard operation time is considered insufficient to accomplish handling of the cargo and departure preparation by the ship crew. A number of cases indicate that, due to these issues, factors of omission and lack of vigilance took place, increasing risk of operation to some extent.

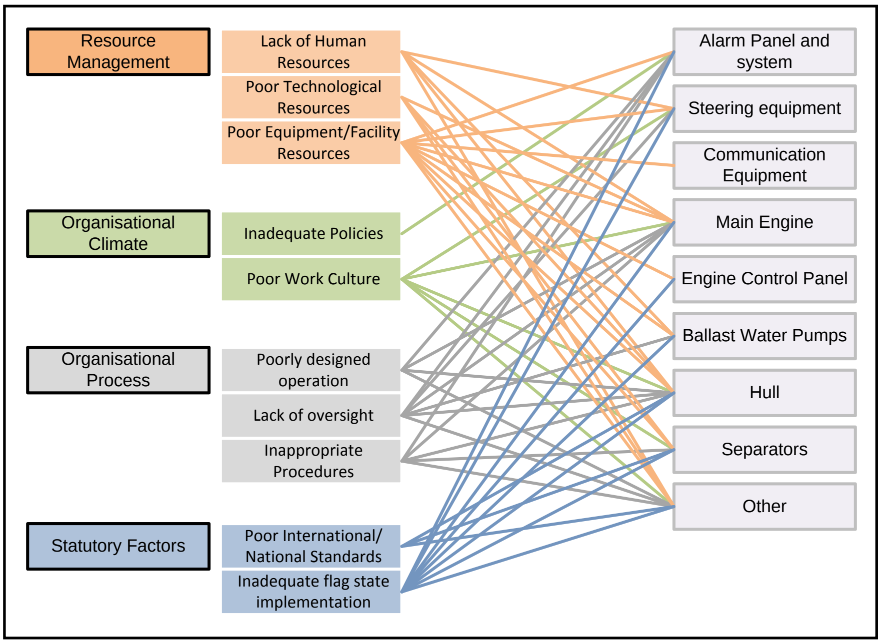


Figure 6-2: illustration of the relationship between technical element with identified HFACS factor Level-3 under *Organisational Influence* category

With regard to the technical element, the chart above presents the common ship equipment that is affected by omissions and misses in the systemic factors. Issues in training, poor equipment/facilities resource, and inadequate flag state implementation were observed to influence mostly the *main engine*, *hull* and *other* types of technical elements such as fixed/portable fire extinguisher system, freeing port structure, and fire retardant layer for accommodation deck. For instance, in case no. 14, the lack of class survey during maintenance of the ship was identified to create the degrading condition of the hull. In another example, in case No. 13, insufficient port inspection of the cargo stacking limit was observed to allow tight spaces in the vehicle arrangement on the car deck (NTSCa, 2012).

Policy on second hand ship placement was also found to be critical since some of cases indicate the issue of improper assessment to operate such kinds of ships beyond their operating limits. Cases no. 5 and 14 are taken as examples indicating the problem in ferry operation policy. Both ships were previously built and operated in the coastal area of Japan which is known for its calm water conditions. Back to Indonesia, the ferries were improperly modified and operated in waters with high probability of high waves (NTSCb, 2012)(NTSCa, 2007). Nonetheless the weather was not considered as a key contributing factor; however, the decision to allocate such type and size of ferries to the risky waters was considered inappropriate.

6.1.2 Supervision

Supervision is, under SCM, considered as the second barrier set up to prevent safety deficiencies from occurring. The SEMOMAP results indicate factors under the *Supervision* category that influence shipborne human element performance.

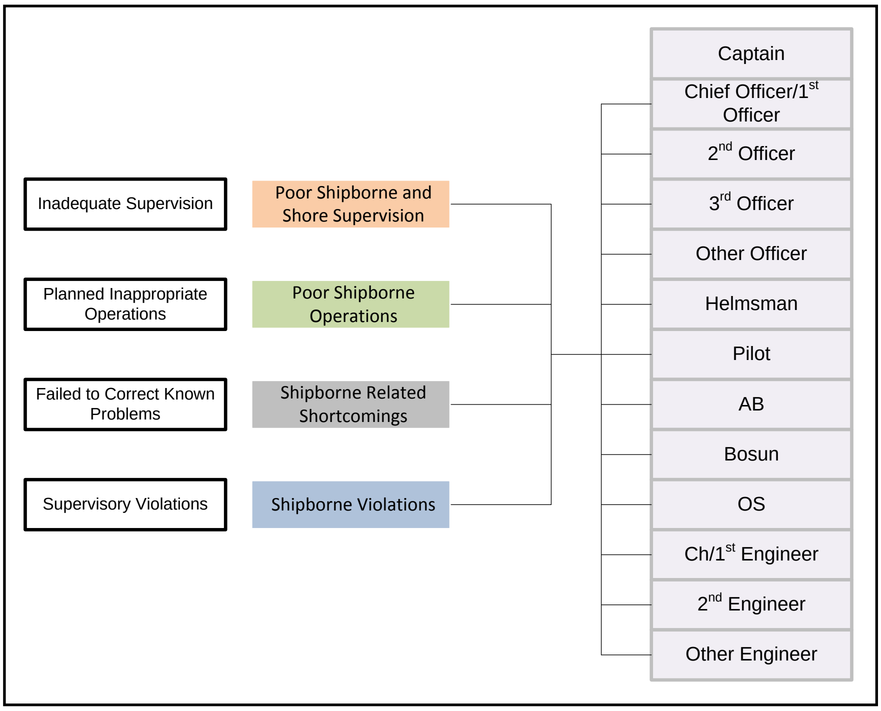


Figure 6-3: identified *Supervision's* factors that influence involved human element in the Indonesian domestic ferry operation

The most identified factors under the supervision category are *poor shipborne and shore supervision, poor shipborne operation* and *shipborne related short comings.* Under level-4 of HFACS under SEMOMAP, lack of risk assessment was the most significant factor influencing the performance of the human element, which mostly affected the master and chief officer.

Risk assessment for shipborne operation is of importance to foresee and take proper action so the risk of operation can be minimised. Lack of risk assessment was mostly identified in the case of fire accidents. In these particular cases, where most of the fires started from external factors such as cargo and passengers, there were limited formal risk assessments performed and there was no proper procedure to support the shipboard operation in performing such action. Case no. 3 and case no. 13 are examples of how lack of risk performance contributes to the accident.

In case no. 3, the ship designed and planned to serve inland waterway in Papua region. However, later in the field application the ship also require to serve Merauke port which was outside the region and to go to the port, the ship must sail in open sea. At the time of accident, the ship experience heavy weather that was considered beyond limits of its operation. The management later found did not properly assess the possibility of higher weather and considered to ignore the actual field operation issues. In case no. 13, ship management tend to ignore the risk of higher cargo stacking loaded on the lorry. This condition resulted in narrower access to ship crew and also public access. When fire started in a lorry on the cardeck, the crew found difficulty to access the fire origin and hinder the overall fire fighting process.

The issues in *Supervision* also affects technical element. From 16 cases reviewed, SEMOMAP identified 7 common technical elements that considerably play more significant role during the accident (Figure 6-4).

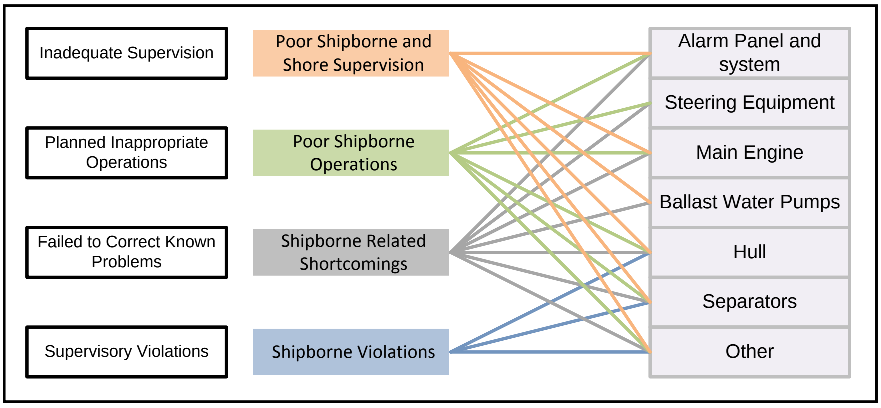


Figure 6-4: identified *Supervision's* factors that influence involved technical element in the Indonesian domestic ferry operation

Factor of *shipborne related shortcomings* and *poor shipborne operations* are identified to be the most influential issues to the technical element. The SEMOMAP identify stronger relations among factors of factor of *failed to correct a safety hazard* and *failed to initiate corrective action* to the technical elements of *main engine, hull* and element under *other* category.

The issues mainly took place during capsize and fire type accident. Under the Capsize type, the hull is the most affected technical subject. In case no 14, condition of scupper is being ignored by the crew that lead the seawater could not freely discharge. Nor shore based management and shipboard crew perform sufficient supervision to this critical issue (NTSCb, 2012). In other capsize case, where the condition of overdraft due to overloading process is also observed took place mostly. Supervision to this particular condition is formally taken by the chief mate that responsible in cargo operation and in addition port inspector before issuing sailing permit. The condition of overdraft was acknowledge, however the redundancy condition frequently took place and resulted in higher risk of accident.

Under Fire type where the main engine affected mostly, case no. 4 shows that improper supervision to the crew work to the engine led to the degrading performance of the main engine. In case no. 4 and case no. 12, improper maintenance by the ship crew led to overheat condition which was increasing risk of fire. In cardeck fire condition, supervision in the vehicle placement operation also had led the condition where there were no sufficient spaces due to tight vehicle arrangement for crew during the fire fighting operation.

Significant issue of supervision also observed in case no. 1, where the port operation could not provide sufficient weighing facility to identify the actual weight of the vehicle and cargo. Later the condition resulted in the overloaded condition to the ship and increased risk of capsize.

6.1.3 Pre Condition

Under HFACS system, precondition is adverse condition that could affect shipboard element performance, conditions and result in unsafe act or unsafe situation. SEMOMAP also consider the degrading performance of technical element affected by factors under precondition.

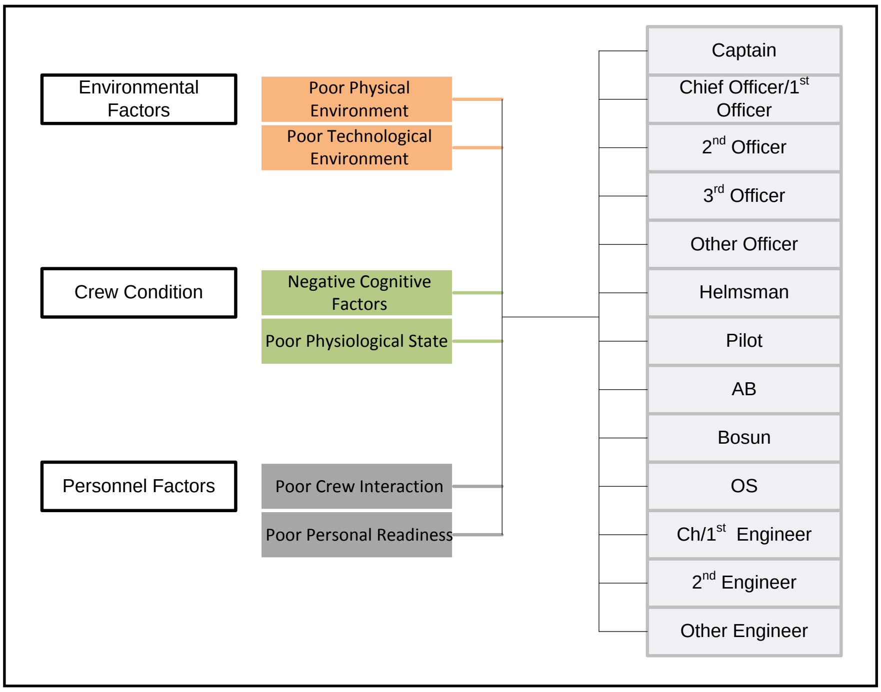


Figure 6-5: Illustration to the relationship between factors under supervision with human element

Since the importance of the factor, the discussion focused to explain each sub category under Supervision

Environmental factors

Shappel and Wiegman noted that environmental factor is one of the key factors that influence shipboard element which is comprises of either physical and/or technological factors. Both sub factors can be interrelated to create unsafe condition or unsafe error climate for. From reviewed to 16 cases of Indonesian domestic ropax ferry accident, SEMOMAP records ship movements and manoeuvre under poor physical environment indicates stronger relation with degrading performance of human element in capsize type accident.

During capsize accident, most of the ship part affected by the heeled condition of the ship. In some extent, engine and propulsion performance could have been affected due to many reasons such as not fully submerged propeller or main engine stopped due to problem of fuel supply since the affected fuel level in the tank. On the other hand, unusual ship angle for passenger could start the panic situation. Another issue on the ship manoeuvre can be also seen in case no. 1. Poor ship manoeuvre and movement gave limited option to the ship crew to handle ship properly. Excessive ship movement during berthing operation had damaged the stern construction and allow the seawater flooded the ship. Another factor identified is the factor of temperature-thermal and stress that contributed significantly in engine room fire accident.

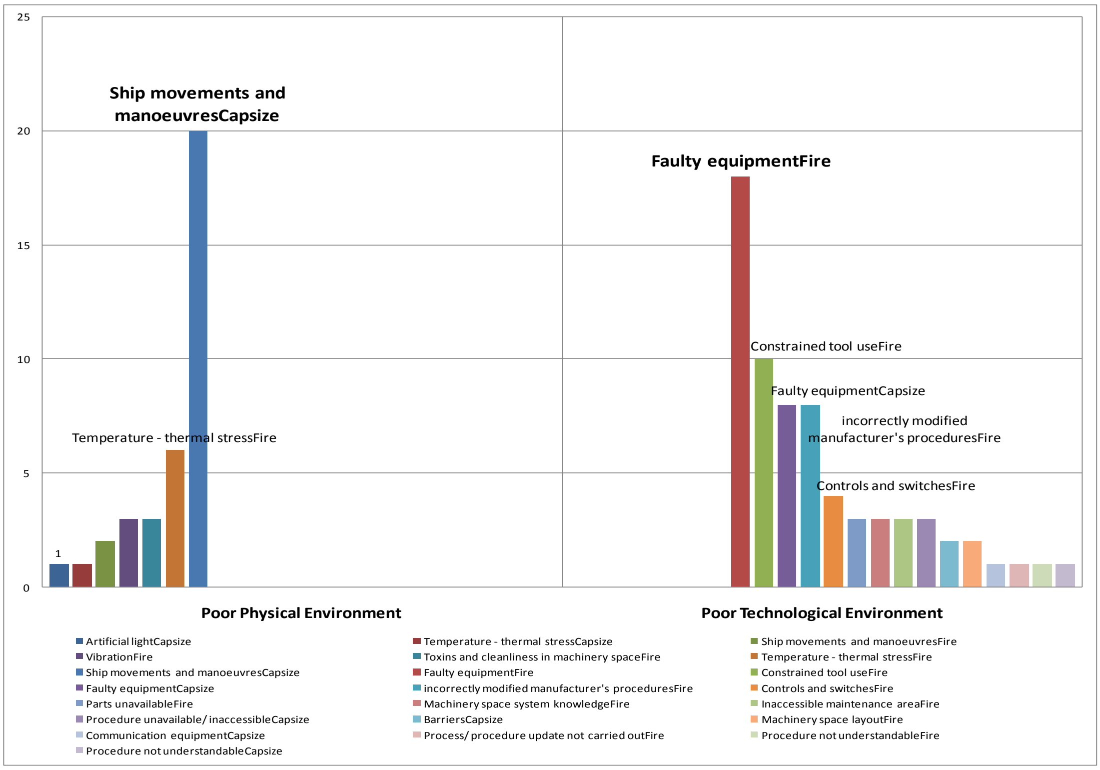


Figure 6-6: Identified factors f L3 under Supervision category that affecting Indonesian domestic ferry operation

Poor technological environment also found influential to the shipboard performance of domestic ferry. Barriers and faulty equipment is the common precondition issues under this category. Faulty equipment not just only identified during fire accident but also identified in capsizes type.

This significant condition under poor technological environment and poor physical environment is relevant with identified factor of lack of engineer support and poor equipment facility resource that identified mostly in the Organisational Influence Category.

When it relates with the condition of the fleet itself, most of the involved ferries are old. Eventhough regular maintenance performed and annual docking is conducted, the ship condition cannot be excluded by the fact that the old structure, machinery space and all its peripherals is still giving the difficult condition for the crew. It required a lot of effort and resource to retrofit the ship condition which is unlikely for the shipowner to do so due to high cost project. Number of evidence showing the technical problem found when the crew attempt to mitigate the risk of operation. Case no. 5 can be taken as example. Faulty of watertight seal on the ramp door resulted in the seawater to enter the car deck. another faulty equipment in different case can also be observed in the case no. 4 where CO2 installation not work properly when it operated to put out the fire in engine room.

Along with the challenges mentioned in the chapter 3 above, this condition is somewhat difficult to deal with due to some factor such as financial problem for shipowner, high demand for transport compare to supply.

Crew Condition

Crew condition play significant role in determining the safe onboard operation. Under the category, the negative cognitive factors are the most influence factor to the human element in the domestic ferry operation.

Under crew condition category, issue on complacency under negative cognitive factors were identified as common factor that influence the crew performance in most of the accident reviewed (Figure 6-7).

This reasonable to believe since ferry typical operation is monotonous and regular. Nearly every time the personnel perform similar operation without any additional work challenge. From 16 cases review, factor of complacency in domestic ferry operation mostly take place in short distance voyage. Complacency takes place in any kind of operations and could result in devastated outcome if not taken care properly. Proper work roster, competency refreshment by providing regular training, adequate crew management can be considered to reduced the excess of the complacency. Case no. 1 and case no16 can be taken as example to indicate the severity of the complacency in ferry operation. In Case no. 1 typical berthing operation provide ease situation the officer and not warned the damaged resulted from excessive operation which later resulting in sea water flooded the cardeck. In case no. 16, regular ferry movement taken in avoiding the other ship which was later found creates critical situation. Later, the officer on watch corrected the action but insufficient to avoid the collision

Issues in technical/procedure/knowledge mostly identified during fire accident and capsize accident. Since no proper training was provided to the crew or proper one, crew found trouble when handling critical situation. In capsize accident, some findings from investigation identified that the master unable to show proper understanding on ship stability. As a result he did not aware with consequence of his wring recovery action to stabilise the ship. Later the ship stability worsens and capsized the ship.

Other than those factor mentioned above some indication on the overconfidence, channelize attention were the other factor that contributed to degrading performance of the crew.

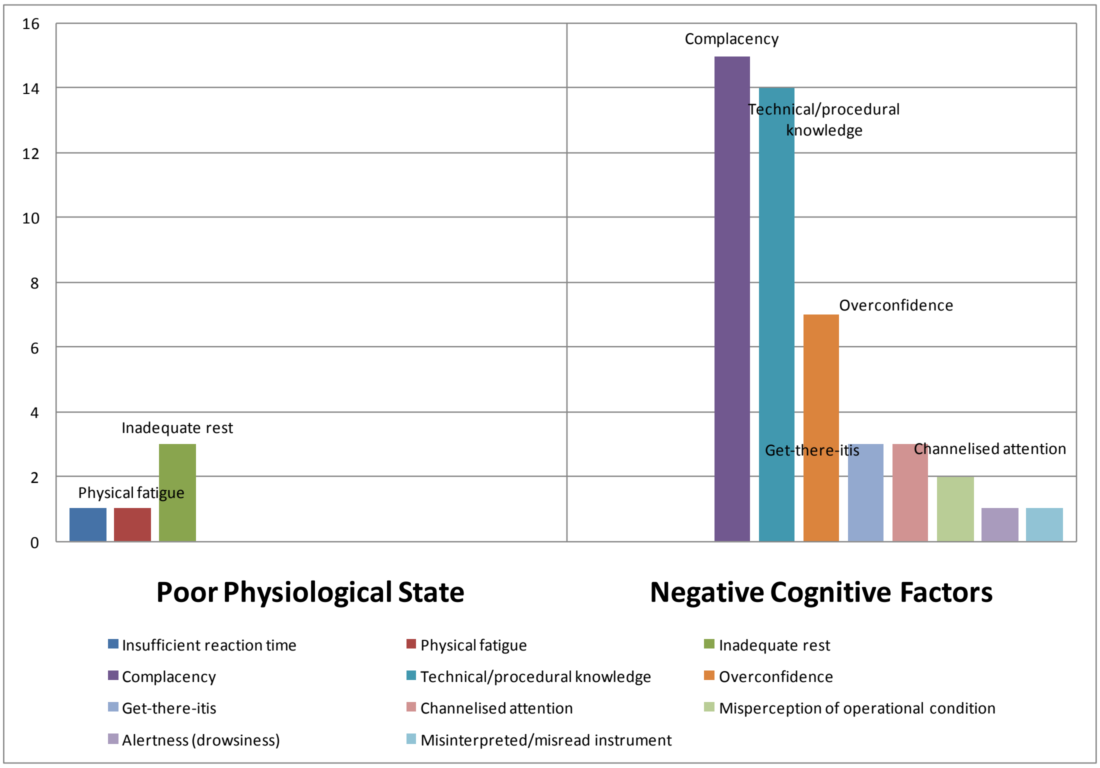


Figure 6-7: identified issues on *crew condition* category

Inadequate rest is other factor that contributes to the degrading performance of ship personnel. Based on the survey conducted by NTSC in 2013, most of the ferries operation in Merak Bakauheni ferry lane adopts what so called “two trip” shift or 12 hours shift. This has been done regularly. In the case no. 8, fire broke out from deck equipment when the ship on her final stage of the voyage. The crew was identified not to have sufficient rest hour and affecting their performance in fire fighting.

Personnel Factors

The table below indicates identified personnel factors issue from 16 domestic ferry accident reports. Issues of cross monitoring performance and challenge and reply are the common findings among other factors in under category of poor crew interaction, whereas pattern of poor risk judgement and inadequate training are two common personnel factors identified under category of poor personal readiness.

Issue in cross monitoring performance took place when no performance monitoring conducted by the shipboard management level or shore side. Challenge and reply is another shipboard performance issues that increase risk of operation. In most of the case reviewed, despite known fault condition and activity conducted performed, the lower rank feel reluctant to remind or warning the adverse condition.

Case no. 10, 13 and 11 can be taken as example to indicate the problem. During loading process, vehicle placement is tighten to provide chance to carry more vehicle. The condition has been proved create problem to the crew activity during emergency response conducted.

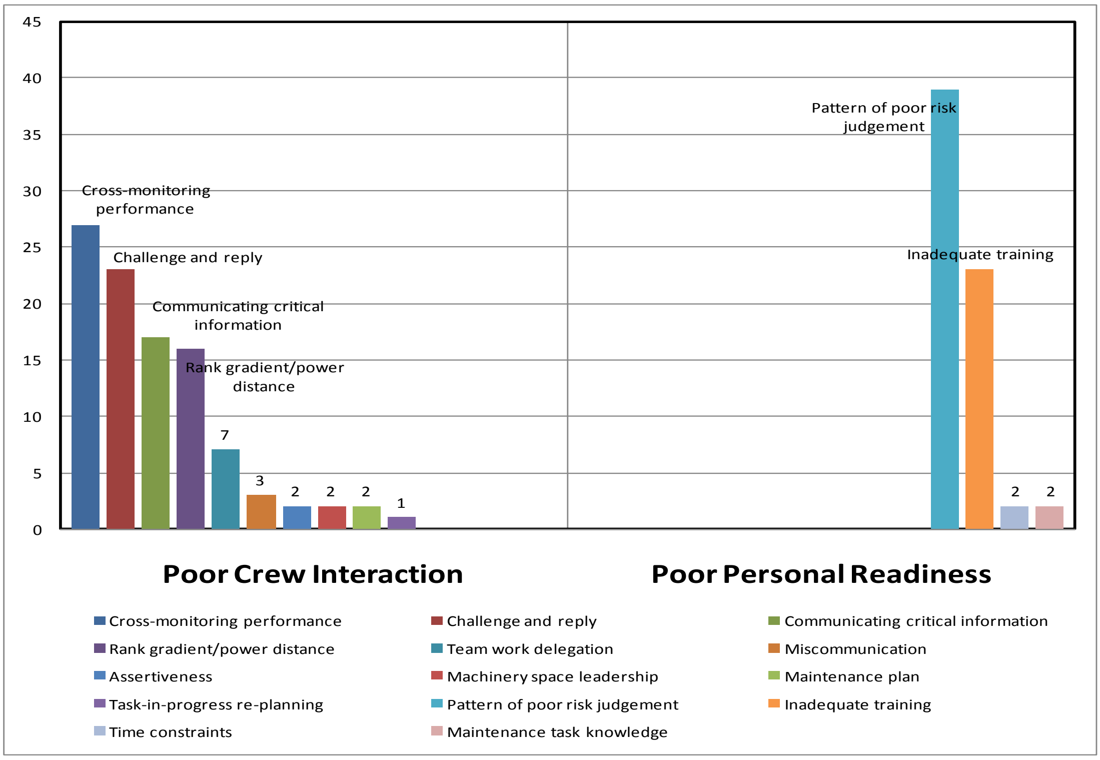


Figure 6-8: factor HFACS Level 4 under personnel factors of Precondition identified in the reviewed cases of domestic ferry accident

Pattern of poor risk judgement were identified also under poor personal readiness category whereas inadequate training as the other factor that contributed significantly to the degrading performance of the human element.

The chart below provides a cross reference how the factors above influence the human element which later considered contributed to misbehaviour of the crew and increasing risk of accident in the ferry operation.

The complex interaction Poor crew interactions found mostly during cases of capsize and fire. Obviously, those cases require intact coordination among the crews since it affecting entire ship system. During capsize, ideally all crew should have been aware with the condition and react based on the each duty under emergency response system, so it goes as well during fire accident. When the crew coordination was poor, the efforts to mitigate risk become useless.

During critical situation such as handling the potential risk of fire, crew coordination is considered utmost importance. Taking example of case no. 8, 11 and 13, the crew unable to perform well due to the emergency response measure was not coordinated properly due to confusion, distraction and factor of lack of training. The situation was worsen when the fire started in inaccessible place such due to tight arrangement of the ship

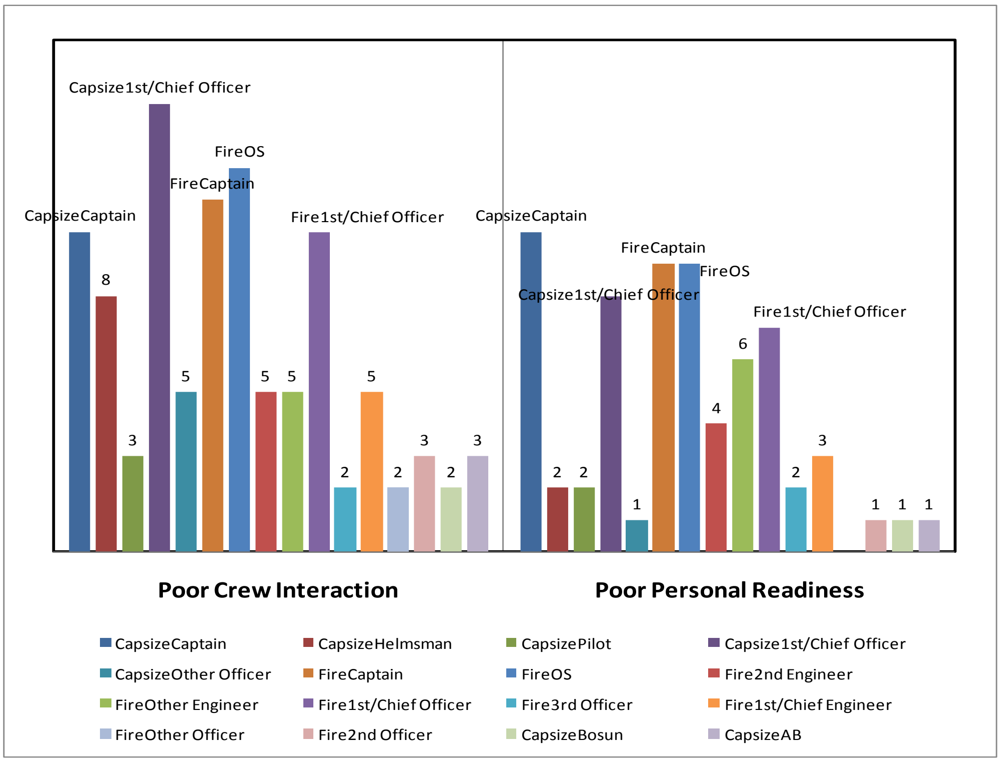


Figure 6-9: Human element interaction with factor under Personnel factor of Supervision

6.1.4 Unsafe Act

The HFACS assume that the unsafe act condition is existed while all previous factors were aligned to create subsequent adverse event. Errors represent the mental and physical activities of individuals that fail to achieve their intended outcome; that is, the result of the person’s action was not as expected. A violation, on the other hand, committed when the person's action reflects a "willful disregard" for manuals, or standard operating procedures or regulations (Wiegmann & Shappel, 2001).

Under SEMOMAP model, the unsafe act considered as the risky behaviour that been repeated in previous time and increase risk in the shipboard operation.

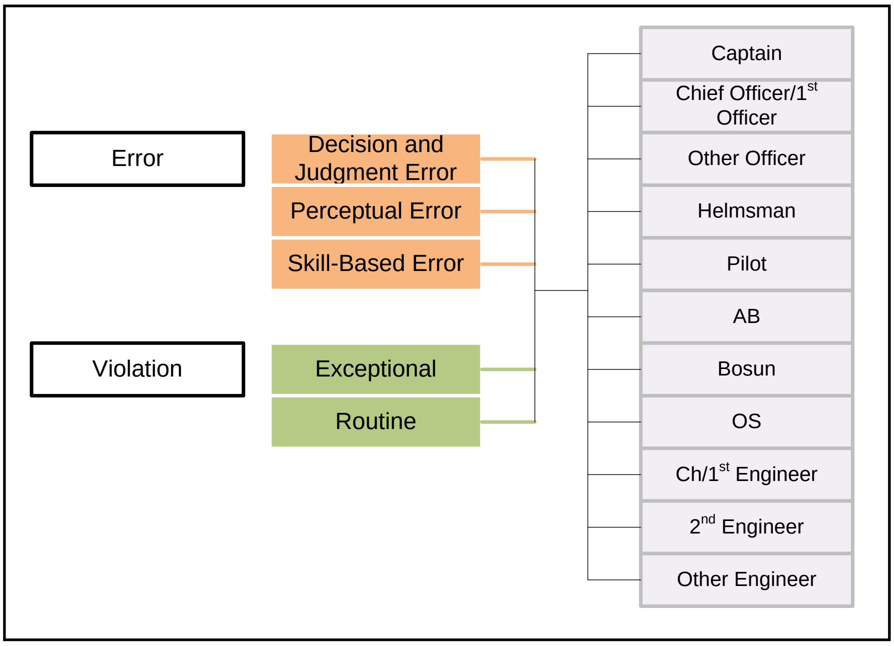


Figure 6-10: Identified human element's unsafe act

The chart above presents the list of human element that mostly involved in the domestic ferry accident. The action by the Captain, Chief Officer, Chief engineer and OS were the subject that identified showing the

The most prominent factor under unsafe act category from 16 reviewed cases is the skill-based type error and decision-judgement errors. All human element involved indicates the symptom in each type of accident. Failure in assessing risk during operation is the most common error whereas, poor techniques/seamanship is the second most common error identified in the reviewed cases of domestic ferry accident.

On the other hand, factors of accepted unnecessary hazard under exceptional violation are the common violation committed by the ship crew whereas factors of exceeded limits of system as the second common factor.

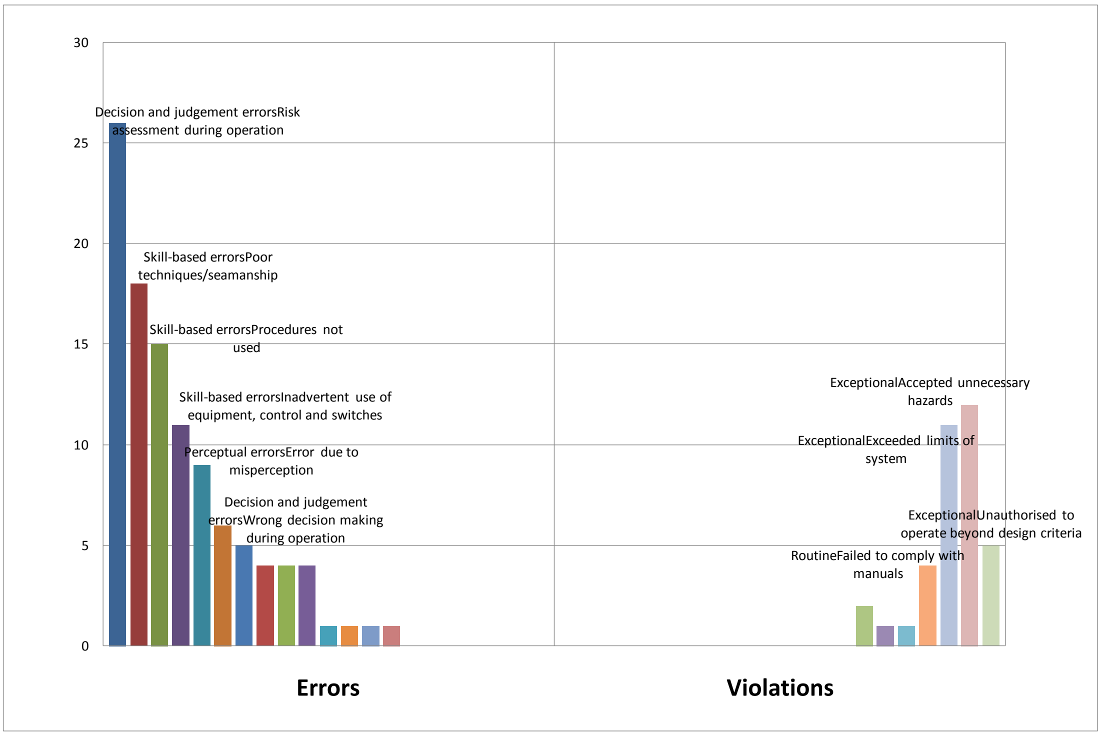


Figure 6-11: Unsafe act factors identified in all reviewed domestic ropax ferry accident

In most of the cases reviewed, poor seamanship technique was observed due to many reasons such as competencies, experience and training. If it related with previous factors start from organisational factors, supervision and precondition, this condition is predicted to be exist. The symptom of error in seamanship technique could be seen by indication of lack of training in the organisational influence. Issues in supervision most likely resulted in the error in risk assessment.

Typical violation committed by the crew also can presumably originate from issues identified in the personnel factor and crew condition. However in some cases, inadequate supervision could have also been the factor that contributes to the violation. Taking example of accepted unnecessary hazard, in most of the fire type accident where it start from the cardeck, the crew experience difficulties during fire fighting process. The hazard should have been recognised when the crew arranged the vehicle tightly. In some other evidence indicates that the violation to the regulation deemed necessary when the ferry frequently encountered other ship that did not take proper manoeuvre under the applied regulation.

In case no. 16, the ferry ships tend to have irregular movement in the strait based on the officers on watch seamanship. While the ferry in a crossing situation, most of the ferry tend to avoid collision with the other ship by aiming the stern of the opposed ships. In some occasion, the action not complies with COLREGs and creates confusion to other ship. In the particular case, the other ship assumed that the ferry maintain its course, meanwhile at the same time the ferry already alter the course to aim the other ships stern since the officer onboard ferry also assumes that no course alteration were made by the other ships. The event later concluded with both ship collide.

It interesting to notes that some unsafe act also influences the condition of technical element. Following data of SEMOMAP, violation type exceptional and routine are considered influence the main engine, hull type and other technical element. The common factors under this violation type accepted unnecessary hazard and failed to comply with manual. Investigation to case no. 6 found that the crew installed the non-marine use cable for electrical installation which increased risk of fire in shipboard operation.

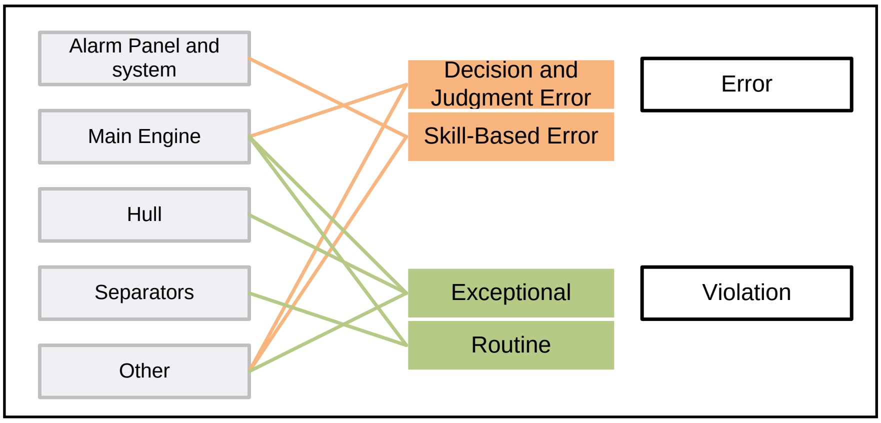


Figure 6-12: identified unsafe act behaviour that influence technical element

Crew error and violation affecting technical element mostly identified in fire type accident. In case no. 4 and 12, the crew was not following the standard manual for main engine maintenance, thus, the maintenance conducted was not properly performed and resulted in the degrading performance of the main engine indicated by event of overheat.

6.2 Pattern for failure and its typical source

During the critical event, humans and machines interact intensively as a whole system to maintain safe shipboard operation. Failure during the interaction could lead to either increased risk of operation, resulting in a new dangerous event or even failure during emergency operation that leads to additional catastrophic consequences.

The SEMOMAP data provides valuable information to demonstrate how human performance influences the overall shipboard operation and system. Overall results indicate that human failure is the main factor affecting shipborne operation during the critical stages such as handling the risk, mitigating the consequence or dealing with emergency action/response.

From 16 cases of Indonesian domestic ferry accidents, SEMOMAP recorded 1683 events of cognition from each phase and stage in different types of accidents. The chart below shows in which phase and stage of phase failures were found to have occurred.

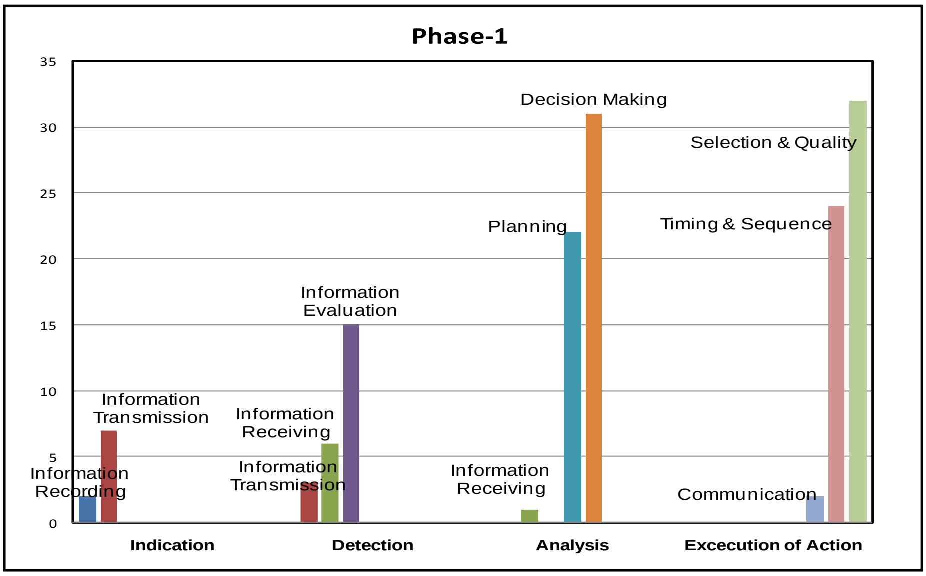


Figure 6-13: SEMOMAP result for failure identification under phase-1 in every cognition stage for all type of domestic ropax ferry involved accident.

During phase-1, most of the cases indicated two main cognitive areas where failure occurred. During analysis of the threat, failure occurred mostly during decision making, and failure in planning occurred in similar proportion (Figure 6-13). Most of the cases reviewed indicated that frequency of failure was observed to be higher during executions of action, mainly in terms of selection and quality, and also in regard to timing and sequence.

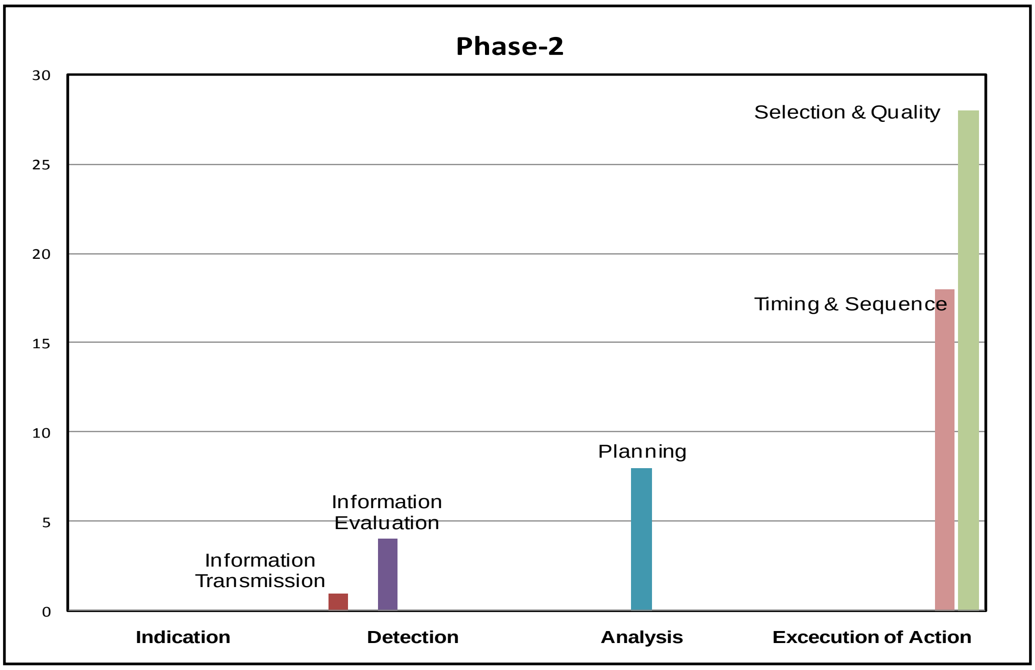


Figure 6-14: SEMOMAP result for failure identification under phase-2 in every cognition stage for all type of domestic ropax ferry involved

During phase-2, the pattern of failure indicates similarities compared to the failure pattern during phase-1. The failures mostly occurred during the execution of action, which, in this particular phase, is action to emerge from critical situation after the accident. Failures in phase-2 were observed to take place most frequently during the stage of timing and sequence. A similar failure pattern was also shown in phase-3.

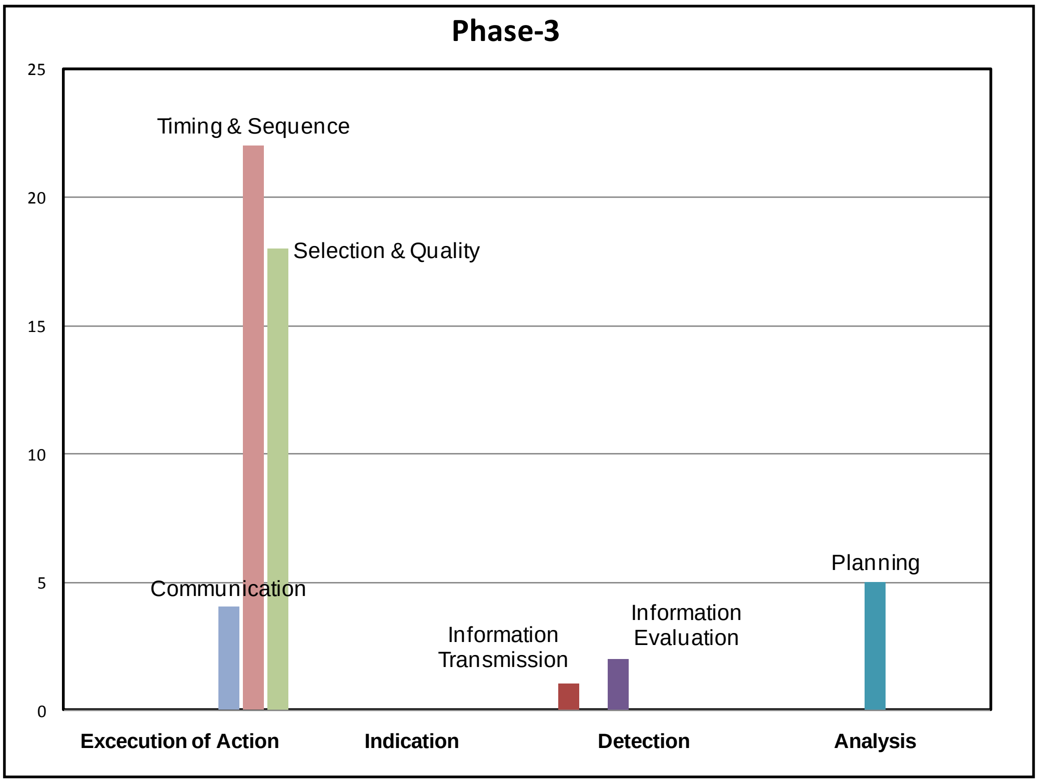


Figure 6-15: SEMOMAP result for failure identification in every cognition stage under phase-3 for all type of domestic ropax ferry involved

Following the data acquired from selected reports, frequency of human failure compared to equipment failure was found to be higher. The proportion of human failure compared to equipment failure was various but within the range of 83% to 93 %, whereas equipment failures ranged from 7% to 17%.

Table 6-1: Failure percentage in the accident assessment process for each type of accident

No	Nature of Accident	Accident Step event	Observeable process fail/safe status			Source of Failure			
			Applicable & Successful	Not Succesfull (failure)	Not Applicable	Human Failure	%	Equipment Failure	%
1	Fire	836	544	120	172	100	83%	20	17%
2	Capsize	495	291	90	114	84	93%	6	7%
3	Collision	352	226	61	65	57	93%	4	7%
		1683	1061	271	351	241	89%	30	11%

In further detail, compared to the number of the cognitive process, human failure was also found to remain high. The proportion of human failure was found to be varied, depending on the type of accident and stage of cognitive process.

The table below indicates percentage of failures identified from cases of Indonesian domestic ferry accidents compared to total cognitive processes in every stage of each phase for different types of accidents. The percentages indicated in the table were calculated from the number of failures observed in every phase of stage compared to the total cognitive events recorded under same phase of stage.

Table 6-2: Percentage of failure source for different type of ropax ferry involved accident

Phase	Stages	Fire				Capsize				Collision			
		No. of event	Event Not successful	Proportion of Failure		No. of event	Event Not successful	Proportion of Failure		No. of event	Event Not successful	Proportion of Failure	
				Human Failure	Equipment Failure			Human Failure	Equipment Failure			Human Failure	Equipment Failure
Phase-1	Threat Indication	52	8	75%	25%	60	1	100%	0%	34	0	-	-
	Threat Detection	78	12	100%	0%	90	7	86%	14%	51	5	100%	0%
	Threat Analysis	78	8	100%	0%	90	23	100%	0%	51	23	100%	0%
	Threat Prevention Action	78	21	81%	19%	90	23	87%	13%	51	14	71%	29%
Phase-2	System Health Indication	56	0	-	-	8	0	-	-	18	0	-	-
	System Health Detection	84	4	100%	0%	12	0	-	-	27	1	100%	0%
	System Health Analysis	84	8	100%	0%	12	6	100%	0%	27	4	100%	0%
	Emergency Response Action	84	34	76%	24%	12	8	88%	13%	27	4	100%	0%
Phase-3	Emergency Response & Evacuation Action	66	23	74%	26%	33	13	92%	8%	18	8	100%	0%
	System Health Indication	44	0	-	-	22	0	-	-	12	0	-	-
	System Health Detection	66	0	-	-	33	3	100%	0%	18	0	-	-
	System Health Analysis	66	2	100%	0%	33	6	100%	0%	18	2	100%	0%

As stated in the previous chapter, failures mostly occurred during selection and execution of action, either action to prevent the threat or emergency action to mitigate the consequences after the accident. A similar condition occurred in the last stage of phase-2 where most of the failures took place.

The following sections identify the contribution of failure from human and equipment failure perspectives.

6.2.1 Human performance in critical situation

The SEMOMAP outcome of the human performance identified some aspects of concern while they dealt with critical situations. As explained in the previous chapter, human performance in every step of cognition plays a significant role in determining the consequence of the event.

The SEMOMAP models views contributing factor under systemic process contribute and affect the shipboard element. By cross relating the data in contributory factor relevant to the human performance behaviour, the significant relation of the factor under Phase-0 can also be presented.

The Figure 5-2, Figure 5-10, Figure 5-19 in chapter 5 indicates how the issues in the systemic factors contributed, influencing and affecting human element performance in shipboard operation in domestic ferry accident. Looking at the proportion of human failures detected in all accident, *masters other crews* and ERT are identified contributed in most of the failure occurred during cognitive process.

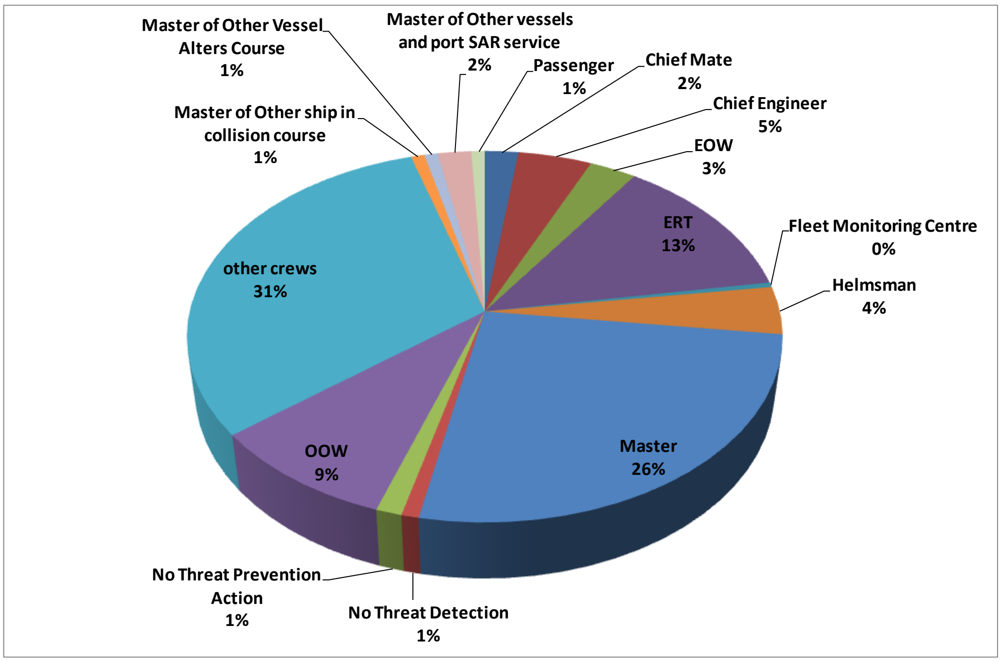


Figure 6-16: Distribution of human failures in all reviewed cases for every phase and every step.

In views of accident step process, the chart below developed based on the total human failure identified during all stage of cognition in different type of accident. The chart below indicates the 6 most failures took place in the event of accident involved domestic ferry in Indonesian water.

From the chart below, the master conducted most of failure during *Analysis* and *Action* stage in fire type accident stage of analysis is the stage where human failure mostly occurs. Failure by *Other Crew* also found higher during analysis process in collision category, whereas failures of *Other Crew* also identified mostly during stage of Action in capsize/listing type accident.

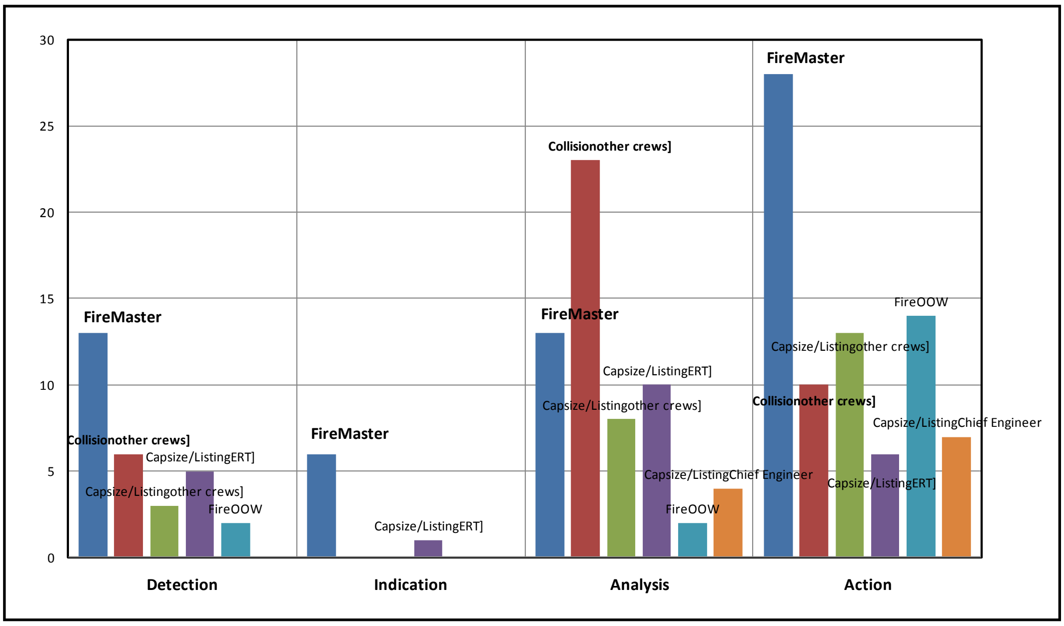


Figure 6-17: Distribution of human failure based on each stage of cognition process and type of accident.

Compare to the data provided in the Contributory Factor and accident development phases, the data found conformity. There are number of systemic factors that have been identified influencing human element which is mostly to the captain. The evidence later supported by number of failures in the event of accident development. This is not to mention that a single subject should bear all responsibility to any failures committed. However, issues in the systemic itself that should have more attention and properly managed.

As mentioned earlier, following the cases reviewed decision making process as well as planning are the cognitive stage where failures mostly occurred. In further detail, factor of *delayed, wrong, unclear* or *even no analysis* is observed.

Human failures planning also mostly found in similar condition. Failures in planning also mostly identified in the collision type accident during stage of threat analysis under phase-1 (Figure 6-18). Factor of *wrong planning* is the most frequent factor observes in the selected 16 cases of domestic ropax ferry accident. This condition took place due to factor of *lack of vigilance, forget long-term training, incorrect detection* and *time pressure*.

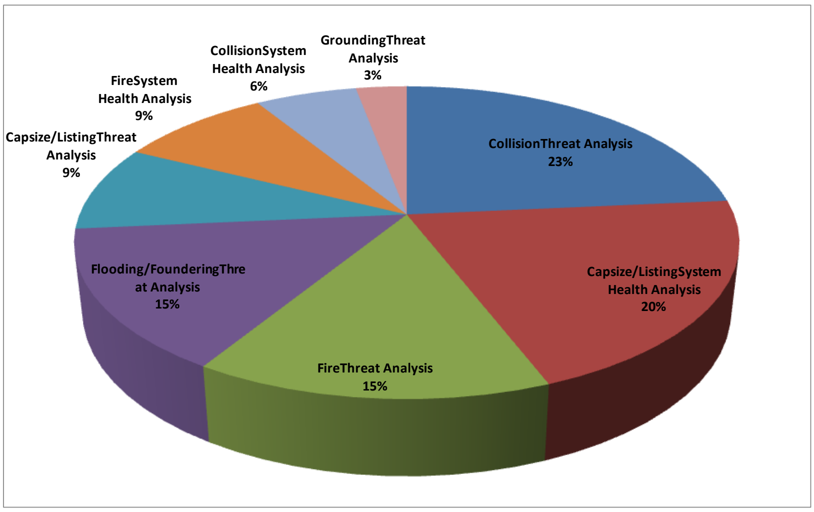


Figure 6-18: Human failure frequency in *planning* based on type of accident, its phase and cognition stage

From all SEMOMAP data on human failures, its indicates that the decision maker was not be able to make correct decision in time during in collision type accident during threat analysis, whereas the other condition also found during capsize/listing type accident (Figure 6-19). The most pertinent human factor under this circumstance is the factors of wrong decision that contributed mostly by lack of long-term training and procedures, condition of confusion, being distracted, tunnel vision and other factors.

In case no. 14, the master unable to assess situation properly due to absent of stability data onboard the ships. His planning to reposition the ship was considered inappropriate and later identified worsen the ship stability.

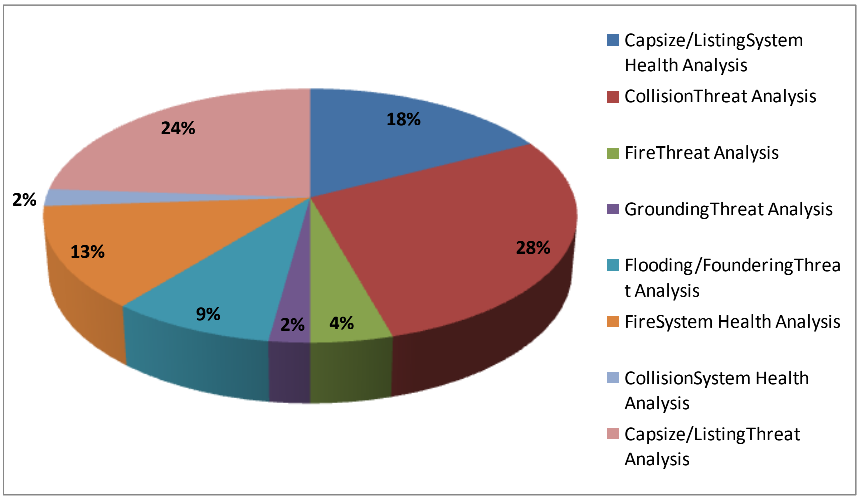


Figure 6-19: human failure frequency in *Decision Making* based on type of accident, its phase and cognition stage.

Human failure in executing the action also found too obvious and frequent. Data of SEMOMAP identify the area of cognition that the particular failures mostly take place. It shows that failure in *timing and sequence* is observed in every stage, every phase of cognition in every type of accident. The SEMOMAP identify that human failure during *timing and sequence* is mostly observed in emergency response action under phase-2 of fire type accident.

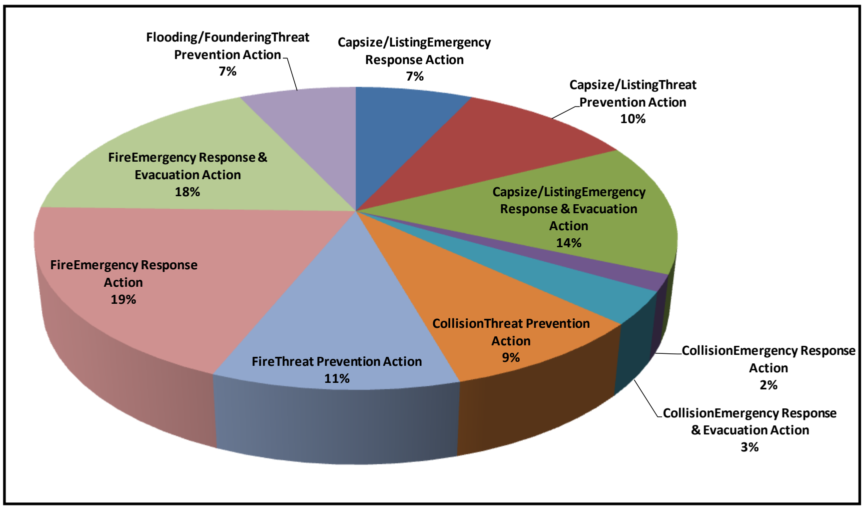


Figure 6-20: Human failure frequency in *Timing and Sequence* based on each type of accident, its phase and cognition stage

In more specific, fire in which started in the cardeck is the condition where the fire fighting action failed. In case no. 13, the crew action to put out the fire was considered too late since the emergency response time required extra effort to access the origin of fire. The issues in timing and sequence commonly on the factor action too late and as a result of confusion, forget long-term training and procedures, expectation bias, distraction.

Failure in *Quality and Selection* also found as the most frequent condition in domestic ferry accident. Along with the failure observed in factor *timing and sequence*, the failures in Quality and Selection also found to took place mostly during emergency response action under phase-2 of fire type accident that also related with more human failure observed during evacuation action under phase-3 for same type of accident (Figure 6-21).

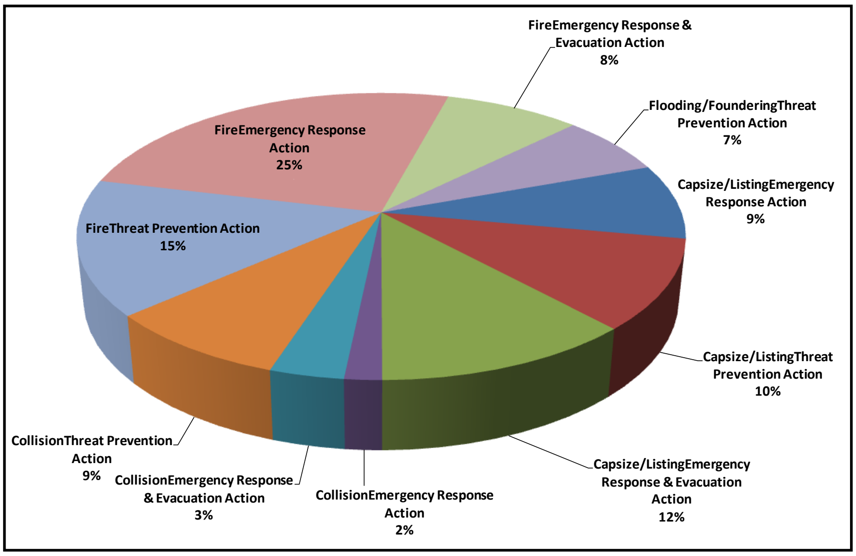


Figure 6-21: Human failure frequency in *Selection and Quality* based on each type of accident, its phase and cognition stage

Most cases of fire shows that the crew unable to identify exactly and reach the source of fire. Hence, the action taken was considered too little and some other actions also indicate that the action taken was in wrong direction. In most of the fire accidents reviewed that resulted in severe loss or total loss, the human failure took place mostly due to lack of training, factor of confusion, distraction, and missee.

From the discussion above, it become obvious that factor of training is crucial to prevent the failure. Even the regulation required the ship to perform regular safe drill and training onboard more than other type of ship, apparently there are significant issues in how the drill was conducted. Some information in the investigation reports mentioned that the drill conducted was based on formality to satisfy the requirement and not reflecting actual condition such as difficulties in fire fighting in cardeck.

6.2.2 Equipment failure

Failure in equipment is observed to be less compare to the failure of human factor in term of domestic ferry accident. However, some failures in equipment also considered significant and contributed more in particular cases.

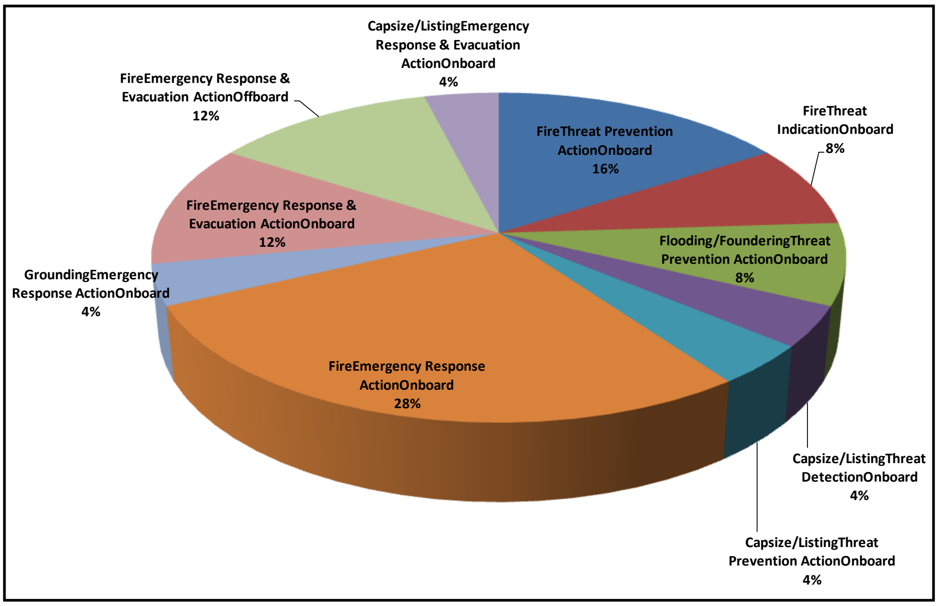


Figure 6-22: Equipment failure frequency based on each type of accident, its phase and cognition stage.

Failure in equipment mostly observed during emergency response action during phase-2 of fire type accident. Similar like human failure observed during same category, equipment failure also observed mostly during aspect of *timing and sequence*, and also in aspect of *selection and quality*. The common failed equipment during fire accident listed as follow:

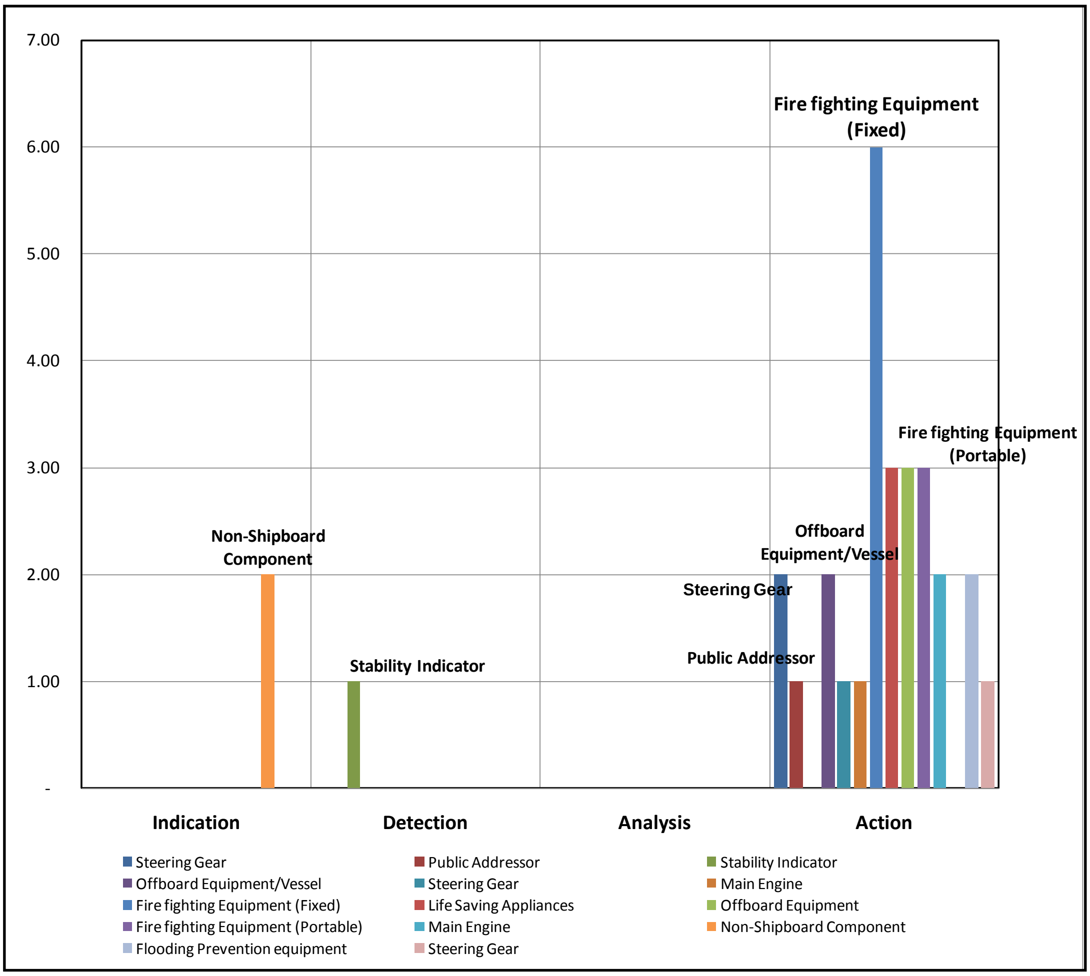


Figure 6-23: Failed equipment identified in each stage for each type of accident

The factor of lack of maintenance and not properly installed is the common factor that influence the performance of the equipment. In case no. 13, the investigation found that the performance of water sprinkler where fire accident started in the cardeck was not sufficient to suppress the fire not to spread and developed.

Under equipment failure, SEMOMAP identify that action provided offboard also found insufficient to assist onboard operation handling the critical situation. In most of the accident, investigation found that readiness of the SAR to provide assistance is found improper. In particular for fire cases, the shore based response was not considered too late due to location of the accident (NTSC, 2008).

Failure during evacuation action also observed in condition that the life jacket was not accessible and the life raft could not be released (NTSC, 2009). Both condition was also contribute to the fact that fatalities were not as a result of fire but caused by drowning while evacuating from the ship (NTSC, 2008).

6.3 Risk mitigated or continued to develop?

One of the key finding is the SEMOMAP also records successful action during accident development step. The percentage of successful action compare to the failed action is remained high (refer to the Table 0-74). However, the accident continuously to develop into further extent. From this condition, despite series of successful action, risk in shipboard operation only needs a single failure to develop into greater event such as accident.

A correct action in handling a risky situation can provide an opportunity for the shipboard operation to maintain the whole safe operation of the ship. This requires total effort from the capable and qualified crew, supported by proper and sufficient onboard resources.

From review of the selected cases, the SEMOMAP outcome can be used to do benchmarking/comparison between saved operations with events of total loss. The variety of the selected cases also supports the comparison process. To observe this matter; fire cases of No. 4 and No. 12 are taken as examples (refer to Table 0-73).

The chart below was developed by observing every single accident assessment process(Loop) to provide a comparison of the cognitive processes in both cases. In each loop the SEMOMAP observed each shipboard performance and identified the failure in every stage of cognition. Each case shows different onboard behaviour in dealing with the fire situation onboard. The loop was generated based on the information stated in the accident reports..

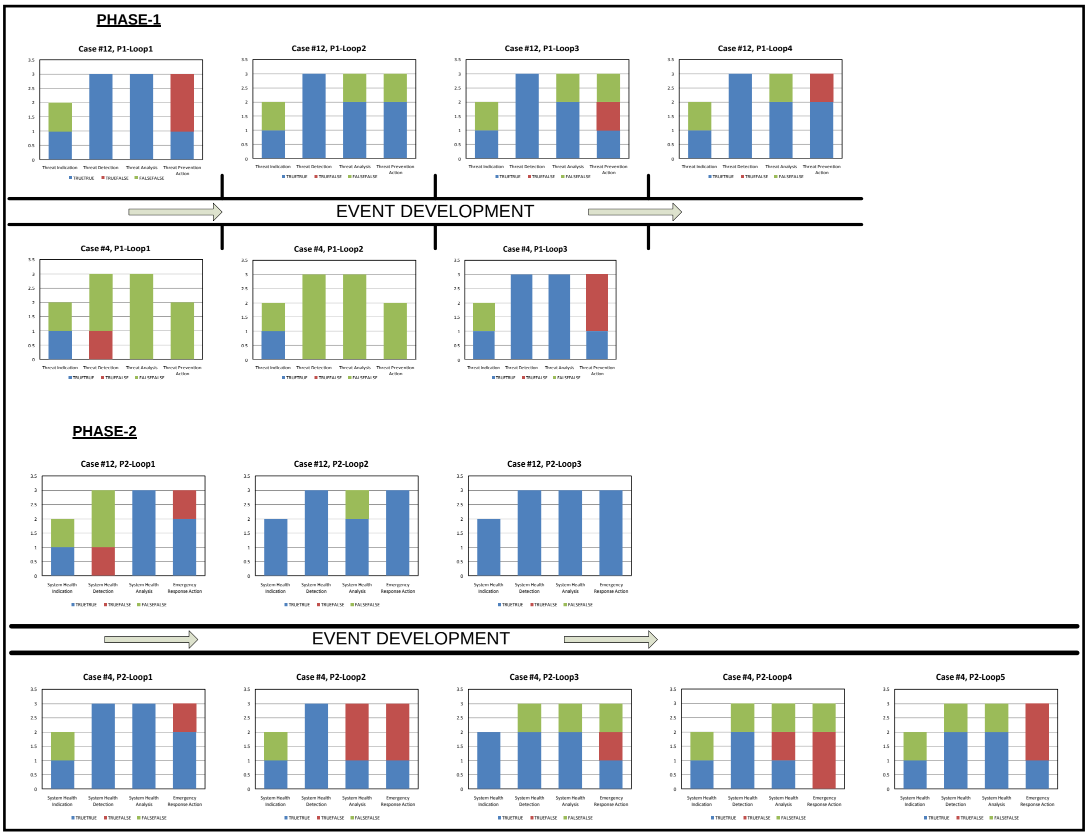


Figure 6-24: Comparison of accident process for fire case no. 4 (below the line) and case no. 12 (above the line) during phase-1 and phase-2 of accident development

From the charts above, failures were observed during phase-1 which led to the event of fire (Figure 6-24). However, significant differences can be seen when the event proceeds to phase-2. From the loop chart of case no. 12, failures were observed during the initial loop; however, they stopped for next loops. Case no. 4 shows the opposite. Failures (indicated by red bars) were identified in every loop of cognition, which was mainly during execution of action taken to reduce or mitigate the effect after the fire occurred (Figure 6-24). SEMOMAP data indicates that failure in action occurred mostly in terms of timing and sequence and also selection and quality.

In case no. 12, the fire was spotted in the main engine no. 2. Some initial action was taken to put out the fire. But the first effort failed. The chief engineer later ordered the crew to evacuate from the engine room and to close all engine room connected openings (doors, blower etc). When all order been complied with, the chief engineer initiated the CO2 system to stop the fire and the action was successful (NTSCa, 2012). Despite some failures in the main engine no. 2 due to lack of maintenance and support from the company, the crew managed to mitigate the risk of fire and contain the damaged into a more controllable area (engine room).

In contrast, Case No.4 shows the opposite outcome. Similar contributing factors were observed compared to Case No. 6. The indicator was obvious to provide sufficient information about the fire. However, when the fire broke out in main engine no.2, the crew experienced difficulties locating the origin the fire. Lack of vigilance and awareness of the condition added to lack of training creates difficulties for the crew to put out the fire. On the other hand, the investigation also found malfunctions in the fixed fire extinguisher system. As a result, the fire could not be controlled and continued to spread.

From comparison above, there are factor to consider in successful operation to mitigate risk or threat not to develop into greater event. Failure is should not be existed in every stage of cognition since it affecting the other stage, which might also amplify the failure in the next cognitive stage. Obviously it requires effort and high degree of crew performance to keep the operation safe. Crew concentration and ability to assess the situation also significant to prevent the failure develop. This can be done by providing continuous training and familiarisation to the crew, better working system and environment.

6.4 Comparison with the original report of the domestic ferry safety

For the same investigation reports, NTSC issued a compilation of the results of the main causal factors in the domestic ferry accidents. In classifying the final contributing factor, the NTSC focused on the two main categories of human and technical factors, without further detail of description.

From a total of 16 ropax ferry accidents, 12 were stated to have been contributed by technical factors, whereas 4 were contributed by human factors. The SEMOMAP results highlighted the outcome of human factors, which contributed significantly to most of the accidents.

There are many factors to explain why the result is different. The investigation reports mainly exclude the complexity of socio-technical relations and tend to be descriptive instead of analytic. The investigations also place too much focus on the main causal factor, without extending the analysis deeper into the consequence of the accident or action taken during the emergency situation.

As explain in the chapter 4, the nature of the investigation models is different compare to the critical thinking utilised in the accident causation models. While the investigation model tends to simplify the information into more general readers consumption, the accident causation models provide details for further analysis.

By this condition mentioned above, the outcome of the SEMOMAP has deviated from the original statement of fact issued by the particular organisation.

6.5 Area of concern

6.5.1 Data availability

The SEMOMAP relies mainly on the sufficiency of data provided in accident investigation reports. It is nearly impossible to reinvestigate since the occurrence happened in past time. Hence, additional data from different sources that are considered appropriate and supportive are acquired, for instance, data from the Indonesian Marine Tribunal verdicts to the cases used. However, the comprehensiveness of the SEMOMAP in providing detailed information also requires some logical assumption, which at some point could lead to different outcomes and interpretations.

On the other hand, SEMOMAP model outcome is found so comprehensive so it can be used to analysis to the sufficiency of information in the investigation report.

6.5.2 Comments on utilising the models

When it tracing back the outcome of the models, the validity of the results is required high level of concentration and consistency during coding of the cases. The interpretation of the SEMOMAP model also relies to the punctuality of the user when selecting the taxonomy.

In addition, the data input is mainly relies onto the comprehensiveness of the investigation reports. On the other side, the overall knowledge possessed by the user is also contributes significantly to the carefulness of the factors selection. The user is required to have sufficient background on the ship operation and human factor concept. In addition, the user is also required to obtain sufficient knowledge in accident causation model and investigation and also not limited to the human factor behaviour in the accident process.

During the dissertation, the analysis conducted to the selected accident where the event is obvious. The writer found some critical condition is not covered specifically within the model. Therefore the *Other* type of factor is become more favourable to select. To provide better validation to the model, continuous development is required. In addition, it strongly recommended utilise near miss data to see which area within the accident that not covered.

6.5.3 Issues in the models

Outcome of the model

The SEMOMAP able provide massive and useful data for identification of the issues in every phase of accident. There are many of details in the outcome that can lead to multiple interpretations. However, the SEMOMAP outcome considered as raw data that requires additional works to filter and analyse it.

In future, it is recommended to develop a better SEMOMAP outcome and summary so confusion and extra works in interpreting the results could be avoided.

7 Conclusion and recommendation

The SEMOMAP data and analysis described in previous chapter is proven how systemic process is considered of importance to sufficiently reveal the causal factor that lies in the domestic ferry operation. Data from investigation report has been scrutinised to identified missing information that later combined with other references to acquired complete pictures on the safety issues in domestic ferry operation.

The data shows that different type of accident is also contributed by different behaviour of the system applied to prevent the accident.

7.1 Conclusion

Accident in any nature and condition shows multiple and complex interaction among elements of shipboard operation for both shore side and onboard side.

The domestic ferry in a developing country such as Indonesia recognised as the major backbone to support socio-economic activity and more over provide access to the remote areas, thus maintain the nation’s integration. Therefore, safety level of the domestic ferry operation should be maintained and improve.

Review to the 16 different type of accident investigation report has provided significant finding in how the safety issues exist in the domestic ferry operation. The identified factors as mentioned in the chapter 6 indicate the trend and pattern how accident develops from earliest stage of the operation.

Despite difference type of accident, there are similarities of identified contributory factor that contribute to the escalation of risk in domestic ferry accident. Under organisational influence, factor of poor equipment/facilities resources should have more attention to deal with since it is the common issues identified in the domestic ferry accident in Indonesia. Under Supervision category, poor shipborne and shore supervision, factor of poor shipborne operations and shipborne related shortcomings are the key issues that increased the risk in domestic ferry operation.

From the analysis to the outcome of the SEMOMAP to the ferry accident, there are some significant points to mention that the human performance play major role in the operation of the domestic ferries. Issues in the execution of the selected action found to be the most prominent issues. When it related to the contributory factors, lack of training is the significant factors while it also contributed by other factors such as lack of proper equipment due to non-supportive shore based management.

The difference of outcome of the cases has shown and provides examples in how the accident could have been prevented and at least mitigated to stop further extent.

The SEMOMAP development managed to provide complex but comprehensive pictures how the accident developed and up to which stage where it considered as the most significant point.

7.2 Recommendation

Following the identified contributing factors under the SEMOMAP models, there is no single or individual works can be done itself to mitigate all issues. Join work and comprehensive cooperation among the domestic ferry stakeholders required with main objective to improve overall ferry safety performance.

Obviously, following the findings to the failures of human factors, extensive work to improve human performance and competencies particularly in assessing the analysis and performance in handling the critical situation are required and should have been come to highest concern by all related parties.

Obviously to prevent the recurrence, the preventive measures should not be placed based on each nature, since the accident can happen in any different form and nature.

Database of mishap can be a resourceful reference as benchmark to determine the trend and identify better on accident development process. It is not surprisingly that most of the administration had only few data for mishap. Therefore the relevant authorities and all domestic ferry operators encourage developing a comprehensive and thorough database system.

Issues Domestic ferry safety will remain blurry due to lack of international attention and common approach among interested states. But the problem of lack world level analysis is not come as itself. Lack of data submitted by the involved states to the relevant organisation also considered as the other factor involved. Further enhancement to the database access and update works are required and be developed to sufficiently understand the current trend of domestic ferry operation.

Further work required to compile more accident report to the SEMOMAP system to acquire better the outcome of understanding the trend in ferry accident. In will be beneficiary to use the model for other domestic ferry accident reports from different region and different condition (regulatory, policy, operational pattern) to seek global trend in the issues of the operation. By doing so, common approach in reducing the risk in domestic ropax ferry operation can be developed for mutual benefit

Additionally, a more specific research, such as narrow it to each type of accident and looking into specific phase, is recommended to observe further trend in the operation.

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Appendices

Appendix – 1: SEMOMAP Workflow

Phase-0: Iterative process workflow under SEMOMAP models

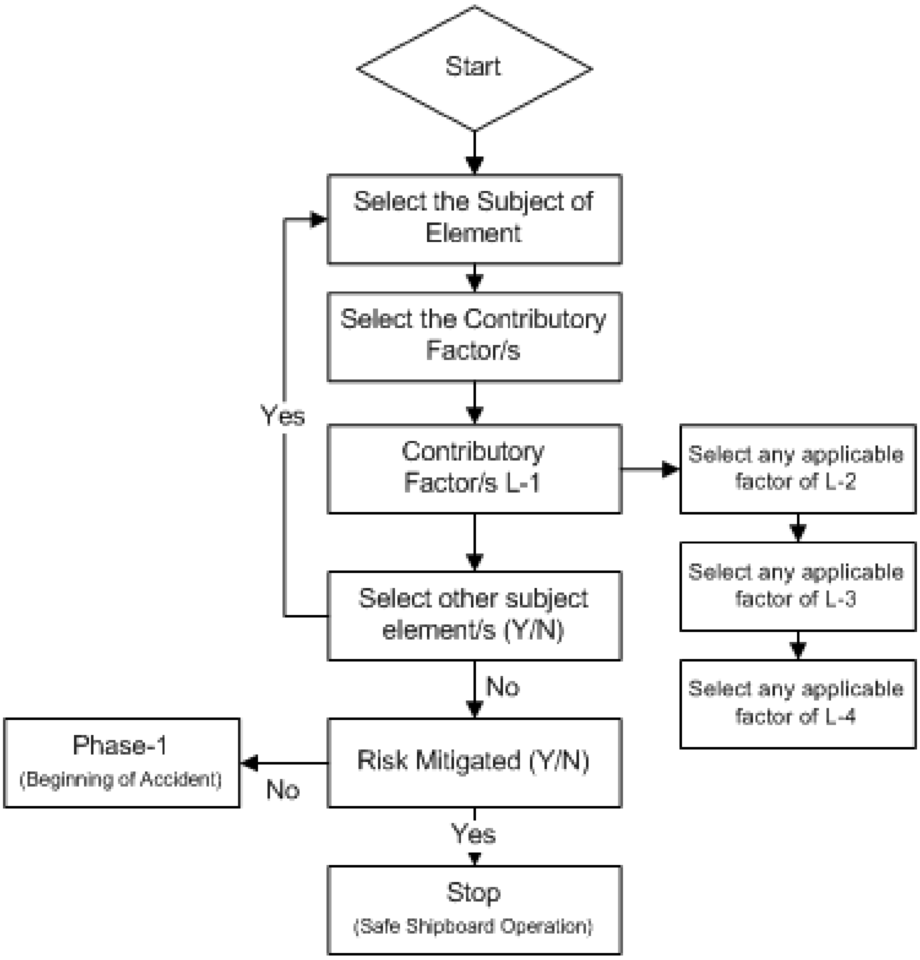


Figure 0-1: Phase-0 SEMOMAP workflow

Phase-1: Iterative process workflow under SEMOMAP models

Figure 0-2: Phase-1 SEMOMAP workflow

Phase-2: iterative process workflow under SEMOMAP Models

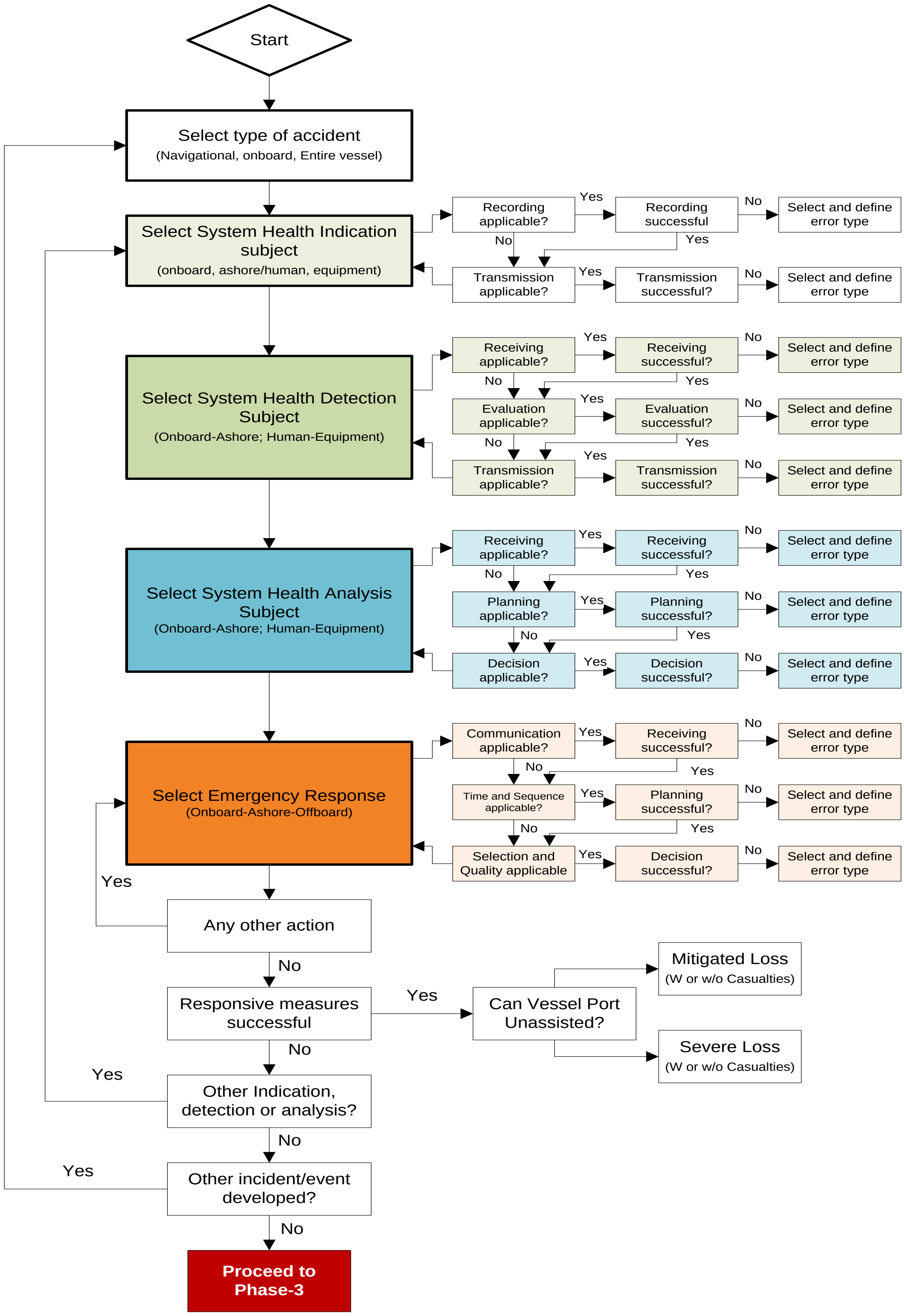


Figure 0-3: Phase-2 SEMOMAP workflow

Phase-3: iterative process workflow under SEMOMAP models

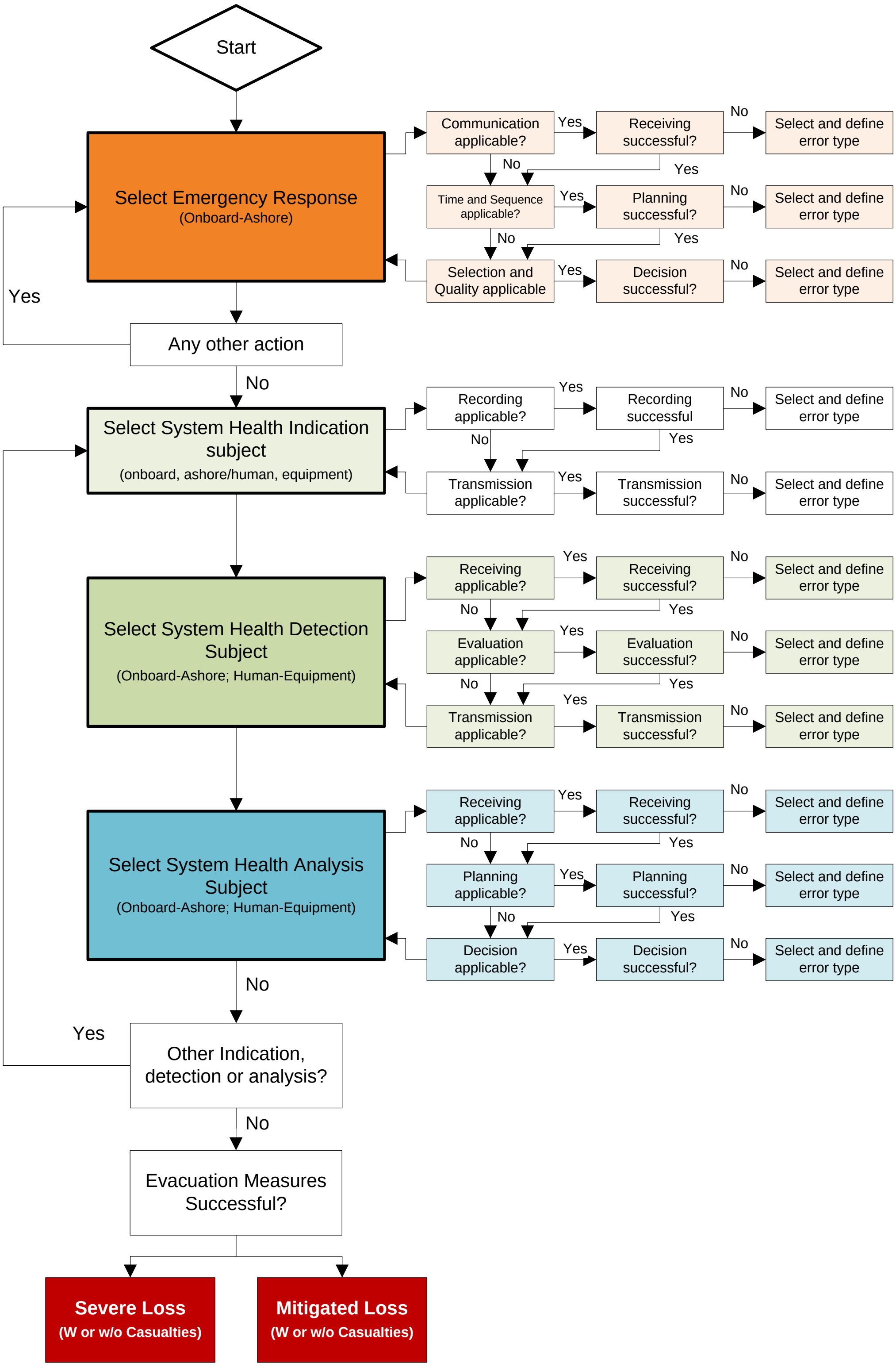


Figure 0-4: Phase-3 SEMOMAP workflow

Appendix – 2: SEMOMAP v2 Model

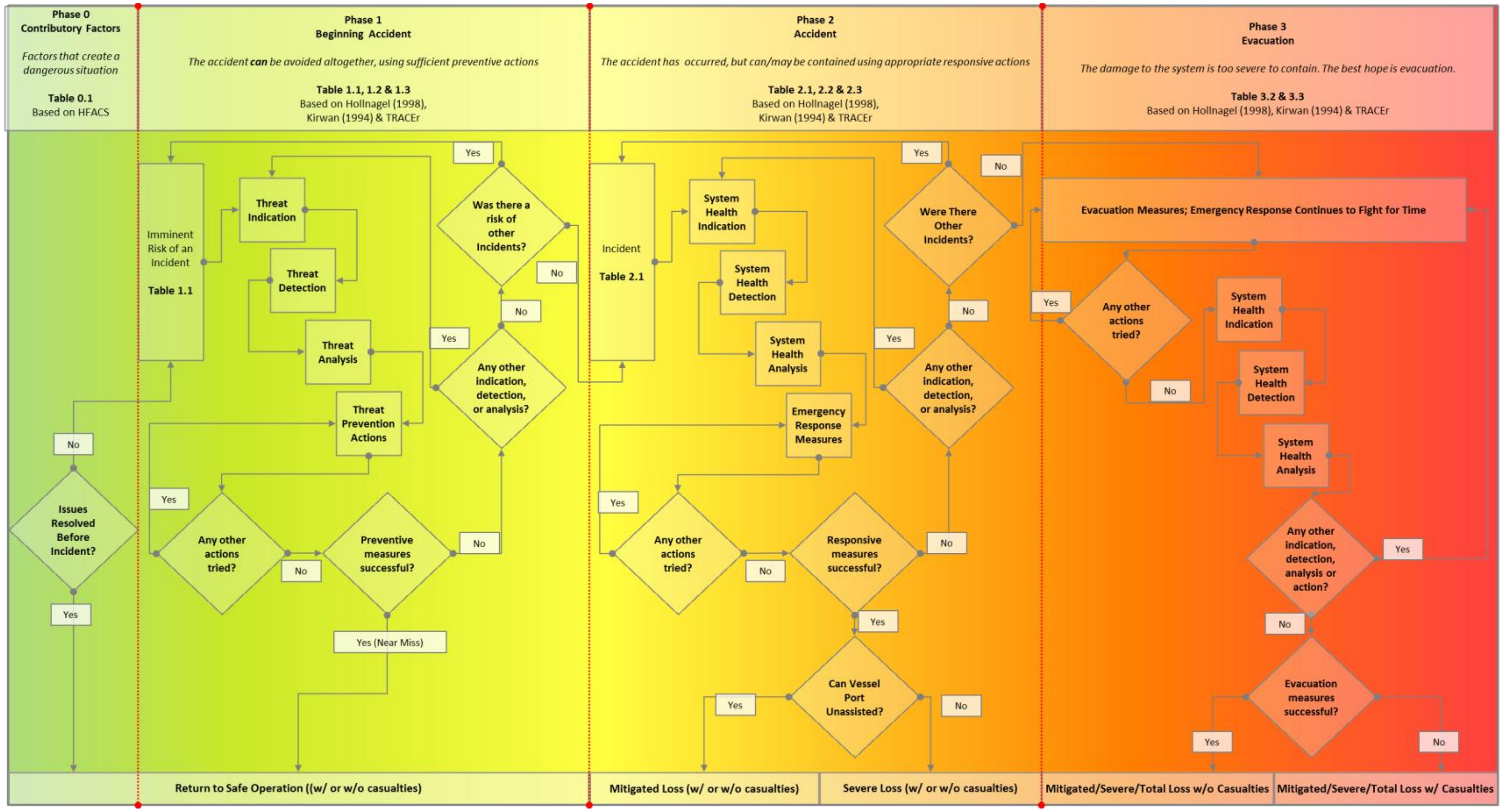


Figure 0-5: SEMOMAP v2. The models developed by Schroeder et al (2014) under unpublished release

Appendix – 3: SEMOMAP taxonomy code book (draft)

The coding developed based on the step by step process following the SEMOMAP framework. The coding assist the user to acknowledge and identify the definition of each terminology used in the Model. The code developed based on the each phase of accident.

Level-1: the main category that contributed directly to the main phase. The definition used for the taxonomy adopted from HFACS

Level-2: the factors that attributed and support the condition of factor in level-1

Level-3: specific factors that support the factors in level-2

Level-4: dropdown list of specific action

Level-5: more specific selection. Under Contributory Factor L5 covers shipboard element. Under accident event assessment process, L5 taxonomy comprise list of error mode based on the TRACEr.

General Information Taxonomy:

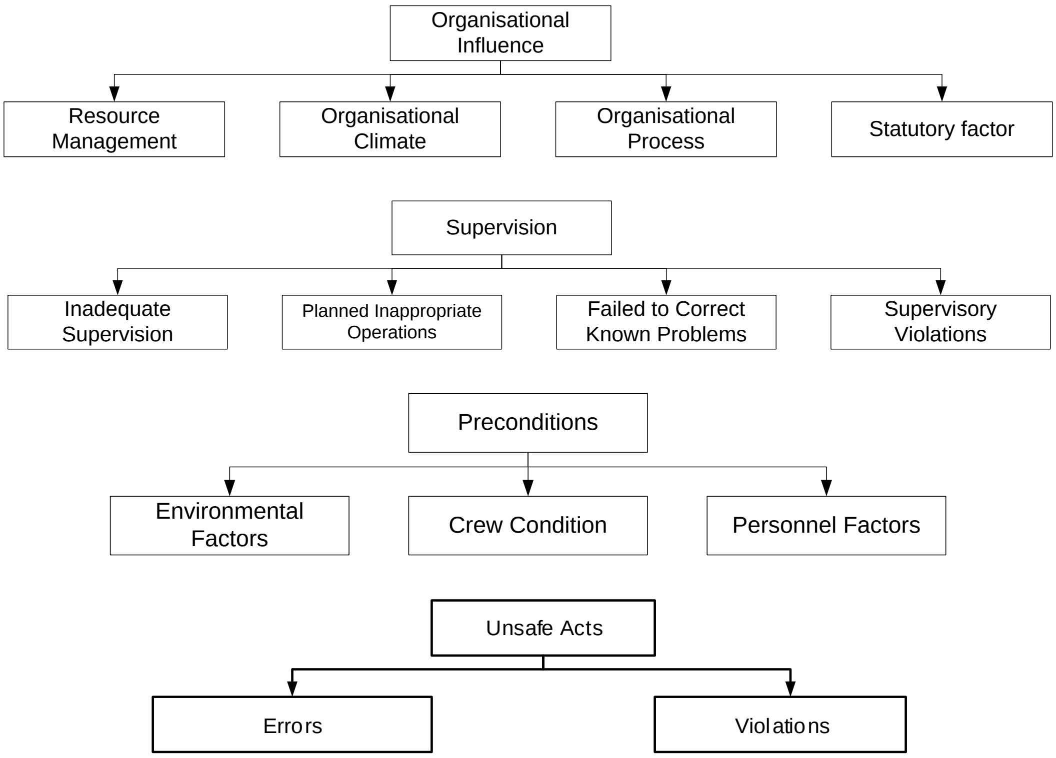
The general information contains involved ship's administration data, the occurrence general information and consequence of accident to the ship, cargo/passengers and environment.

L1	**L2**
IMO Number	State the IMO number of the ship
Vessel Name	State ship name and its previous name
Vessel type	Classify the type of ship by its functionality to carry its cargo: GC, Container, Bulk Carrier, Tanker, Passenger, Ro-Ro, Others
Vessel Flag State	State ship flag at the time of the accident
Classification Society	State the class society the ship was classified under at the time of the accident
Keel Laid Year	State the keel laid year as indicated in ship certificate
Built at	State the location (shipyard, country) the ship built
Deadweight Ton (DWT)	DWT of the ship
Ship Length Over All (m)	Overall length of the ship
Ship Beam (m)	State ship breadth
Ship Loaded Draft (m)	State the ship draft at the time of the occurrence
Ship Height (m)	state the vertical measure of ship bottom to the upmost deck
Date of Occurrence	State date of occurrence
Time of Occurrence	State time of occurrence by Local time and GMT

L1	L2
Geographical Occurrence Location	State the location of the occurrence by its fix gps position and other geographical reference
Type of Occurrence	Classify nature of accident with following event: Collision, Grounding, Contact, Fire/explosion, Hull failure, Loss of control, Ship/equipment damage, Capsize/listing, Flooding/foundering, Ship Missing, Occupational accident, Others, Unknown
Number of Fatalities / Injuries	State number of the fatalities as a result of the accident at the point and subsequent fatality,
Consequence to the Ship	Provide sufficient information of the end consequences to the ship due to accident,
Narratives	Brief overview of the occurrence

Taxonomy for Phase-0: Contributory Factors

As mentioned earlier, the taxonomy for Phase 0 was adapted from HFACS. This section breaks down the HFACS taxonomy, and provides descriptions of what each option. The taxonomy used for SEMOMAP consists of 4 levels; for brevity, however, the taxonomy definitions provided in the codebook are only for levels 1, 2 and 3 (1992).



Under the phase-0, SEMOMAP taxonomy provides detail selection of element as follow:

Table 0-1: Affected shipboard subject

Subjects Effected by Influencing Factors	Category	Details
Human Subjects	Captain & Officers	Captain
		1st/Chief Officer
		2nd Officer
		3rd Officer
		Other Officer
	Navigators	Helmsman
		Pilot
	Other Crew	AB
		Bosun
		OS
	Engineers	1st/Chief Engineer
		2nd Engineer
		Other Engineer
Technical Subjects	Bridge & Deck	Steering Equipment
		Navigation Aids (AIS, ECDIS, Radar, GPS, etc…)
		Communication Equipment
		Alarm Panels & System
	Engine Room	Main Engine
		Auxiliary Engine
		Engine Control Panel
		Fuel Pumps
		Ballast Water Pumps
		Generators
		Boilers
	Ship Structure & Design	Hull
		Separators

Level-1 Taxonomy:

Table 0-2: Contributory Factor Level-1 definition

Terminology	Definition
Organisational Influence	factors in a mishap if the communications, actions, omissions or policies of upper-level management directly or indirectly affect supervisory practices, conditions or actions of the operator(s) and result in system failure, human error or an unsafe situation
Supervision	a mishap event can often be traced back to the supervisory chain of command.
Pre-Condition	factors in a mishap if active and/or latent preconditions such as conditions of the operators, environmental or personnel factors affect practices, conditions or actions of individuals and result in human error or an unsafe situation
Unsafe Acts	Acts are those factors that are most closely tied to the mishap, and can be described as active failures or actions committed by the operator that result in human error or unsafe situation

Level-2 Taxonomy

Taxonomy under Organisational influence

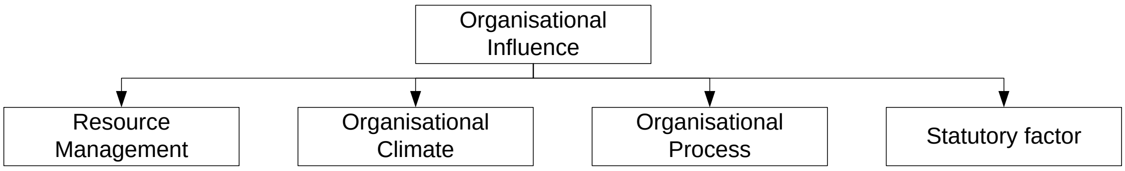


Table 0-3: Definition for L2 Factor under organisational influence

Parent Level	Terminology	Definition
Organisational Influence	Resource Management	factor in a mishap if resource management and/or acquisition processes or policies, directly or indirectly, influence system safety and results in poor error management or creates an unsafe situation
	Organisational Climate	Factor in a mishap if organizational variables including environment, structure, policies, and culture influence individual actions and results in human error or an unsafe situation.
	Organisational Process	Factor in a mishap if organizational processes such as operations, procedures, operational risk management and oversight negatively influence individual, supervisory, and/or organizational performance and results in unrecognized hazards and/or uncontrolled risk and leads to human error or an unsafe situation
	Statutory factors	Considered as external factor that mostly on the policy and regulatory side

Taxonomy under supervision

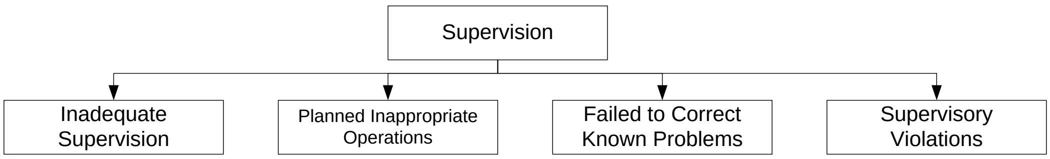


Table 0-4: Definition for L2 Factor under Supervision

Parent Level	L-2: Terminology	Definition
Supervision	Inadequate supervision	factor in a mishap when supervision proves inappropriate or improper and fails to identify a hazard, recognize and control risk, provide guidance, training and/or oversight and results in human error or an unsafe situation
	Planned inappropriate operation	factor in a mishap when supervision fails to adequately assess the hazards associated with an operation and allows for unnecessary risk. It is also a

Parent Level	L-2: Terminology	Definition
		factor when supervision allows non-proficient or inexperienced personnel to attempt missions beyond their capability or when crew or flight makeup is inappropriate for the task or mission.
	Failure in correct known problem	factor in a mishap when supervision fails to correct known deficiencies in documents, processes or procedures, or fails to correct inappropriate or unsafe actions of individuals, and this lack of supervisory action creates an unsafe situation.
	Supervisory violation	factor in a mishap when supervision, while managing organizational assets, wilfully disregards instructions, guidance, rules, or operating instructions and this lack of supervisory responsibility creates an unsafe situation.

Taxonomy under Precondition

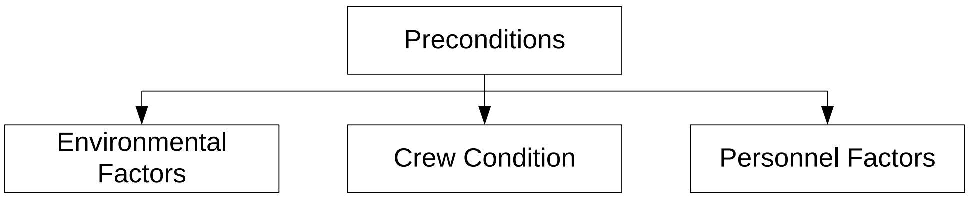


Table 0-5: Definition for L2 Factor under Precondition

Parent Level	L-2: Terminology	Definition
Pre Condition	Condition of Individual	Factors in a mishap if cognitive, psycho-behavioural, adverse physical state, or physical/mental limitations affect practices, conditions or actions of individuals and result in human error or an unsafe situation.
	Environmental Factor	factors in a mishap if physical or technological factors affect practices, conditions and actions of individual and result in human error or an unsafe situation
	Personal Factor	factors in a mishap if self-imposed stressors or crew resource management affects practices, conditions or actions of individuals, and result in human error or an unsafe situation

Taxonomy under Unsafe Acts

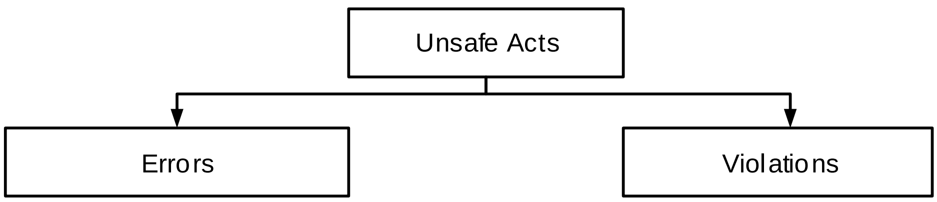


Table 0-6: Definition for L2 Factor unsafe Act

Parent Level	L-2: Terminology	Definition
Unsafe Acts	Errors	Factors in a mishap when mental or physical activities of the operator fail to achieve their intended outcome as a result of skill-based, perceptual, or judgment and decision making errors, leading to an unsafe situation
	Violations	Factors in a mishap when the actions of the operator represent wilful disregard for rules and instructions and lead to an unsafe situation. Unlike errors, violations are deliberate.

Level-3 Taxonomy

Taxonomy under resource management

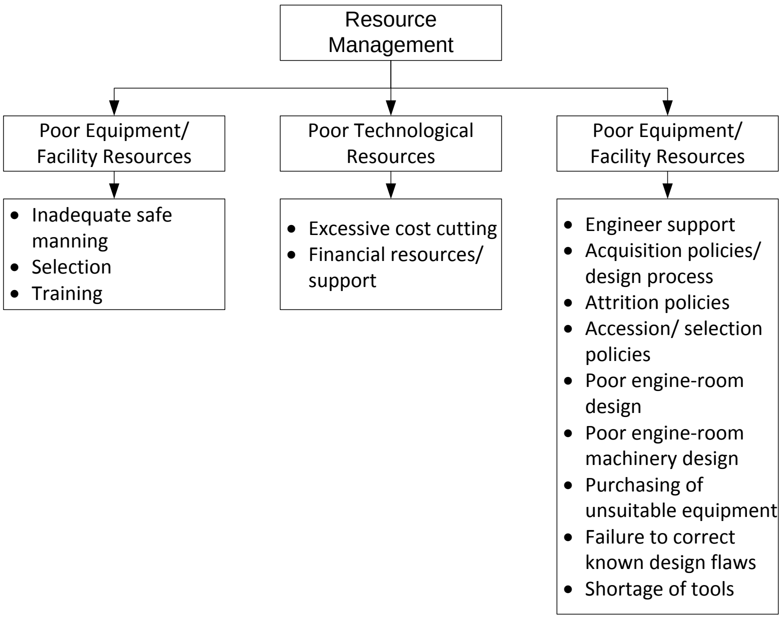


Table 0-7: Definition for L3 Factor under Resource Management

Parent Level	L-3: Terminology	Definition
Resource Management	Lack of human resource	Issues that directly influence safety include selection (including background checks), training, and staffing/manning
	Poor technological resources	Are factors in a mishap when ship design factors or automation affect the actions of individuals and result in human error or an unsafe situation
	Poor equipment/facility	issues related to equipment design, including the purchasing of unsuitable equipment, inadequate design of workspaces, and failures to correct known design flaws

Taxonomy under organisational climate

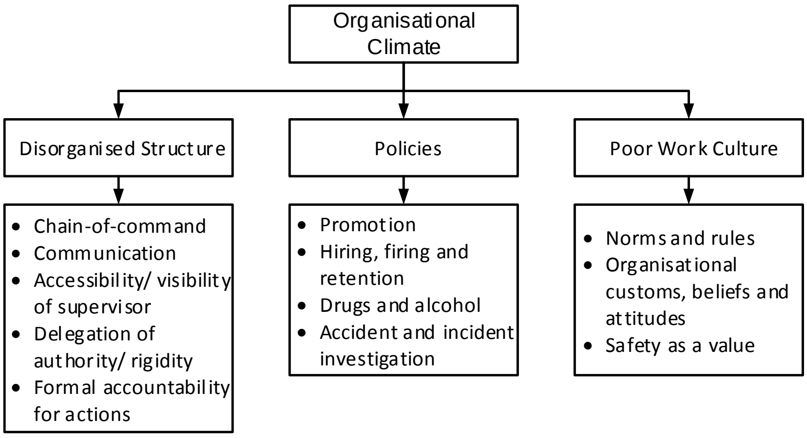


Table 0-8: Definition for L3 Factor under Organisational Climate

Parent Level	L-3: Terminology	Definition
organizational climate	Disorganised Structure	a factor when the chain of command of an individual or structure of an organization is confusing, non-standard or inadequate and this creates an unsafe situation
	Inadequate Policies	A course or method of action that guides present and future decisions. Policies may refer to hiring and firing, promotion, retention, raises, sick leave, drugs and alcohol, overtime, accident investigations, use of safety, equipment, etc. When these policies are ill-defined, adversarial, or conflicting, safety may be reduced
	Poor Work Culture	a factor when explicit/implicit actions, statements or attitudes of unit leadership set unit/organizational values (culture) that allow an environment where unsafe mission demands or pressures exist

Taxonomy under Organisational Process

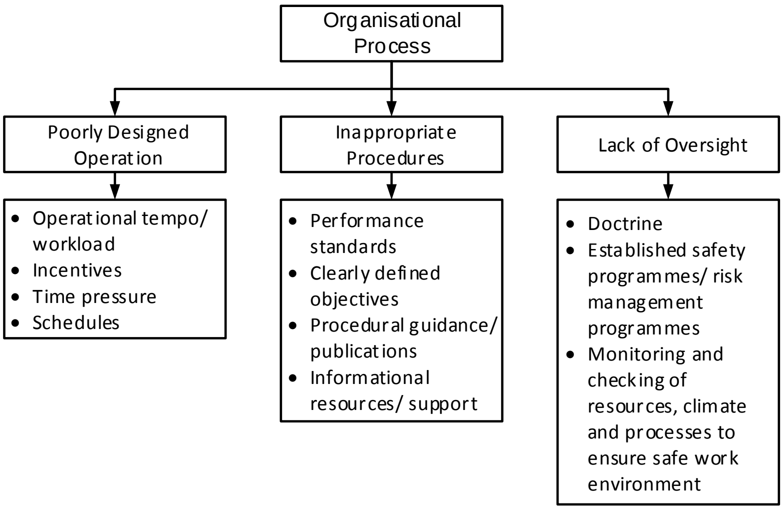


Table 0-9: Definition for L3 Factor under Organisational Process

Parent Level	L-3: Terminology	Definition
Organisational Process	Poorly designed operation	a factor when the potential risks of a large program, operation, acquisition or process are not adequately assessed and this inadequacy leads to an unsafe situation.
	Inappropriate procedures	a factor when written direction, checklists, graphic depictions, tables, charts or other published guidance is inadequate, misleading or inappropriate and this creates an unsafe situation
	Lack of oversight	a factor when programs are implemented without sufficient support, oversight or planning and this leads to an unsafe situation

Taxonomy under statutory factor

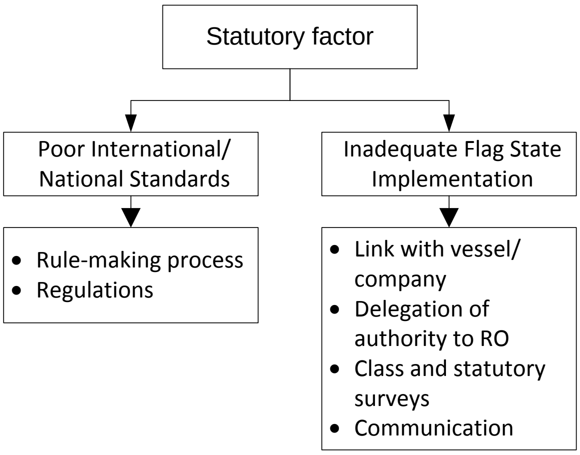


Table 0-10: Definition for L3 Factor under Statutory Factor

Parent Level	L-3: Terminology	Definition
Statutory	Poor	Factor that inadequate standards and regulations

factor	international/ national standards	cause an unsafe condition or situation
	Inadequate flag state implementation	Factor in a mishap if the implementation of the flag state such as audit/survey/enforcement considered insufficient so it create unsafe condition

Taxonomy under Inadequate Supervision

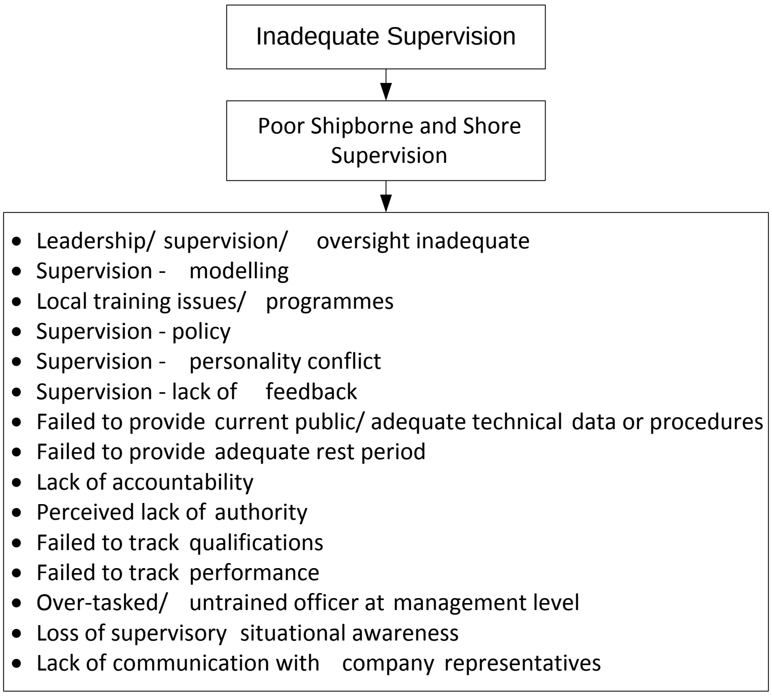


Table 0-11: Definition for L3 Factor under Inadequate Supervision

Parent Level	L-3: Terminology	Definition
Inadequate supervision	Poor shipborne and shore supervision	a factor when the availability, competency, quality or timeliness of leadership, supervision or oversight does not meet task demands and creates an unsafe situation

Taxonomy under planned inappropriate operations

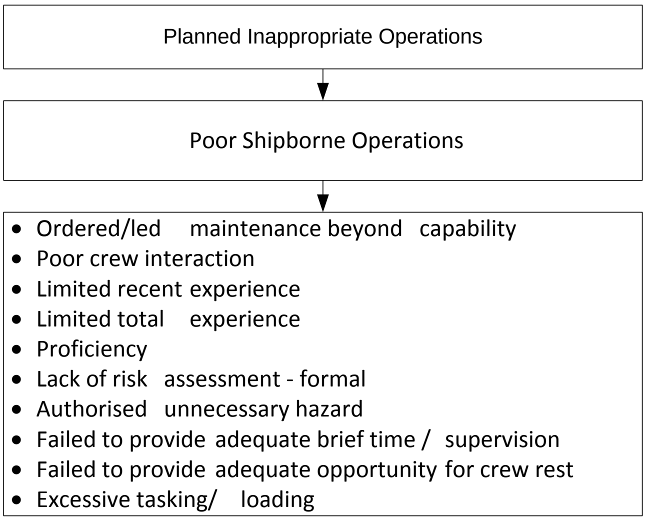


Table 0-12: Definition for L3 Factor under planned inappropriate operations

Parent Level	L-3: Terminology	Definition
Planned inappropriate operations	Poor shipborne operations	a factor in a mishap when supervision fails to adequately assess the hazards associated with an operation and allows for unnecessary risk

Taxonomy under failed to correct problems

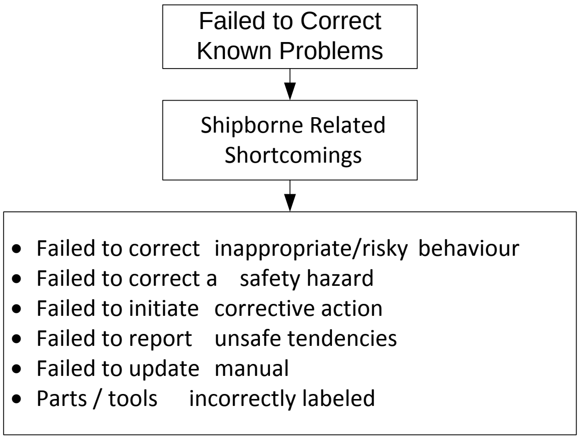


Table 0-13: Definition for L3 Factor under Failed to correct known problems

Parent Level	L-3: Terminology	Definition
Failed to correct known problems	Shipborne related shortcomings	a factor when the supervisor selects an individual who's experience for either a specific manoeuvre, event or scenario is not sufficiently current to permit safe mission execution.

Taxonomy under supervisory violations

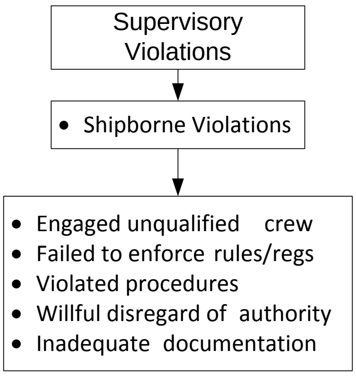


Table 0-14: Definition for L3 Factor under Supervisory violations

Parent Level	L-3: Terminology	Definition
Supervisory violations	Shipborne violations	Is a factor in a mishap when supervision while managing organizational assets wilfully disregards instructions, guidance, rules, or operating instructions and this lack of supervisory responsibility creates an unsafe situation

Taxonomy under supervisory violations

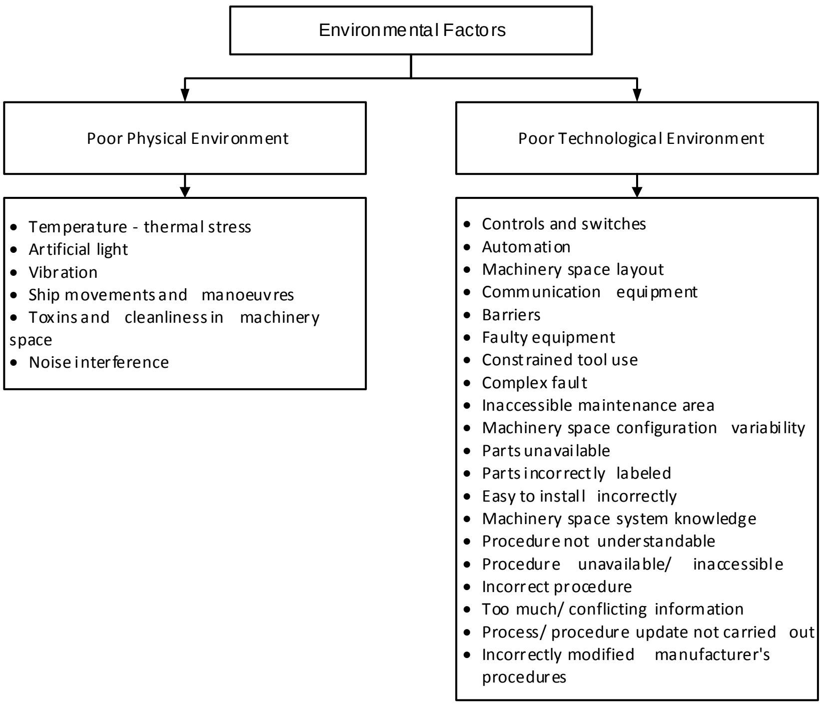


Table 0-15: Definition for L3 Factor under Environmental Factors

Parent Level	L-3: Terminology	Definition
Environmental factors	Poor physical environmental	Physical environment are factors in a mishap if environmental phenomena such as weather, climate, white-out or dust-out conditions affect the actions of

Parent Level	L-3: Terminology	Definition
		individuals and result in human error or an unsafe situation
	Poor technological environment	Technological environment are factors in a mishap when cockpit/vehicle/workspace design factors or automation affect the actions of individuals and result in human error or an unsafe situation

Taxonomy under crew condition

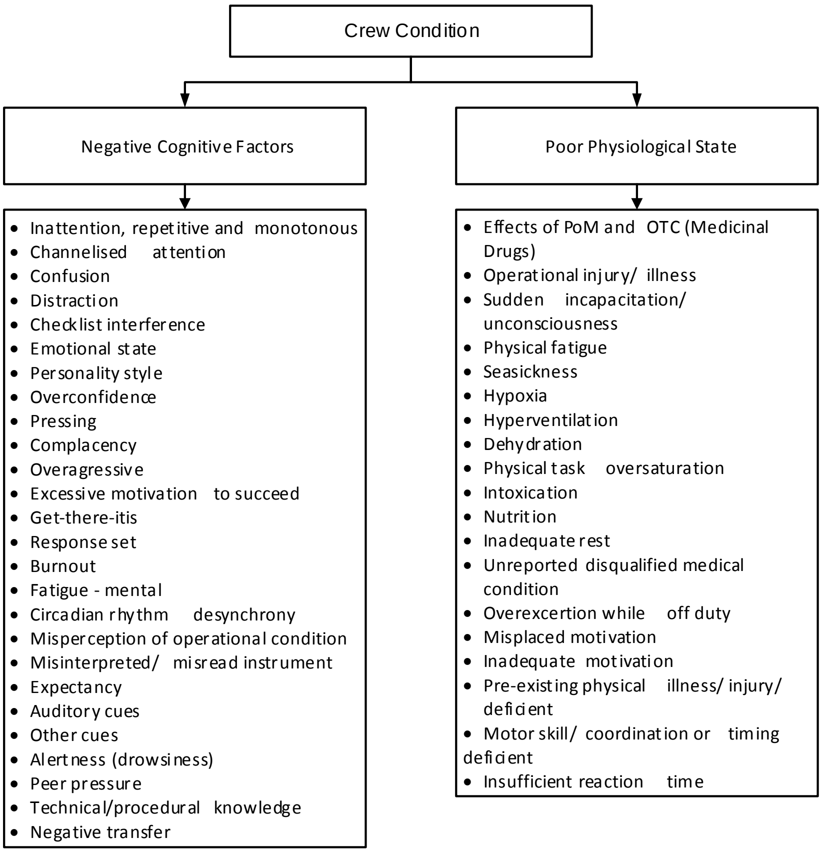


Table 0-16: Definition for L3 Factor under Crew Condition

Parent Level	L-3: Terminology	Definition
Crew condition	Negative cognitive factors	Are factors in a mishap if cognitive or attention management conditions affect the perception or performance of individuals and result inhuman error or an unsafe situation
	Poor physiological state	Are factors when an individual's personality traits, psychosocial problems, psychological disorders or inappropriate motivation creates an unsafe situation

Taxonomy under personnel factors

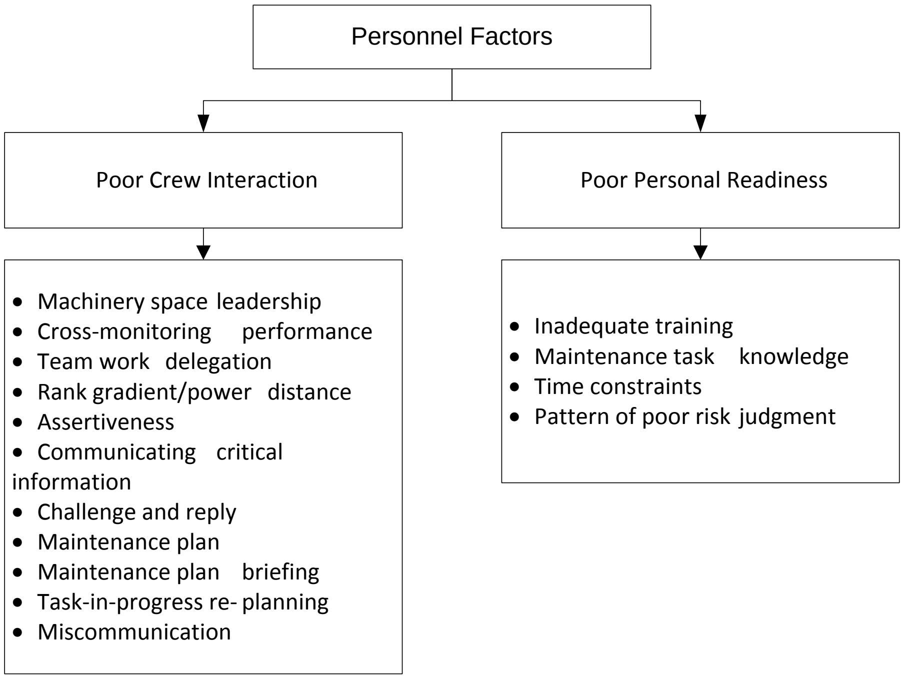


Table 0-17: Definition for L3 Factor under Personnel Factors

Parent Level	L-3: Terminology	Definition
Personnel factors	Poor crew interaction	Refer to interactions among individuals, crews, and teams involved with the preparation and execution of a mission that resulted in human error or an unsafe situation
	Poor personal readiness	factors in a mishap if the operator demonstrates disregard for rules and instructions that govern the individuals readiness to perform, or exhibits poor judgment when it comes to readiness and results in human error or an unsafe situation

Taxonomy under errors

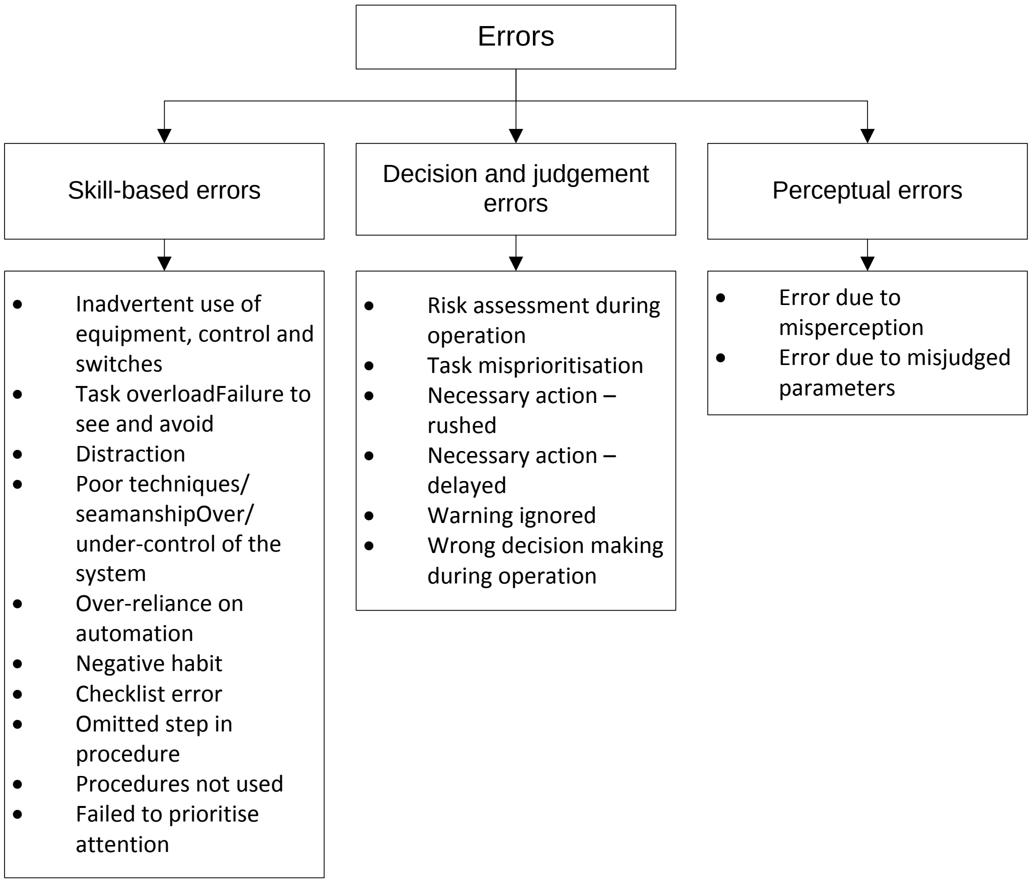


Table 0-18: Definition for L3 Factor under Errors

Parent Level	L-3: Terminology	Definition
Errors	Skilled based errors	Are factors in a mishap when errors occur in the operator's execution of a routine, highly practiced task relating to procedure, training or proficiency and result in an unsafe a situation
	Decision and judgement errors	Are factors in a mishap when behaviour or actions of the individual proceed as intended yet the chosen plan proves inadequate to achieve the desired end-state and results in an unsafe situation
	Perceptual errors	Are factors in a mishap when misperception of an object, threat or situation, (such as visual, auditory, pro prioceptive, or vestibular illusions, cognitive or attention failures, etc), results in human error

Taxonomy under violations

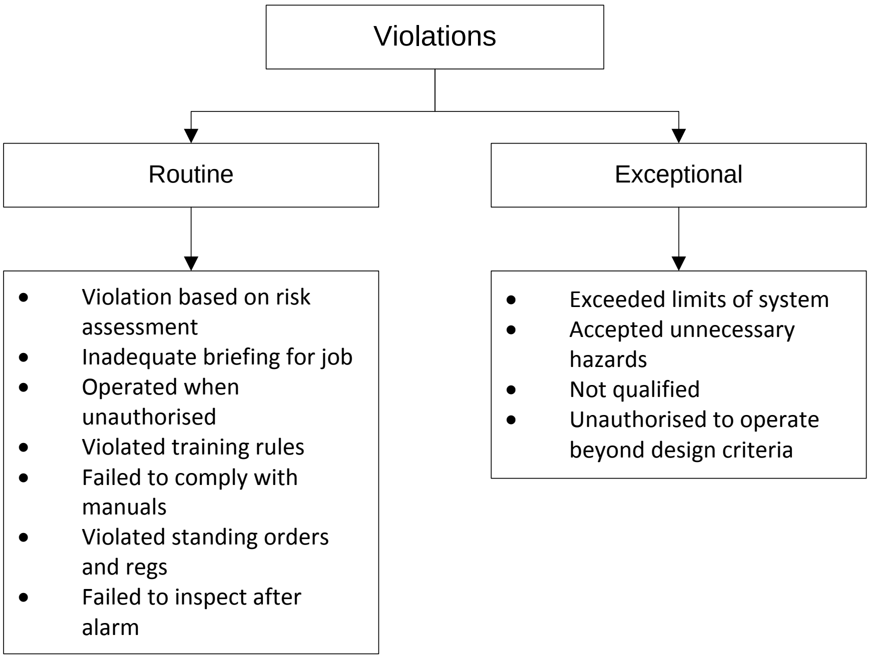
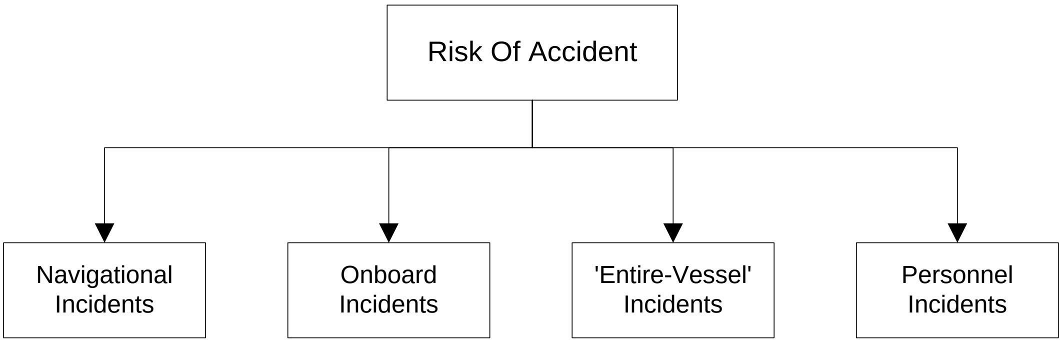


Table 0-19: Definition for L3 Factor under Violations

Parent Level	L-3: Terminology	Definition
Violations	Routine	a factor when a procedure or policy violation is systemic in a unit/setting and not based on a risk assessment for a specific situation. It needlessly commits the individual, team, or crew to an unsafe course-of-action. These violations may have leadership sanction and may not routinely result in disciplinary/administrative action. Habitual violations of a single individual or small group of individuals within a unit can constitute a routine/widespread violation if the violation was not routinely disciplined or was condoned by supervisors
	Exceptional	a factor when an individual, crew or team intentionally violates procedures or policies without cause or need. These violations are unusual or isolated to specific individuals rather than larger groups. There is no evidence of these violations being condoned by leadership

Taxonomy for phase-1: Risk of Accident



Phase I under navigational incidents

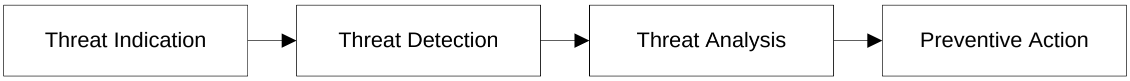


Table 0-20: Taxonomy for threat indication under navigational incidents

L2B	L2C	L2D	L2E
Threat Indication	Onboard	Equipment	Radar
			Echo Sounder
			AIS
			ECDIS
			Sea Charts
			GPS
			Other
		Human	Lookout
			OOW
			Other Crew Member
			Passenger
			Other
	Ashore	Equipment	Foghorn
			Lighthouse
			Bouy/Navigational Aid
			Other
		Human	VTS
			Coastguard
			Other

Table 0-21: Taxonomy for threat detection under navigational incidents

L2B	L2C	L2D	L2E
Threat Detection	Onboard	Equipment	Decision Support System
			Other
		Human	Master
			OOW
			Other
	Ashore	Human	VTS
			Other

Table 0-22: Taxonomy for threat analysis under navigational incidents

L2B	L2C	L2D	L2E
Threat Analysis	Onboard	Equipment	Decision Support System
			Other
		Human	Master
			OOW
			Other
	Ashore	Human	VTS
			Other

Table 0-23: Taxonomy for threat prevention action under navigational incidents

L2B	L2C	L2D	L2E
Threat Prevention Action	Onboard	Action	Steering & Maneuvering
			Altering Speed
			Dropping Anchor
			Reverse Thrust
			Other
	Offboard	Action	Other Vessel Alters Course
			Other Vessel Alters Speed
			Other

Taxonomy for On-board incidents

Table 0-24: Taxonomy for threat indication under Onboard incidents

L2B	L2C	L2D	L2E
Threat Indication	Onboard	Equipment	Fire Alarm System
			Heat Detector
			Smoke Detector
			CCTV & Cameras
			Other
		Human	Lookout
			OOW/EOW
			Other Crew Member

L2B	L2C	L2D	L2E
			Passenger
			Other
	Ashore	Equipment	Fleet Monitoring System
			Other
		Human	Fleet Monitoring Centre
			Other

Table 0-25: Taxonomy for threat detection under Onboard incidents

L2B	L2C	L2D	L2E
Threat Detection	Onboard	Equipment	Decision Support System
			Other
		Human	Master
			OOW/EOW
			Other
	Ashore	Human	Fleet Monitoring Centre
			Other

Table 0-26: Taxonomy for threat analysis under Onboard incidents

L2B	L2C	L2D	L2E
Threat Analysis	Onboard	Equipment	Decision Support System
			Other
		Human	Master
			OOW
			Other
	Ashore	Equipment	Fleet Monitoring System
			Other
		Human	Fleet Monitoring Centre
			Other

Table 0-27: Taxonomy for threat prevention action under Onboard incidents

L2B	L2C	L2D	L2E
Threat Prevention	Onboard	Action	Cut off oxygen supply to flammable area
			Close fire doors
			Move flammable goods to safe place
			Reduce heat
			Shut down engine
			Shut down affected systems
			Other

Type of risk under 'Entire-Vessel' Incidents

Table 0-28: Taxonomy for threat indication under 'Entire-Vessel' Incidents

L2B	L2C	L2D	L2E
Threat Indication	Onboard	Equipment	Alarms & Warning
			Stability Indicators
			Water Level Indicators
			CCTV & Cameras
			Other
		Human	Lookout
			OOW
			Other Crew Member
			Passenger
			Other
	Ashore	Equipment	Fleet Monitoring System
			Other
		Human	Fleet Monitoring Centre
			Other

Table 0-29: Taxonomy for threat detection under 'Entire-Vessel' Incidents

L2B	L2C	L2D	L2E
Threat Detection	Onboard	Equipment	Decision Support System
			Other
		Human	Master
			OOW
			Other
	Ashore	Equipment	Fleet Monitoring System
			Other
		Human	Fleet Monitoring Centre
			Other

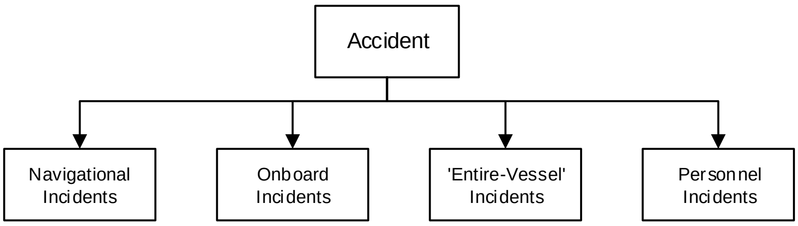
Table 0-30: Taxonomy for threat analysis under 'Entire-Vessel' Incidents

L2B	L2C	L2D	L2E
Threat Analysis	Onboard	Equipment	Decision Support System
			Other
		Human	Master
			OOW
			Other
	Ashore	Equipment	Fleet Monitoring System
			Other
		Human	Fleet Monitoring Centre
			Other

Table 0-31: Taxonomy for threat prevention action under 'Entire-Vessel' Incidents

L2B	L2C	L2D	L2E
Threat Prevention action	Onboard	Action	Altering Speed
			Stabilize & Secure Cargo
			Seal Hull Compartments
			Other

Taxonomy for phase-2: The Accident



Phase-2 Taxonomy for Navigational Incidents

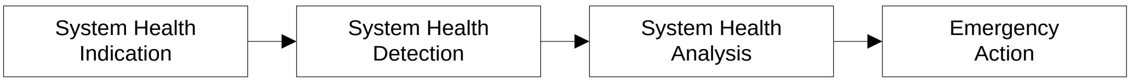


Table 0-32: Taxonomy for system health indication under Navigational Incidents

L2B	L2C	L2D	L2E
System Health Indication	Onboard	Equipment	Hull Damage Sensors
			List Indicators
			Water Level Indicators
			Stability Indicators
			Other
		Human	OOW
			Other Crew Member
			Passenger
			Other
	Ashore	Equipment	Fleet Monitoring System
			Other
		Human	Fleet Monitoring Centre
			Other

Table 0-33: Taxonomy for system health detection under Navigational Incidents

L2B	L2C	L2D	L2E
System Health Detection	Onboard	Equipment	Decision Support System
			Other
		Human	Master

L2B	L2C	L2D	L2E
			OOW
			Other
	Ashore	Equipment	Fleet Monitoring System
			Other
		Human	Fleet Monitoring Centre
			Other

Table 0-34: Taxonomy for system health analysis under Navigational Incidents

L2B	L2C	L2D	L2E
System Health Analysis	Onboard	Equipment	Decision Support System
			Other
		Human	Master
			OOW
			Other
	Ashore	Equipment	Fleet Monitoring System
			Other
		Human	Fleet Monitoring Centre
			Other

Table 0-35: Taxonomy for emergency response under Navigational Incidents

L2B	L2C	L2D	L2E
Emergency Response	Onboard	Action	Contain Hull Damage
			Contain Equipment Damage
			Drop Anchor
			Reverse Thrust
			Other
	Offboard	Action	Tug Vessel
			Other

Phase-2 Taxonomy for On-board Incidents

Table 0-36: Taxonomy for system health indication under Onboard Incidents

L2B	L2C	L2D	L2E
System Health Indication	Onboard	Equipment	Fire Alarm System
			Heat Detector
			Smoke Detector
			CCTV & Cameras
			Other
		Human	Lookout
			OOW/EOW
			Other Crew Member
			Passenger
			Other
	Ashore	Equipment	Fleet Monitoring System

			Other
		Human	Fleet Monitoring Centre
			Other

Table 0-37: Taxonomy for system health detection under Onboard Incidents

L2B	L2C	L2D	L2E
System Health Detection	Onboard	Equipment	Decision Support System
			Other
		Human	Master
			OOW
			Other
	Ashore	Human	Fleet Monitoring Centre
			Other

Table 0-38: Taxonomy for system health analysis under Onboard Incidents

L2B	L2C	L2D	L2E
System Health Analysis	Onboard	Equipment	Decision Support System
			Other
		Human	Master
			OOW
			Other
	Ashore	Equipment	Fleet Monitoring System
			Other
		Human	Fleet Monitoring Centre
			Other

Table 0-39: Taxonomy for emergency response under Onboard Incidents

L2B	L2C	L2D	L2E
Emergency Response	Onboard	Action	Fire-fighting
			Sprinkler System
			Muster Crew
			Move flammable goods to safe place
			Cut off oxygen supply to flammable area
			Close fire doors
			Shut down engine
			Shut down affected systems
			Other
	Offboard	Action	Fire-fighting vessel
			Other

Phase-2 Taxonomy for 'Entire-Vessel' Incidents

Table 0-40: Taxonomy for system health indication under 'Entire-Vessel' Incidents

L2B	L2C	L2D	L2E
System Health Indication	Onboard	Equipment	Alarms & Warning
			Stability Indicators
			Water Level Indicators
			CCTV & Cameras
			Other
		Human	Lookout
			OOW
			Other Crew Member
			Passenger
			Other
	Ashore	Equipment	Fleet Monitoring System
			Other
		Human	Fleet Monitoring Centre
			Other

Table 0-41: Taxonomy for system health detection under 'Entire-Vessel' Incidents

L2B	L2C	L2D	L2E
System Health Detection	Onboard	Equipment	Decision Support System
			Other
		Human	Master
			OOW
			Other
	Ashore	Equipment	Fleet Monitoring System
			Other
		Human	Fleet Monitoring Centre
			Other

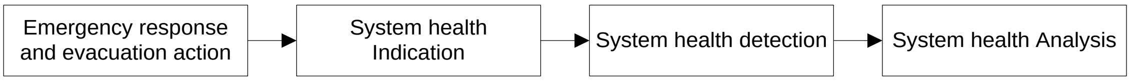
Table 0-42: Taxonomy for system health analysis under 'Entire-Vessel' Incidents

L2B	L2C	L2D	L2E
System Health Analysis	Onboard	Equipment	Decision Support System
			Other
		Human	Master
			OOW
			Other
	Ashore	Equipment	Fleet Monitoring System
			Other
		Human	Fleet Monitoring Centre
			Other

Table 0-43: Taxonomy for emergency response under 'Entire-Vessel' Incidents

L2B	L2C	L2D	L2E
Emergency Response	Onboard	Action	Altering Speed
			Stabilize & Secure Cargo
			Seal Hull Compartments
			Seal Watertight Compartments
			Ballast Water Stabilisation
			Other
	Ashore	Action	Tug Vessel
			Other

Taxonomy for phase-3: Phase III- Evacuation



Phase-3 for Navigational Incident

Table 0-44: Taxonomy of Emergency response and evacuation for phase-3 under navigational incident

L2B	L2C	L2D	L2E
Emergency Response & Evacuation	Onboard	Action	Contain Hull Damage
			Contain Equipment Damage
			Drop Anchor
			Reverse Thrust
			Lower Lifeboats
			Lower MES/Liferafts
			Muster Personnel
			Other Emergency Response Measure
			Other Evacuation Measure
	Offboard	Action	Call Tug Vessel
			Call SAR Services
			Other

Table 0-45: Taxonomy of system health indication for phase-3 under navigational incident

L2B	L2C	L2D	L2E
System Health Indication	Onboard	Equipment	Hull Damage Sensors
			List Indicators
			Water Level Indicators
			Stability Indicators
			Other
		Human	OOW
			Other Crew Member
			Passenger
			Other
	Ashore	Equipment	Fleet Monitoring System
			Other

		Human	Fleet Monitoring Centre
			Other

Table 0-46: Taxonomy of system health detection for phase-3 under navigational incident

L2B	L2C	L2D	L2E
System Health Detection	Onboard	Equipment	Decision Support System
			Other
		Human	Master
			OOW
			Other
	Ashore	Equipment	Fleet Monitoring System
			Other
		Human	Fleet Monitoring Centre
			Other

Table 0-47: Taxonomy of system health detection for phase-3 under navigational incident

L2B	L2C	L2D	L2E
System Health Analysis	Onboard	Equipment	Decision Support System
			Other
		Human	Master
			OOW
			Other
	Ashore	Equipment	Fleet Monitoring System
			Other
		Human	Fleet Monitoring Centre
			Other

Onboard Incident

Table 0-48: Taxonomy of Emergency response and evacuation for phase-3 under onboard incident

L2B	L2C	L2D	L2E
Emergency Response & Evacuation	Onboard	Action	Fire-fighting
			Sprinkler System
			Muster Crew
			Move flammable goods to safe place
			Cut off oxygen supply to flammable area
			Close fire doors
			Shut down engine
			Shut down affected systems
			Lower Lifeboats
			Lower MES/Liferafts
			Muster Personnel
			Other Emergency Response Measure
			Other Evacuation Measure
	Offboard	Action	Call Fire-fighting vessel

L2B	L2C	L2D	L2E
			Call SAR Services
			Other

Table 0-49: Taxonomy of system health detection for phase-3 under Onboard incident

L2B	L2C	L2D	L2E
System Health Indication	Onboard	Equipment	Fire Alarm System
			Heat Detector
			Smoke Detector
			CCTV & Cameras
			Other
		Human	Lookout
			OOW/EOW
			Other Crew Member
			Passenger
			Other
	Ashore	Equipment	Fleet Monitoring System
			Other
		Human	Fleet Monitoring Centre
			Other

Table 0-50: Taxonomy of system health detection for phase-3 under onboard incident

L2B	L2C	L2D	L2E
System Health Detection	Onboard	Equipment	Decision Support System
			Other
		Human	Master
			OOW
			Other
	Ashore	Human	Fleet Monitoring Centre
			Other

Table 0-51: Taxonomy of system health analysis for phase-3 under onboard incident

L2B	L2C	L2D	L2E
System Health Analysis	Onboard	Equipment	Decision Support System
			Other
		Human	Master
			OOW
			Other
	Ashore	Equipment	Fleet Monitoring System
			Other
		Human	Fleet Monitoring Centre
			Other

Phase taxonomy for 'Entire-Vessel' Incidents

Table 0-52: Taxonomy of Emergency response and evacuation for phase-3 under 'Entire-Vessel' Incidents

L2B	L2C	L2D	L2E
Emergency Response & Evacuation	Onboard	Action	Altering Speed
			Stabilize & Secure Cargo
			Seal Hull Compartments
			Seal Watertight Compartments
			Ballast Water Stabilisation
			Lower Lifeboats
			Lower MES/Liferafts
			Muster Personnel
			Other Emergency Response Measure
			Other Evacuation Measure
	Ashore	Action	Call Tug Vessel
			Call SAR Services
			Other

Table 0-53: Taxonomy of System health indication for phase-3 under 'Entire-Vessel' Incidents

L2B	L2C	L2D	L2E
System Health Indication	Onboard	Equipment	Alarms & Warning
			Stability Indicators
			Water Level Indicators
			CCTV & Cameras
			Other
		Human	Lookout
			OOW
			Other Crew Member
			Passenger
			Other
	Ashore	Equipment	Fleet Monitoring System
			Other
		Human	Fleet Monitoring Centre
			Other

Table 0-54: Taxonomy of system health detection for phase-3 under 'Entire-Vessel' Incidents

L2B	L2C	L2D	L2E
System Health Detection	Onboard	Equipment	Decision Support System
			Other
		Human	Master
			OOW
			Other
	Ashore	Equipment	Fleet Monitoring System
			Other
		Human	Fleet Monitoring Centre
			Other

Table 0-55: Taxonomy of system health analysis for phase-3 under 'Entire-Vessel' Incidents

L2B	**L2C**	**L2D**	**L2E**
System Health Analysis	Onboard	Equipment	Decision Support System
			Other
		Human	Master
			OOW
			Other
	Ashore	Equipment	Fleet Monitoring System
			Other
		Human	Fleet Monitoring Centre
			Other

Error Mode for each Phase

Specify whether the step was Applicable and Successful – Level 3A & 3B

This stage firstly breaks down each step into smaller 'sub-steps', as follows:

Step	Sub-Steps
Indication	Information Recording
	Information Transmission
Detection	Information Receiving
	Information Evaluation
	Information Transmission
Analysis	Information Receiving
	Planning
	Decision Making
Action	Communication
	Timing & Sequence
	Selection & Quality

Once again, these steps and sub-steps are self-explanatory.

At this stage, the user must determine whether each sub-step was applicable or not. If it was not applicable (for instance, if the threat indicator and detector are the same person and there is therefore no transmission or receiving or information; or if there was no threat detection) the user does not need to answer any more questions, and can move to the next sub-step or step. Alternatively, if a sub-step was applicable, and successful, in that case too, the user can move to the next sub-step without going into further stages of the sub-step.

If, however, a sub-step is applicable, and unsuccessful, the user must answer further questions, and moves to stage 5.

Note here that successful means success in the context of the sub-step – and not in the context of the entire accident or incident; a successful action might still be a *wrong* action in terms of the accident, but it was 'successful' because *in itself*, it was done correctly, but may, for example, have been based on wrong information from the previous step.

Specify whether Human or Equipment Failure – Level 4A

If a sub-step was unsuccessful, the user can select in this stage if it was due to human or equipment failure.

Specify *what* the Human or Equipment Failure Was – Level 4B

In this level, the user gets to specify what the exact human or equipment failure was. It depends on the sub-step, and the phase that the user is in. Tables on the following pages show the possible failures for each possible sub-step as defined in earlier on this page. This taxonomy is adapted from the TRACEr taxonomy of Kirwan and Shorrock (2002).

Table 0-56: Possible Failures for Information Recording

No Information Recorded
Unclear Information Recorded
Partial Information Recorded
Wrong Information Recorded
Delay in Information Recorded
Unnecessary Information Recorded

Table 0-57: Possible Failures for Information Transmission

No Information Transmitted
Unclear Information Transmitted
Partial Information Transmitted
Wrong Information Transmitted
Delay in Information Transmitted
Unnecessary Information Transmitted

Table 0-58: Possible Failures for Information Transmission

No Information Received
Unclear Information Received
Partial Information Received
Wrong Information Received
Delay in Information Received
Unnecessary Information Received

Table 0-59: Possible Failures for Information Evaluation

No Evaluation
Unclear Evaluation
Partial Evaluation
Incorrect Evaluation
Delayed Evaluation

Table 0-60: Possible Failures for Planning

No Planning
Unclear Planning
Partial Planning
Wrong Planning
Delay in Planning
Unnecessary Planning

Table 0-61; Possible Failures for Decision Making

No Decision
Unclear Decision
Partial Decision
Wrong Decision
Delay in Decision

Table 0-62: Possible Failures for Communication

No Action Information Provided/Recorded
Unclear Action Information Provided/Recorded
Partial Action Information Provided/Recorded
Wrong Action Information Provided/Recorded
Delay in Action Information

Provided/Recorded
Unnecessary Action Information Provided/Recorded

Table 0-63: Possible Failures for Timing & Sequence

Action too long
Action too short
Action too early
Action too late
Action repeated
Action in wrong sequence

Table 0-64: Possible Failures for Selection & Quality

Omission
Action too much
Action too little
Action in wrong direction
Wrong action on right object
Right action on wrong object
Wrong action on wrong object
Extraneous act

In this level, the user gets to specify why the human or equipment made an error or failed. It depends solely on whether a human or technical subject committed a failure, regardless of the phase or the step. The taxonomy for this stage too (at least for the human subjects) is adapted from TRACEr (Kirwan, Shorrock 2002).

The following tables show possible internal error modes for human subjects.

Table 0-65: possible internal error modes for human subjects

Perception: to acknowledge information, make a mental note of the information	
Mishear	The signal(s) of technical equipment were not heard accurately.
Mis-see	The signal of technical equipment was not seen properly. This aspect focusses on the ergonomic or physical part of human perception.
No detection (audio/visual)	The signal of technical equipment was not seen or heard.
Late detection	The signal of technical equipment was only detected when it was too late to correct the situation.
Repeat error	Repeating a mistake leading to a worsening of the situation.
Misread	The information from the technical equipment was misread.
Visual misperception	The visual signal was inaccurately perceived/ misperceived by the operator.
Memory: Remembering information	
Forget to monitor	The operator forgot to monitor the technical equipment.
Omitted or late action	The occurrence can be traced back to an operator who omitted to act or reacted late to a warning signal.
Forget temporary information	The occurrence can be traced back to a user who temporarily forgot relevant information.
Forget store information	The occurrence can be traced back to a failure in storing relevant information.
Mis-recall information/action	The user recalls inaccurate information and provides an inaccurate account of his actions post incident.
Prospective memory failure	Post-incident failure in recalling the event as it happened.
Forget to ask / share information	The operator suffered from a lack of information as he forgot to ask for relevant information/ share relevant information with other crew members.

Table 0-66: Possible Failures for decision making, action & violation

Decision making	
Mis-projection	Faulty interpretation of information.
Poor decision/planning	A wrong decision taken that led to or could not prevent the occurrence.
Late decision/planning	The decision was taken too late to prevent the occurrence.
No decision/planning	No decision was taken to prevent the occurrence.
Action	
Information/data entry error	Wrong information was entered into the technical equipment
Selection error	Wrong technical equipment was selected for performing a certain task.
Unclear information	The information transferred to another party via technical equipment was not clear.
Incorrect information	The information transferred to another involved party via technical equipment was not correct.
Non-performed action	No action was taken in order to prevent the occurrence.
Timing error	The action taken was not faulty itself, but occurred at the wrong moment
Unclear information recorded	The information that was recorded was not clear.
Information not transmitted	Necessary information was not transmitted / transferred to the involved parties.
Violation	
Routine violations	On the vessel some informal work practise followed instead of complying with the formal rules. The formal rule was therefore routinely disobeyed.
Exceptional violation	The formal rule was not followed only in this one scenario which led to the incident.
Sabotage	The official rule was not followed with the intention to cause harm.

The following tables show the possible respective psychological error modes, also for human subjects.

Table 0-67: Psychological error modes for human subjects for perception and memory

Perception: to acknowledge information, make a mental note of the information	
Expectation	Information was not perceived properly as the operator was influenced by an expectation bias, i.e. the operator did only perceive the information that was expected and supported his view of the situation.
Confusion	The operator confused the perceived information with something else.
Discrimination failure	The operator perceived the information, but did not process it as he perceived it to be irrelevant
Tunnel vision	The operator focused on one single technical equipment or piece of information, ignoring all the others and not perceiving the relevant information.
Overloaded	The operator was overloaded with other information and therefore did not perceive the new information
Vigilance	The operator did not perceive the necessary information due to lack of vigilance
Distraction	The operator was distracted and therefore did not perceive the information
Memory: Remembering information	
Memory confusion	The operator got confused and used the wrong information for the given situation
Memory overloaded	The Operator's memory was overloaded as he was simultaneously processing other information.
Insufficient familiarisation	The operator was not familiar with the kind of information that he should process and therefore erred in processing it.
Mental block	Operator could not access the relevant information.
Distraction	The operator was processing other information and therefore did not realize the relevance of the new information and failed to process it.
Similarity interference	Due to the similarity of the character of the information the operator processed the information based on wrong assumptions.

Table 0-68: Psychological error modes for human subjects for decision making, action and Intended violation

Decision making	
Misinterpretation	The data were misinterpreted leading to a wrong decision.
Failure to consider side or long effects	The operator did not consider the long term or the side effects of the situation.
Mind set	The mind set and world view of the operator had an important influence on the decision making and eventually led to a wrong decision.
Knowledge/competency problems	The operator did not have the necessary competency or knowledge to make the right decision.
Decision freeze or overloaded	The operator was overloaded with information or tasks and was therefore unable to make a decision.
Risk cognition failure	The operator failed to recognize the risk in a given situation or the decision taken by him.
Action	
Manual Variability	The risky situation occurred due to a mistake in the manual handling of technical equipment.
Confusion	The operator got confused and used the wrong technical equipment for the action he wanted to perform.
Habit intrusion	Out of habit the operator handled the technical equipment in a certain way. However, this action led to a mistake in the given situation.
Distraction/preoccupation	The operator was distracted or preoccupied with something else and therefore did not perform the necessary action.
Other slip	Any other slip that occurred in the connection with the handling of technical equipment.
(intended) Violation	
Stress/pressure	Stress and pressure to perform lead to risky actions consciously violating existing rules.
Fatigue	Bodily and cognitive fatigue leading to risk taking behaviour/risky decisions taken consciously.
Intoxication	The operator is intoxicated due to alcohol, drugs or medicines and takes a risky decision consciously.
Lack of knowledge	The operator takes a risk knowing about the rules that are being violated, but not being aware of/not knowing the potential consequences.
Emotional condition	The operator is dissatisfied or emotional unstable leading him to willingly not follow the procedures and rules in place.

With regards to equipment failures, there is no ‘taxonomy’ per se. However, it is broadly been identified that an equipment may cause a failure if it is not installed, if it is turned off, is on the wrong settings, suffers from an electric failure, has a poor maintenance record, is out-dated technology, has loose connections or unreliable software. Some of these errors too can be traced back to human mistakes, but primarily may be considered ‘equipment’ failure causes.

Stage of Indication

Table 0-69: error mode and cognitive process during stage of indication

Information Recording Applicable?	Information Recording Successful? If not:	Equipment Failure - Specify	No Threat Information Recorded	Choose a problem based on chosen hardware - e.g. not installed, turned off, wrong settings, electric failure, poor maintenance record, out-of-date technology, loose connections, unreliable software
			Unclear Threat Information Recorded	
			Partial Threat Information Recorded	
			Wrong Threat Information Recorded	
			Delay in Threat Information Recorded	
			Unnecessary Threat Information Recorded	
			Correct Threat Information Recorded	
		Human Failure - Specify	No Threat Information Recorded	Mis-hear, mis-see, mis-read threat; ignore threat; late detection of threat; forget to monitor for threat; forget to share information of threat; omitted action
			Unclear Threat Information Recorded	
			Partial Threat Information Recorded	
			Wrong Threat Information Recorded	
			Delay in Threat Information Recorded	
			Unnecessary Threat Information Recorded	
Information Transmission Applicable?	Information Transmission Successful? If not:	Equipment Failure - Specify	No Threat Information Transmitted	Choose a problem based on chosen Auto. System - e.g. not installed, turned off, wrong settings, electric failure, poor maintenance record, out-of-date technology, loose connections, unreliable software
			Unclear Threat Information Transmitted	
			Partial Threat Information Transmitted	
			Wrong Threat Information Transmitted	
			Delay in Threat Information Transmitted	
			Unnecessary Threat Information Transmitted	
			Correct Threat Information Transmitted	
		Human Failure - Specify	No Threat Information Transmitted	Mis-hear, mis-see, mis-read threat; ignore threat; late detection of threat; forget to monitor for threat; forget to share information of threat; omitted action
			Unclear Threat Information Transmitted	
			Partial Threat Information Transmitted	
			Wrong Threat Information Transmitted	
			Delay in Threat Information Transmitted	
			Unnecessary Threat Information Transmitted	

Stage of Detection

Table 0-70: error mode and cognitive process during stage of detection

Information Receiving Applicable?	Information Receiving Successful? If not:	Equipment Failure - Specify	No Threat Information Received	No or incorrect threat indication; Choose a problem based on chosen Auto. System - e.g. not installed, turned off, wrong settings, electric failure, poor maintenance record, out-of-date technology, loose connections, unreliable software
			Unclear Threat Information Received	
			Partial Threat Information Received	
			Wrong Threat Information Received	
			Delay in Threat Information Received	
			Unnecessary Threat Information Received	
			Correct Threat Information Received	
		Human Failure - Specify	No Threat Information Received	No or incorrect threat indication; Mis-hear, mis-see, or mis-read threat indicator; ignore threat indicator; late detection of threat indicator; forget to monitor threat indicator; forget to ask information of threat indicator; omitted action
			Unclear Threat Information Received	
			Partial Threat Information Received	
			Wrong Threat Information Received	
			Delay in Threat Information Received	
			Unnecessary Threat Information Received	
Information Evaluation Applicable?	Information Evaluation Successful? If not:	Equipment Failure - Specify	No Evaluation	No or incorrect threat indication; Choose a problem based on chosen hardware - e.g. not installed, turned off, wrong settings, electric failure, poor maintenance record, out-of-date technology, loose connections, unreliable software
			Incorrect Evaluation	
			Delayed Evaluation	
			Partial Evaluation	
			Unclear Evaluation	
			Correct Evaluation	
		Human Failure - Specify	No Evaluation	No or incorrect threat indication; **Perception Problems** (Expectation bias, confusion, discrimination failure, tunnel vision, overload of information, lack of vigilance, distractions, time pressure, desire for harmony, group think); **Memory Problems** (Mis-recall information about threat; prospective memory failure; forget temporary information; forget long term training & procedures)
			Unclear Evaluation	
			Partial Evaluation	
			Incorrect Evaluation	
			Delayed Evaluation	
Information Transmission Applicable?	Information Transmission Successful? If not:	Equipment Failure - Specify	No Threat Evaluation Transmitted	Choose a problem based on chosen Auto. System - e.g. not installed, turned off, wrong settings, electric failure, poor maintenance record, out-of-date technology, loose connections, unreliable software
			Unclear Threat Evaluation Transmitted	
			Partial Threat Evaluation Transmitted	
			Wrong Threat Evaluation Transmitted	
			Delay in Threat Evaluation Transmitted	
			Unnecessary Threat Evaluation Transmitted	
			Correct Threat Evaluation Transmitted	
		Human Failure - Specify	No Threat Evaluation Transmitted	Mis-hear, mis-see, mis-read threat; ignore threat; late detection of threat; forget to monitor for threat; forget to share information of threat; omitted action
			Unclear Threat Evaluation Transmitted	
			Partial Threat Evaluation Transmitted	
			Wrong Threat Evaluation Transmitted	
			Delay in Threat EvaluationTransmitted	
			Unnecessary Threat EvaluationTransmitted	

Stage of Analysis

Table 0-71: error mode and cognitive process during stage of analysis

<table>
<tr><td rowspan="13">Information Receiving Applicable?</td><td rowspan="13">Information Receiving Successful? If not:</td><td rowspan="7">Equipment Failure - Specify</td><td>No Threat EvaluationReceived</td><td rowspan="7">No or incorrect threat indication; Choose a problem based on chosen Auto. System - e.g. not installed, turned off, wrong settings, electric failure, poor maintenance record, out-of-date technology, loose connections, unreliable software</td></tr>
<tr><td>Unclear Threat Evaluation Received</td></tr>
<tr><td>Partial Threat Evaluation Received</td></tr>
<tr><td>Wrong Threat Evaluation Received</td></tr>
<tr><td>Delay in Threat Evaluation Received</td></tr>
<tr><td>Unnecessary Threat EvaluationReceived</td></tr>
<tr><td>Correct Threat EvaluationReceived</td></tr>
<tr><td rowspan="6">Human Failure - Specify</td><td>No Threat Evaluation Received</td><td rowspan="6">No or incorrect threat indication; Mis-hear, mis-see, or mis-read threat indicator; ignore threat indicator; late detection of threat indicator; forget to monitor threat indicator; forget to ask information of threat indicator; omitted action</td></tr>
<tr><td>Unclear Threat EvaluationReceived</td></tr>
<tr><td>Partial Threat Evaluation Received</td></tr>
<tr><td>Wrong Threat Evaluation Received</td></tr>
<tr><td>Delay in Threat Evaluation Received</td></tr>
<tr><td>Unnecessary Threat Evaluation Received</td></tr>
<tr><td rowspan="13">Planning Applicable?</td><td rowspan="13">Planning Successful? If not:</td><td rowspan="7">Equipment Failure - Specify</td><td>No Preventive Planning</td><td rowspan="7">No or incorrect threat detection; Choose a problem based on chosen hardware - e.g. not installed, turned off, wrong settings, electric failure, poor maintenance record, out-of-date technology, loose connections, unreliable software</td></tr>
<tr><td>Unclear Preventive Planning</td></tr>
<tr><td>Partial Preventive Planning</td></tr>
<tr><td>Wrong Preventive Planning</td></tr>
<tr><td>Delay in Preventive Planning</td></tr>
<tr><td>Unnecessary Preventive Planning</td></tr>
<tr><td>Correct Preventive Planning</td></tr>
<tr><td rowspan="6">Human Failure - Specify</td><td>No Preventive Planning</td><td rowspan="6">No or incorrect threat detection; Perception Problems (Expectation bias, confusion, discrimation failure, tunnel vision, overload of information, lack of vigilance, distractions, time pressure, desire for harmony, group think); Memory Problems (Mis-recall information about threat; prospective memory failure; forget temporary information; forget long term training & procedures)</td></tr>
<tr><td>Unclear Preventive Planning</td></tr>
<tr><td>Partial Preventive Planning</td></tr>
<tr><td>Wrong Preventive Planning</td></tr>
<tr><td>Delay in Preventive Planning</td></tr>
<tr><td>Unnecessary Preventive Planning</td></tr>
<tr><td rowspan="11">Decision Making Applicable?</td><td rowspan="11">Decision Successful? If not:</td><td rowspan="6">Equipment Failure - Specify</td><td>No Decision</td><td rowspan="6">No or incorrect planning; Choose a problem based on chosen hardware - e.g. not installed, turned off, wrong settings, electric failure, poor maintenance record, out-of-date technology, loose connections, unreliable software</td></tr>
<tr><td>Unclear Decision</td></tr>
<tr><td>Partial Decision</td></tr>
<tr><td>Wrong Decision</td></tr>
<tr><td>Delay in Decision</td></tr>
<tr><td>CorrectDecision</td></tr>
<tr><td rowspan="5">Human Failure - Specify</td><td>No Decision</td><td rowspan="5">No or incorrect planning; Perception Problems (Expectation bias, confusion, discrimation failure, tunnel vision, overload of information, lack of vigilance, distractions, time pressure, desire for harmony, group think); Memory Problems (Mis-recall information about threat; prospective memory failure; forget temporary information; forget long term training & procedures)</td></tr>
<tr><td>Unclear Decision</td></tr>
<tr><td>Partial Decision</td></tr>
<tr><td>Wrong Decision</td></tr>
<tr><td>Delay in Decision</td></tr>
</table>

Selection of action

Table 0-72: taxonomy for source of failure, error mode and cognitive process during selection of action

Communication Applicable?	Communication Successful? If not:	Equipment Failure - Specify	No Action Information Provided/Recorded Unclear Action Information Provided/Recorded Partial Action Information Provided/Recorded Wrong Action Information Provided/Recorded Delay in Action Information Provided/Recorded Unnecessary Action Information Provided/Recorded Correct action communication	No Threat analysis; Choose a problem based on chosen hardware - e.g. not installed, turned off, wrong settings, electric failure, poor maintenance record, out-of-date technology, loose connections, unreliable software
		Human Failure - Specify	No Action Information Provided/Recorded Unclear Action Information Provided/Recorded Partial Action Information Provided/Recorded Wrong Action Information Provided/Recorded Delay in Action Information Provided/Recorded Unnecessary Action Information Provided/Recorded	No Threat Analysis; Mis-hear, mis-see, mis-read instructions; ignore instructions ; forget to share instructions; omitted action, **Perception Problems** (Expectation bias, confusion, discrimation failure, tunnel vision, overload of information, lack of vigilance, distractions, time pressure, desire for harmony, group think); **Memory Problems** (Mis-recall instructions; prospective memory failure; forget temporary information; forget long term training & procedures)
Timing & Sequence Applicable?	Timing & Sequence Successful? If not:	Equipment Failure - Specify	Action too long Action too short Action too early Action too late Action repeated Action in wrong sequence Correct action timing & sequence	No Threat analysis; Choose a problem based on chosen hardware - e.g. not installed, turned off, wrong settings, electric failure, poor maintenance record, out-of-date technology, loose connections, unreliable software
		Human Failure - Specify	Action too long Action too short Action too early Action too late Action repeated Action in wrong sequence	E.g., Mis-hear, mis-see, mis-read instructions; ignore instructions ; forget to share instructions; omitted action, **Perception Problems** (Expectation bias, confusion, discrimation failure, tunnel vision, overload of information, lack of vigilance, distractions, time pressure, desire for harmony, group think); **Memory Problems** (Mis-recall instructions; prospective memory failure; forget temporary information; forget long term training & procedures)
Selection & Quality Applicable?	Selection & Quality Successful? If not:	Equipment Failure - Specify	Omission Action too much Action too little Action in wrong direction Wrong action on right object Right action on wrong object Wrong action on wrong object Extraneous act Correct action selction & quality	No Threat analysis; Choose a problem based on chosen hardware - e.g. not installed, turned off, wrong settings, electric failure, poor maintenance record, out-of-date technology, loose connections, unreliable software
		Human Failure - Specify	Omission Action too much Action too little Action in wrong direction Wrong action on right object Right action on wrong object Wrong action on wrong object Extraneous act	E.g., Mis-hear, mis-see, mis-read instructions; ignore instructions ; forget to share instructions; omitted action, **Perception Problems** (Expectation bias, confusion, discrimation failure, tunnel vision, overload of information, lack of vigilance, distractions, time pressure, desire for harmony, group think); **Memory Problems** (Mis-recall instructions; prospective memory failure; forget temporary information; forget long term training & procedures)

Appendix – 4: List of selected investigation report into domestic RoPax ferry accidents and incidents

Table 0-73: list of selected Indonesian domestic ferry cases

No	Involved ship/s	Location and time	Nature of Accident	Consequences			Probable Cause)*
				Ship/Structure	Passenger	Other Cargo	
1	Indonesian registered ro-ro passenger ferry MV. Wimala Dharma	Lombok Strait, Nusa Tenggara Barat, on 7 September 2003	Sunk	Total Loss	-	Loss of Vehicle	Technical
2	Taiwan register container ship MV. Uni Chart with Indonesian register ro-ro passenger ferry MV. Mandiri Nusantara	West Surabaya traffic lane, Madura Strait, on 27 September 2003	Collision	Minor damage to the Bulk Carrier. Partial damage to the ferry	Loss of life	-	Human Factor
3	Indonesian registered ro-ro passenger ferry MV. Digul	Off Merauke coast, Papua, 14 July 2005	Capsize/Sunk	Total Loss	Loss of life	Loss of Vehicle	Technical
4	Indonesian registered ro-ro passenger ferry MV. Lampung 2006	Sunda strait, 23 November 2006	Engine room fire	Extensive damage	-	Loss of Vehicle	Technical
5	Indonesian registered ro-ro passenger ferry MV. Senopati Nusantara 2006	Java Sea, 29 Desember 2006	Capsize/Sunk	Total Loss	Loss of life	-	Technical
6	Indonesian registered Ro-ro Passenger ferry MV. Nusa Bhakti	Off Buk-buk Beach, Bali on 13 January 2007	Engine Room Fire	Partial Damage	-	-	Technical
7	Indonesian registered Ro-ro Passenger ferry MV. Levina I	40 Nm northern Tanjung Priok Port, Seribu Island, DKI	Fire	Extensive damage to ship structure	Loss of life	Loss of Vehicle	Technical

No	Involved ship/s	Location and time	Nature of Accident	Consequences			Probable Cause)*
				Ship/Structure	Passenger	Other Cargo	
		Jakarta on 22 February 2007					
8	Indonesian registered Ro-ro Passenger ferry MV. Dharma Kencana I	Mentaya Hilir Selatan river, West Kalimantan on 18 May 2008	Fire	Partial Damage	Loss of life	-	Technical
9	Indonesian registered Ro-ro Passenger ferry MV. Teratai Prima	25 Nm off Pare-pare, Makassar Strait, 11 January 2009	Capsize/Sunk	Total Loss	Loss of life	Loss of Vehicle	Human Factor
10	Indonesian registered Ro-ro Passenger ferry MV. Mandiri Nusantara	Java Sea, on 30 May 2009	Fire	extensive damage	Loss of life	Loss of Vehicle	Technical
11	Investigation into fire on board Indonesian registered Ro-ro Passenger ferry MV. Laut Teduh 2	Sunda Strait, on 28 January 2011	Fire	extensive damage	-	-	Technical
12	Indonesian registered Ro-ro Passenger ferry MV. Salvia	Seribu Island, on 08 February 2011	Engine room fire	Medium damage in the engine room	-	-	Technical
13	Indonesian registered Ro-ro Passenger ferry MV. Musthika Kencana II	Java Sea, on 04 July 2011	Fire	Extensive damage to ship structure, subsequently total loss	-	Loss of Vehicle	Technical
14	Indonesian registered Ro-ro Passenger ferry MV. Windu Karsa	Bone Bay, South east Celebes on 27 August 2011	Capsize/Sunk	Total Loss	-	Loss of Vehicle	Technical
15	Indonesian registered Ro-ro Passenger ferry MV. Marina Nusantara with Indonesian	Barito River, on 26 September 2011	Collision	Minor damage to the Barge, Extensive damage to the ferry	Loss of life	Loss of Vehicle	Human Factor

No	Involved ship/s	Location and time	Nature of Accident	Consequences			Probable Cause)*
				Ship/Structure	Passenger	Other Cargo	
	registered tugged barge Bg. Pulau Tiga 330-22			due to fire resulted from collision			
16	Indonesian registered Ro-ro Passenger ferry MV. Bahuga Jaya with Singapore registered chemical tanker MV. Norgas Cathinka	Sunda Strait, on 26 September 2012	Collision	Minor damage to the Tanker ship, Total the ferry	Loss of life	Loss of Vehicle	Human Factor
	*: NTSC summary reports. Data obtained courtesy of NTSC, 2014						

Appendix – 5: SEMOMAP model results compilation data

Table 0-74: the compilation of SEMOMAP result for each phase and each stage to the selected cases

Nature of Accident	Phase	Stages	Number of Subject	Number of event	Observable process of fail/safe status			Source of Failure	
					Applicable & Successful	Applicable Not Succesfull	Not Applicable	Human Failure	Equipment Failure
Fire	Phase-1	Threat Indication	7	52	27	8	17	6	2
		Threat Detection	4	78	47	12	19	12	0
		Threat Analysis	5	78	46	8	24	8	0
		Threat Prevention Action	5	78	31	21	26	17	4
	Phase-2	System Health Indication	5	56	38	0	18	0	0
		System Health Detection	3	84	70	4	10	4	0
		System Health Analysis	3	84	68	8	8	8	0
		Emergency Response Action	7	84	43	34	7	26	8
	Phase-3	Emergency Response & Evacuation Action	8	66	42	23	1	17	6
		System Health Indication	4	44	30	0	14	0	0
		System Health Detection	4	66	51	0	15	0	0
		System Health Analysis	4	66	51	2	13	2	0
	Total			836	544	120	172	100	20
Capsize	Phase-1	Threat Indication	6	60	34	1	25	1	0
		Threat Detection	5	90	66	7	17	6	1
		Threat Analysis	4	90	51	23	16	23	0
		Threat Prevention Action	4	90	47	23	20	20	3
	Phase-2	System Health Indication	2	8	4	0	4	0	0
		System Health Detection	2	12	10	0	2	0	0
		System Health Analysis	1	12	4	6	2	6	0
		Emergency Response Action	1	12	4	8	0	7	1
	Phase-3	Emergency Response & Evacuation Action	4	33	20	13	0	12	1
		System Health Indication	5	22	15	0	7	0	0
		System Health Detection	1	33	22	3	8	3	0
		System Health Analysis	1	33	14	6	13	6	0
				495	291	90	114	84	6
Collision	Phase-1	Threat Indication	5	34	25	0	9	0	0
		Threat Detection	4	51	31	5	15	5	0
		Threat Analysis	4	51	12	23	16	23	0
		Threat Prevention Action	6	51	35	14	2	10	4
	Phase-2	System Health Indication	5	18	13	0	5	0	0
		System Health Detection	4	27	21	1	5	1	0
		System Health Analysis	3	27	20	4	3	4	0
		Emergency Response Action	6	27	23	4	0	4	0
	Phase-3	Emergency Response & Evacuation Action	6	18	10	8	0	8	0
		System Health Indication	4	12	10	0	2	0	0
		System Health Detection	4	18	14	0	4	0	0
		System Health Analysis	2	18	12	2	4	2	0
	Total			352	226	61	65	57	4