Hazard Analysis of Inland Passenger Ship Operation in Bangladesh Using Systems Theoretic Approach

by

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Submitted to the Department of Naval Architecture and Marine Engineering

In partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

in

Naval Architecture and Marine Engineering

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY (BUET)

DHAKA-1000, BANGLADESH

October 2019

The thesis titled "Hazard Analysis of Inland Passenger Ship Operation in Bangladesh Using Systems Theoretic Approach", submitted by Md. Imran Uddin, Roll No. 1015122009, Session October 2015, has been accepted as satisfactory in partial fulfillment of the requirements for the degree of Master of Science in Naval Architecture and Marine Engineering on October 26, 2019.

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I hereby declare that all the information in this study has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that as required by these rules and conduct, I have fully cited and referenced all materials and results those are not original to this work. This thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma (except for publications).

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DEDICATED TO

My Parents

ACKNOWLEDGEMENT

I wish to express my heartiest gratitude to the Almighty ALLAH for the successful completion of the research work as planned.

My deepest gratitude and sincere appreciation goes to my supervisor Dr. Zobair Ibn Awal, Associate Professor, Department of Naval Architecture and Marine Engineering, BUET, under whose continuous support and supervision this research work has been carried out. Without his constant guidance, inspiration and encouragement, invaluable suggestions and constructive criticism, this work could not be possible to accomplish.

I am highly thankful to Dr. Nancy Leveson, professor of Massachusetts Institute of Technology (MIT) for her valuable suggestions and guidelines she provided regarding the methodology and application of the STPA analysis.

I want to take the opportunity to thank my colleagues at Accident Research Institute (ARI) for their passionate support and suggestions during the research period. I would also like to thank the Chairman of Bangladesh Inland Water Transport Authority (BIWTA), Director General of the Department of Shipping and other respected persons who helped by providing the necessary information and data. Besides, I am particularly indebted to Rear Admiral (retd.) A. S. M. Abdul Baten, Former Vice-Chancellor of Bangabandhu Sheikh Mujibur Rahman Maritime University; Mr. Mirza Saifur Rahman, Engineer and Ship Surveyor of the Department of Shipping; Mr. Md. Abu Alam Haolader, AGM (Commerce) of Dhaka Ghat, BIWTC; Mr. Md. Nadiruzzaman, Assistant Engineer, BIWTA for their passionate support during the field visit. I would also like to thank the masters, officers, inland marine engineers, drivers and other crews of the inland passenger ships for helping me during the field visit.

Lastly, I would like to thank the honorable members of my thesis committee for their invaluable suggestions. I thank Dr. Mir Tareque Ali, Dr. Md. Shahjada Tarafder, and the external member Dr. Md. Shamsul Hoque.

ABSTRACT

Inland waterway is a natural and relatively cheaper mode of transportation in Bangladesh. It carries a significant portion of total arterial freight traffic and passenger traffic in Bangladesh, thereby, contributing significantly to the national GDP. However, every year many people die, get injured and reported missing due to inland water transport accidents. The most significant fact is that accidents involving the passenger ships share the majority of fatality of overall maritime accidents in Bangladesh. However, there have been very limited studies to address this vital issue. Most of the studies conducted on the passenger vessel safety are based on simple statistical approach due to lack of adequate accident data. Therefore, the underlying causal factors behind the accidents had never come into the observation of researchers and stakeholders. The present study attempts to perform a hazard analysis of inland passenger ship operation in Bangladesh by applying the System-Theoretic Process Analysis (STPA) method. This method can identify the causal factors and hazardous scenarios, particularly those related to system design, human behavior and software.

In this study, the STPA method is applied in two phases. The first phase investigates the safety of passenger ship operation at inland river terminal. The other phase investigates the safety of passenger ship operation during the voyage. At first, the accidents and associated hazards are identified that are needed to be prevented. Then, a hierarchical control structure of passenger ship operation is designed that captures the functional interactions among different subsystems by modeling the ship operation as a set of feedback control loops. The control structure is then analyzed to identify the Unsafe Control Actions (UCA) by the controllers (concerned personnel of maritime operation). Then, the causal scenarios are identified that describe the causal factors which can lead to the Unsafe Control Actions (UCA) and to hazards. The safety requirements are also determined that can mitigate the factors and eliminate or control the hazards so that accidents can be prevented. The results indicate that most of the UCA exist in the bridge deck of the passenger ship. The most significant category of the causal factor responsible for the occurrence of UCA is the human factor. The successful implementation of the suggested safety requirements can prevent the occurrence of the causal factors and consequently the accidents of inland passenger ships in Bangladesh can be mitigated.

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INTRODUCTION

1.1 General

Being a riverine country, Bangladesh has a vast network of rivers and canals that are stretched throughout the length and breadth of the land. This blessing from nature leads to easy accessibility to any region of the country by waterways. Besides, it is also favored by most of the people for being the cheapest mode of transport of this developing country. Therefore, inland water transport plays a very significant role in the socio-economic aspect of Bangladesh. Out of 24,000 km of inland waterways of the country, almost 5,968 km is navigable by mechanized vessels during the monsoon season which shrinks to about 3,865 km during the summer season (Bangladesh Inland Water Transport Authority, 2019). The river network of Bangladesh, including the major river ports and terminals is illustrated in figure 1.1. The inland water transportation carries above 50% of the total arterial traffic and one-fourth of total passenger traffic in Bangladesh. Therefore, the inland water transport sector has a significant contribution to the national GDP (0.71%) of Bangladesh (Bangladesh Bureau of Statistics, 2018). Different types of watercrafts like Passenger vessels, cargo vessels, container ships, oil tankers, tug boats, dumb barges, trawlers and country boats etc. ply in the inland waterways of Bangladesh. There are 10,593 vessels registered under the Department of Shipping; even though, the number of unregistered vessels is expected to be about three times higher than those registered (Akhter, 2017). Most of the vessels operate in the inland routes and coastal zones of the country and only a few numbers of vessels are being operated in the sea-route.

Fig. 1.1: River network of Bangladesh, reproduced from Banglapedia (2015).

1.2 Background of the Study

In spite of having vital significance and economic importance, there remain numerous deficiencies on the safety of inland water transportation system of Bangladesh. A large number of people are killed every year due to accidents in the inland waterways of the country. In the last few decades, a number of tragic maritime accidents of Bangladesh shocked the whole world. Hundreds of people died in each of the accidents. The actual death toll of these accidents is, in fact, higher than the reported number, as the people who are reported missing after the accident are never found at all. In addition, the information of the accidents involving the unregistered vessels is not generally recorded by the enforcement authorities. Sometimes these accidents cause a detrimental effect on the natural balance or environment. The most important fact is that the greater portion of fatality in the maritime accidents of Bangladesh occurs due to the accidents involving the passenger vessels (Rahman, 2017). The investigation committees are formed by the government after each accident to identify the causes behind the accident and generate some recommendations to prevent such an accident in the future. Despite making remarkable efforts to execute such recommendations, the safety scenario in the inland waterways of Bangladesh is not improving by any means. Therefore, improvement of inland water transportation safety is a contemporary demand of the whole nation.

1.3 Present State of the Problem

A number of studies have addressed the safety issues related to the operation of inland passenger ships in Bangladesh. A few studies based on the statistical analysis ended upon providing some suggestions based on the nature and types of accidents (Rahman, 2017; Awal et al., 2006). These studies have identified the immediate reasons behind the accident and consequently focused on providing a number of primary recommendations. The detailed analysis of the causal factors responsible for those immediate reasons have been inadequate in those studies. Some other studies have given emphasis on suggesting solutions on some specific areas like mitigation of overload problem by installing digital sensors (Rahman and Rosli, 2014), improving design of passenger ship to avoid capsizing (Iqbal et al., 2007), structural and design modification to improve stability of the ship (Khalil and Tarafder, 2004). Each of the research works was oriented to a specific topic. Therefore, most of the studies focused on preventing accidents rather than improving the safety culture related to the operation of the ship. To be precise, the operating procedures of the operators of the passenger ship, human-machine interactions, communications etc. were not aimed for investigation and research. As a result, the researchers could not come up with an output that could encourage the ship operators and stakeholders to ensure the safety of inland passenger ship operation. Therefore, there is indeed an urgent need for a new approach to analyze the hazards that are responsible for the occurrence of accidents of inland passenger ships in Bangladesh.

1.4 Objective of the Study

This thesis is aimed to analyze the hazards associated with the operation of inland passenger ships in Bangladesh by applying the hazard analysis technique named System-Theoretic Process Analysis (STPA). STPA is a relatively new hazard analysis method based on the accident causation model named Systems Theoretic Accident Model and Processes (STAMP). STPA is capable of identifying the causal factors which are ultimately responsible for the occurrence of hazardous states and accidents of any system (Leveson and Thomas, 2018). So far it has not been applied to assess the safety of inland water transportation system of Bangladesh.

At first, a statistical analysis is performed to reveal the contemporary safety scenario of inland passenger ship operation in Bangladesh. A passenger launch is considered for the STPA analysis. The first step of STPA is to define the accidents and associated hazards that are to be mitigated. The next step is to construct a hierarchical safety control structure based on the responsibilities of each crew or operator (termed as a controller in STPA) of the ship. The third step is to identify the Unsafe Control Actions (UCA) of each controller by analyzing the feedback control loops of the safety control structure. The final step includes creating the loss scenarios and to recommend some safety requirements to mitigate the accidents involving the passenger ships.

1.5 Organization of the Thesis

The contents of the thesis are divided into six chapters.

This chapter, Chapter 1, highlights the research background, objectives and significance of the study.

Chapter 2 presents the background study related to the theme of this research. At first the global context of passenger vessel safety and peculiarities of inland water transportation system of Bangladesh are discussed. Then, the literature reviews on the previous studies on passenger vessel safety of Bangladesh are presented. Finally, the traditional view regarding safety, limitations of traditional accident causation models, the concept of systems theory and application of STPA etc. are demonstrated.

Chapter 3 describes the methodology of the study. The step-by-step procedures of applying STPA method are described elaborately in this chapter.

Chapter 4 presents the analysis part of this thesis. Firstly, the drawbacks of maritime accident data collection system of Bangladesh and a statistical analysis of the accidents involving the inland passenger ships of Bangladesh are presented. Then, the hazard analysis of inland passenger ship operation in Bangladesh by applying the STPA method is presented.

Chapter 5 presents the findings of the field observation that are relevant to the STPA analysis. Several causal factors and possible requirements described by the STPA method that are identified during the visit to an inland passenger terminal and some inland passenger ships are presented in this chapter.

Chapter 6 presents the results of the analysis. The classification of the factors related to the occurrence of Unsafe Control Actions (UCA), possible safety requirements and distribution of UCA in different zones of the ship are outlined in the study.

Chapter 7 outlines the conclusions and recommendations of the study. The key findings of this research and recommendations for future research are discussed in the chapter.

CHAPTER 2

BACKGROUND STUDY

2.1 General

Accidents involving the passenger vessels have been a severe problem for Bangladesh for a long time. Moreover, the comprehensive scientific investigations were also limited on this vital topic. This chapter gives a brief overview of the global context of passenger vessel safety, peculiarities of inland water transportation system of Bangladesh, key findings of the research works of safety of inland passenger ship operation in Bangladesh. Besides, overviews of accident causation theory, hazard analysis, systems theory etc. are also described in this chapter.

2.2 Global Context of Passenger Vessel Safety

The world has experienced lots of disastrous passenger vessel mishaps in the last century. A particular accident among these had cost more than thousands of lives. Passenger ferry is the most vulnerable type of passenger ship for the occurrence of the accidents. Therefore, passenger ferry safety has become an important global issue. In this context many actions have been undertaken by some global organizations to improve ferry safety. Among those organizations the activities of the Worldwide Ferry Safety Association (WFSA) are very significant.

The Worldwide Ferry Safety Association (WFSA) is a not-for-profit organization dedicated to bringing innovation in training methods, as well as use of technology to control overloading, provide notification for sudden inclement weather, and enhance marine rescue technology (Worldwide Ferry Safety Association, 2019). The mission of the organization is to reduce ferry fatalities and expand the use of safe ferries globally. This organization encourages innovative new ideas in ferry safety and design. To that end WFSA has been sponsoring a design competition for safe affordable ferries in each year. The objective of this design competition is to reduce ferry fatalities with designs of safe affordable vessels.

WFSA undertakes needed ferry safety technology projects. Besides, a new innovation of 'low-cost Automatic Weather Monitors for ferries' will be revealed soon. The organization has sought to advance implementation of IMO-mandated AIS (Automatic Identification System) through advocacy publications and presentations and has brokered implementation actions. There is widespread recognition of the importance of implementing AIS on the inland waterways of Bangladesh, which can have massive influence to improve safety.

WFSA continues to maintain a database with 25 data points for each fatal accident since the year 2000. In order to fully comprehend the information, the data is aggregated into causation trends, national trends, and more recently regional trends. The most important trends illustrated by the data are:

- Improvements in Bangladesh ferry safety over the last three years i.e. from 2016 to 2018;
- Improvements in ferry safety in the Philippines since 2010;
- Increasing reports of sudden hazardous weather particularly in Indonesia.
- Lake Victoria as a ferry fatality hotspot, when aggregating data from Tanzania, Uganda and Kenya.

The accident data maintained by WFSA reveals that the inclement weather has been implicated as the cause of over half of fatal ferry accidents globally. Interferry, the trade association for WFSA recently publishes a statistics that 93% of ferry fatalities occur on domestic routes, with two-thirds of these occurring in just seven countries, most notably the Philippines, Bangladesh and Indonesia (Interferry, 2019). Besides, it is also revealed that till 2014, 95% of the overall ferry accidents occurred in the developing countries (Ali et al. 2015). According to International Maritime Organization (IMO), a specialized agency of the United Nations (UN) responsible for ensuring global maritime safety, the situation has definitely reached to a worrying state in Bangladesh. Even though many of these accidents involve non-conventional domestic watercrafts that fall outside the IMO regulations; IMO feels the urgency to enhance the safety of vessels carrying passengers on non-international voyages in certain parts of the world like Bangladesh. In order to address this particular problem concerning the massive death toll due to launch accidents in the inland waterways of Bangladesh; the IMO and Interferry started a ferry safety project for developing countries to significantly cut down fatalities through technical cooperation, workshops, etc. IMO and Interferry have already jointly organized a training course for launch crews in Bangladesh. Considering the seriousness of this issue, IMO is already prompted to develop, adopt and implement safety codes for non-conventional water-crafts like passenger launches for developing countries like Bangladesh.

2.3 Peculiarities of Inland Water Transportation System of Bangladesh

Bangladesh is widely known for the occurrence of disastrous maritime accidents. In most cases the poor management of overall maritime transportation system is found to be responsible for the accidents. This poor management may hardly be found anywhere in the world. This section presents some peculiarities of the inland water transportation system of Bangladesh that act as a threat to the safe operation of the vessels.

2.3.1 Haphazard movement of country boats across the river

Being a riverine country the movement of country boats in the rivers of Bangladesh is a familiar scenario. These boats are used for carrying passengers and cargoes. However, there is no proper management for the transportation of these watercrafts. There is also no opportunity for the institutional training of the boatmen. These boats move in a haphazard way across the river which poses a high risk of collision with the larger vessels. Moreover, a huge number of boats are found to move chaotically just beside the inland river port terminals. The main reason behind this fact is the movement of passengers and cargo to the launch terminal. Figure 2.1 illustrates the disorganized movement of country boats across the river.

Fig. 2.1: Disorganized movement of country boats across the river, source: author.

2.3.2 Embarkation of passengers into passenger launch from country boats

Embarkation of passengers into the passenger launches from the country boats is a common scenario in Bangladesh. In previous many accidents have occurred due to the failure of embarking safely into the passenger launches. Lack of regular safety awareness campaigns may be a vital reason for neglecting personal safety by the people of the country. Figure 2.2 illustrates the embarkation of passengers into passenger launch from country boats in an unsafe way.

Fig. 2.2: Embarkation of passengers into passenger launch from country boats, source: author.

2.3.3 Movement of a huge number of unregistered vessels

It has been mentioned previously that the number of unregistered vessels in Bangladesh is approximately more than three times than the registered ones. The Ministry of Shipping of Bangladesh had not taken any proper initiative to bring the unregistered vessels under the registration process so far. These unregistered vessels operate independently and do not follow any rules and regulations of the regulatory bodies. Besides, the sailors of these vessels usually do not have any institutional training. Therefore, the movement of these huge numbers of unregistered vessels can be termed as one of the most important threats to the maritime safety of Bangladesh.

2.3.4 Movement of overloaded sand carrying cargo vessels

In Bangladesh, the sand carrying cargo vessels are locally named as ‘Bulkheads’. Usually, these bulkheads move in the overloaded condition. Although there is no provision of movement of such vessels during night; however, the practical scenario is different. Huge numbers of bulkheads move during day and night creating a high risk for other types of vessels. In particular, the risk is higher for the passenger vessels which mostly operate during night. Since bulkheads do not have any proper lighting system and move in an overloaded condition, therefore during night the masters of passenger vessels face a huge trouble for navigating the vessel safely. Figure 2.3 illustrates the movement of a bulkhead in an overloaded condition.

Fig. 2.3: Movement of a ‘Bulkhead’ in the overloaded condition, source: author.

2.3.5 Movement of unfit vessels

Most of the vessels in Bangladesh do not go under the proper survey process. An annual survey is a must for each vessel to be performed each year. During survey, the condition of all equipment, machineries, life-saving appliances etc. must be checked properly.

Fig. 2.4: A damaged vessel is allowed to move in the inland waterway routes, source: author.

However, due to the lack of adequate number of surveyors, the survey process is not done properly. As a result, most of the vessels remain in the unfit condition and become the source of risk for other vessels. Figure 2.4 illustrates a damaged as well as unfit vessel that is allowed to move in the inland waterway routes.

2.3.6 Lack of trained masters

The Government of Bangladesh has formed a number of training centers for the masters of the vessels. However, after the successful completion of the training course, most of the masters are not recruited in an inland ship. Rather, they are recruited in the sea-going or coastal vessels of Bangladesh for having better financial benefits. As a result, there is a considerable lack of trained masters in the inland waterways of Bangladesh. The masters who are appointed in the inland ships, therefore, have a lack of proper training and may experience accidents consequently.

2.3.7 Practice of blame culture in maritime accident investigation system

After every inland water transport accident, a maritime accident investigation committee is formed constituting of safety experts. The responsibility of the committee is to identify the factors related to the accident. However, the committee is usually given a short span of time to submit the reports. Therefore, it becomes very tough to perform a detailed investigation of an accident. Besides, one of the prime objectives of the committee is to blame the operators of the ships according to the rules specified in the Inland Shipping Ordinance of Bangladesh. In spite of focusing to improve the overall maritime system, the emphasis is given on identifying the fault or mistakes of the crews or operators inside the ship. Moreover, different stakeholders related to the ship operation start blaming each other after an accident. This blame game has been a great threat to the maritime safety of Bangladesh. It creates significant difficulty against identifying the actual causes of an accident. As a result, the overall maritime system of Bangladesh suffers a lot due to the deficiency of practice of the safety culture.

The recommendations of the maritime accident investigation committee are mainly divided into five categories. These are stated below:

- Legal recommendations
- Maritime safety related recommendations
- Vessel survey related recommendations

- Administrative recommendations
- Other recommendations

An important fact regarding these recommendations is that most of the recommendations are usually not followed up later on. That is the implementations of these vital recommendations are not ensured properly. However, in the developed countries the situation is completely different. After the occurrence of an accident, first of all it is checked that whether the previous recommendations put forward by the investigation committees are properly implemented or not. Therefore, to ensure the safety of maritime transportation system, stopping the blame culture and proper implementation of the recommendations of the maritime accident investigation committee are indispensable.

2.4 Literature Review on Safety of Inland Passenger Ship Operation in Bangladesh

The studies conducted so far on the safety and accident analysis of inland waterways of Bangladesh have been mainly based on the simple statistical approach. The scope is even limited due to the inadequacy of primary data. This is due to the fact that the existing accident investigation and reporting method possess technical deficiencies.

In a study by Khalil (1985) it is mentioned that in Bangladesh many inland motor-propelled passenger launches founder at the middle of the river due to defective construction and other associated effects. Lack of sufficient surveyors to run prior safety checks to identify construction faults of the launches often means that appropriate inspection is not conducted properly. Islam (1997) developed a computer program for evaluation of stability and economic potentials of inland passenger ships. The study concluded that the accidents involving the passenger vessels of Bangladesh cannot be solely attributed to the stability or any other major faults in the design of the vessels. In fact, the problem is not purely technical but socio-economic in nature.

Huq and Dewan (2003) analyzed the passenger launch accidents of Bangladesh during the period 1977 to 2000. The study reveals that the majority of passenger launch accidents in Bangladesh have occurred due to the collision where unskilled operators and faulty construction of the launches are the main causal factors. Apart from collision, the other most common cause of launch accidents are stability failure and overloading. The least frequent accident types occurred due to underwater currents, presence of underwater shoals, leaning electricity poles, and movement of country boats without lights at night. The study also revealed that passenger launches carry commercial cargo along with the passengers in the upper deck making the launch highly unstable. Lack of safety awareness by the passengers and improper monitoring by the enforcement authorities are mainly responsible for overloading issues.

Khalil and Tarafder (2004) proposed a number of design modifications for improving the initial stability for preventing capsizing of the vessels during emergency situations. A study by Baten (2005) pointed out the irregularity and discrepancy of the safety issues in the inland water transportation system of Bangladesh; specifically the operation of inland passenger vessels. Additionally, the study proposed the formation of a classification society for successful supervision of safety issues related to the inland water transportation system.

Chowdhury (2005) applied the Geographical Information System (GIS) to analyze the characteristics of the accidents related to the formal and informal motor propelled passenger vessels in the inland waterways of Bangladesh. Analyzing the accidents during the period 1994 to 2003 the study revealed that accidents mostly occur during fair weather and good visibility condition. Therefore, it was concluded that human factors are more responsible than the non-human factors behind the occurrence of these accidents.

Sakalayen (2006) conducted a study on the safety of inland passenger launch transportation of Bangladesh. The study found that the root causes of passenger launch accidents in Bangladesh are poor water transport administration and monitoring system, inadequate regulations and enforcement, poor waterways and infrastructure, faulty design and construction of vessels, insufficient manpower and poor training systems, absence of proper funding and insurance, business policies, less political commitment. The study concluded that the extents of these factors are so severe that it needs urgent technical support to address the issues.

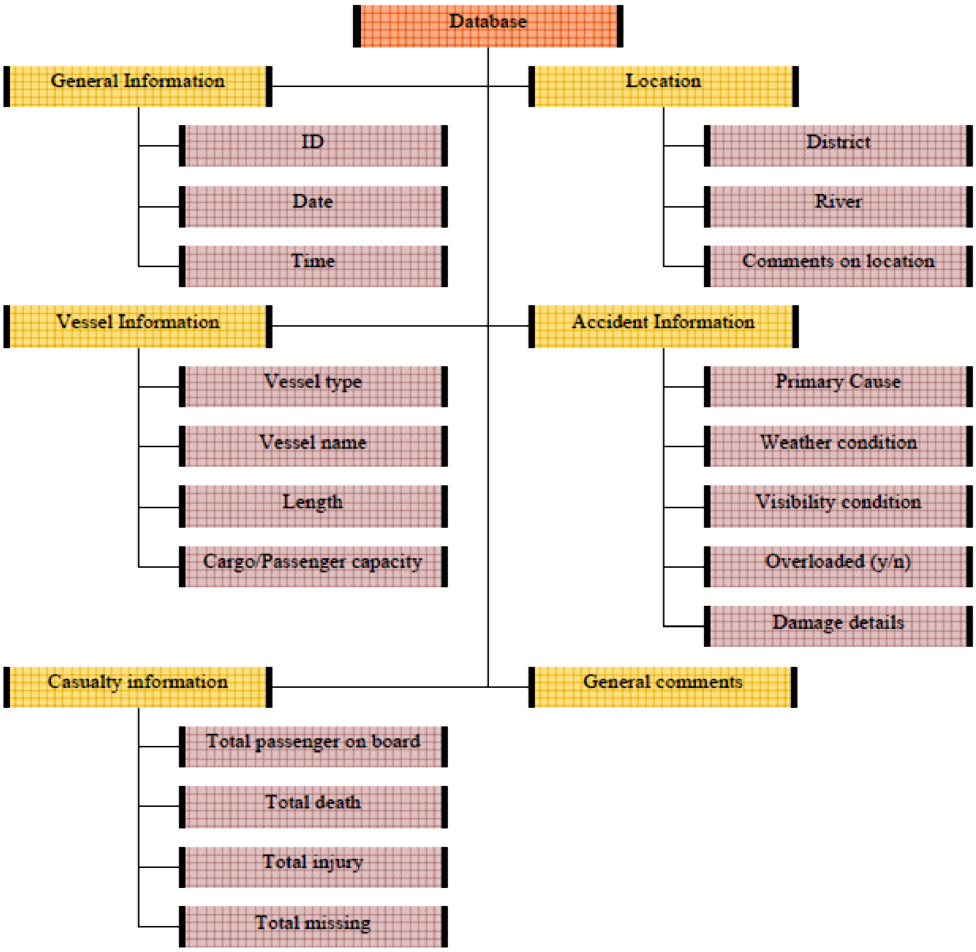


Fig. 2.5: A database structure for analysis of passenger vessel accidents, reproduced from Awal *et al.* 2006.

Awal *et al.* (2006) conducted a study by analyzing the accident data of inland passenger vessels from 1995 to 2005 by taking into account of 67 accident cases. The study found severe limitations of maritime accident database of Bangladesh. Therefore attempts were made to prepare a separate spreadsheet database consisting of 19 different parameters which are grouped to 6 major categories. Figure 2.5 illustrates the spreadsheet database developed in that study. The findings of the study revealed that the leading causes of accidents involving passenger vessels in the inland water routes of Bangladesh are collision and Nor'wester (77%), out of which collision due to human error alone stands 56% of total accidents. The other accident types identified by the study are stability failure, overloading, and grounding etc.

The study also applied the Geographical Information System (GIS) to identify the most hazardous locations of accidents. The result by GIS revealed that the southern part of Bangladesh contains the most hazardous locations and the waterway along the river

Meghna appeared to be the most vulnerable route, as shown in figure 2.6. The passenger vessels having the length in the cohort of 40-60 meter experience more accidents (44%) than any other groups. The study has also found that there is a slightly higher tendency of accidents occurring during the afternoon period due to the occurrence of most of the nor'wester during the time range of 1200 to 1800 hrs.

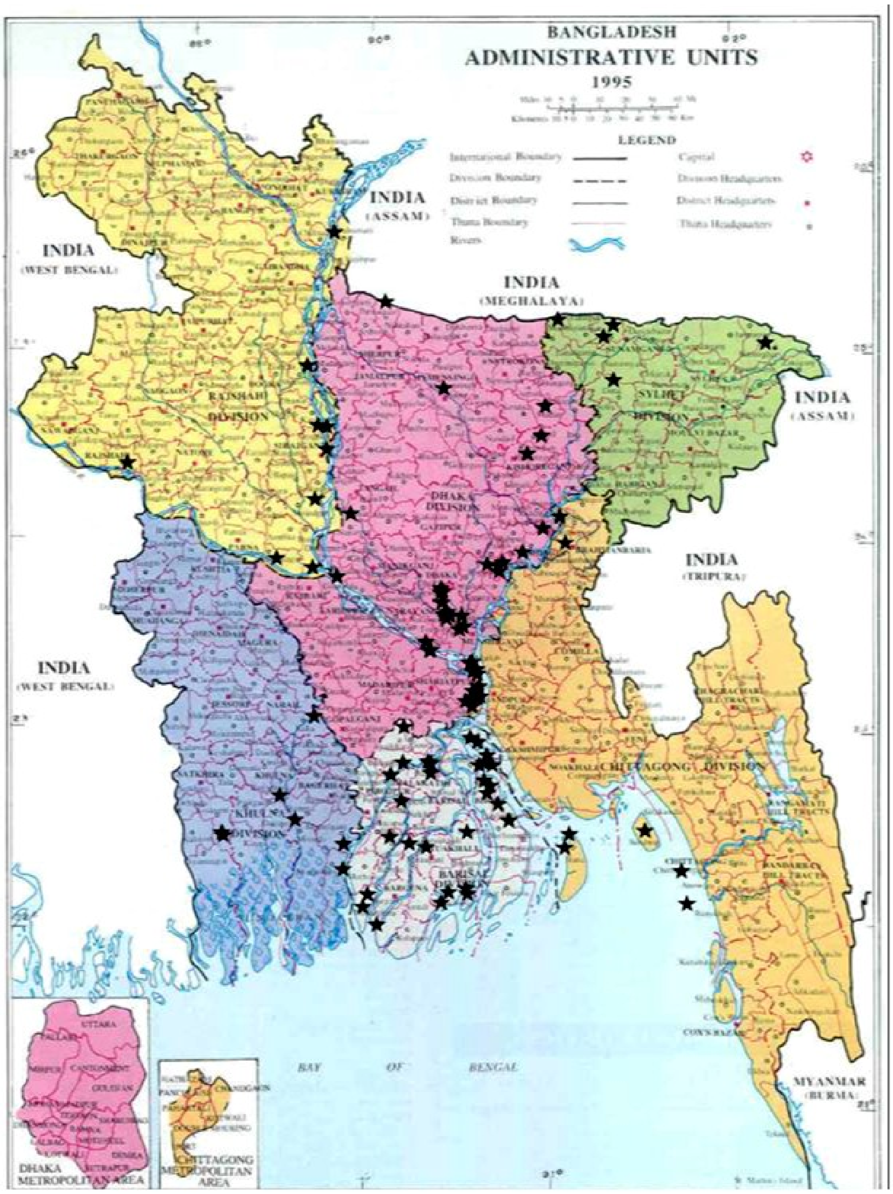


Fig. 2.6: Accident locations shown using GIS, reproduced from Awal *et al.* 2006.

Awal (2007) mentioned the factors that are responsible for the accidents in the inland waterways of Bangladesh. A number of causes are listed against the four main categories of factors that are responsible for the accidents, as shown in table 2.1. The study considered 197 cases that included the accident of passenger and cargo vessels.

Table 2.1: Factors behind water transport accidents, reproduced from Awal 2007.

Factors	Some Causes
Vessel design factor	• Faulty design and construction • Mechanical failure of the vessels • Insufficient and flawed navigational instruments
Operating environment factor	• Foggy weather condition • Excessive current and whirlpool • Cyclone and stormy weather
Human factor	• Overcrowding and overloading • Rush of passengers during embarking and disembarking • Incompetence of captains, master and other professionals
Enforcement and educational factor	• Negligible amount of application and practice of vessel safety regulations • Deficiency in public awareness building programs • Deficiency in weather warning and counter measure system

Iqbal et al. (2007) conducted an analysis of the inland water passenger transport accidents occurred in the period 1981-2005 and found that the main cause behind structural failure is the collision. In case of intact stability failures (capsizing), the main causes have been identified as adverse weather conditions and overloading, with consequent likely crowding of passengers to one side of the passenger ship. The operation of vessels by unskilled crews and inadequate navigational equipment were found to be responsible for collision and grounding leading to structural failure. It is also discussed that the effectiveness of ballasting the ship could be largely reduced due to the risk of progressive flooding.

A study by Awal (2008) has found that passenger vessels and cargo vessels contribute significantly to the total number of fatalities (57%) of inland water transport accidents of Bangladesh. Iqbal et al. (2008) assessed the risk of flooding in the engine room in case of the absence of hatch covers, revealing the effectiveness of the hatch coamings with the increase of the angle of progressive flooding. Moreover, the detrimental effect of the presence of curtains on the openings of the superstructure has also been assessed in the study. It is explained that the passengers very often use to close the windows in order to shelter from wind and rain. Therefore, it has been recommended to take into account the possible presence of the curtains by considering all the openings as closed with the help of the regulatory framework. In another study by Iqbal et al. (2008a) it was recommended for modification of the original hull of the passenger vessels in order to improve the safety, where the ship is equipped with added reserve buoyancy above the waterline to increase the restoring lever at large angles of heel.

Azad (2009) analyzed the inland passenger vessel accidents in Bangladesh by taking into consideration of 201 accidents from 1975 to 2009. One of the main findings of the study is that the majority of inland passenger vessel accidents in Bangladesh are related to the collision where adverse weather, unskilled operators and machinery breakdown are responsible. Besides, the study also revealed that the exact number of people onboard and victims are never known as the vessels mostly don't keep passenger lists or follow operational rules set by the maritime transport authorities. An investigation by Awal et al. (2010) have found that the majority (54%) of the inland water transport accidents are caused by passenger launches, trawlers, ferries, and country boats. Besides, the study also revealed that cargo vessels and passenger vessels contribute to 75 percent of all vehicles in the collision.

Hossain et al. (2014) applied the Fault Tree method to analyze the contact type marine accidents of Bangladesh. The study developed a fault tree for collision and grounding type of accidents as a tool for the collection and analysis of accident data to identify the hazardous chain of events. It is claimed at the end of the study that, with the help of this fault tree analysis the errors and hazards which are related to the accident process, both explicitly and implicitly can be identified.

Rahman and Rosli (2014) proposed the concept of the operation of elevator as a design solution to mitigate the overload problem of the passenger ships in Bangladesh. In the proposed solution the weight of passenger and other goods will be detected at the entry point of the passenger vessel. In case of the ship getting overloaded by adding that additional weight, an automatic alarm will be sounded. This sensor cannot be controlled by the master or other crews of the ship as it will installed inside the hull of the ship. In order to sail for the voyage, it is therefore required to remove the excess load from the ship. Figure 2.7 shows the elevator concept that was applied in the study.

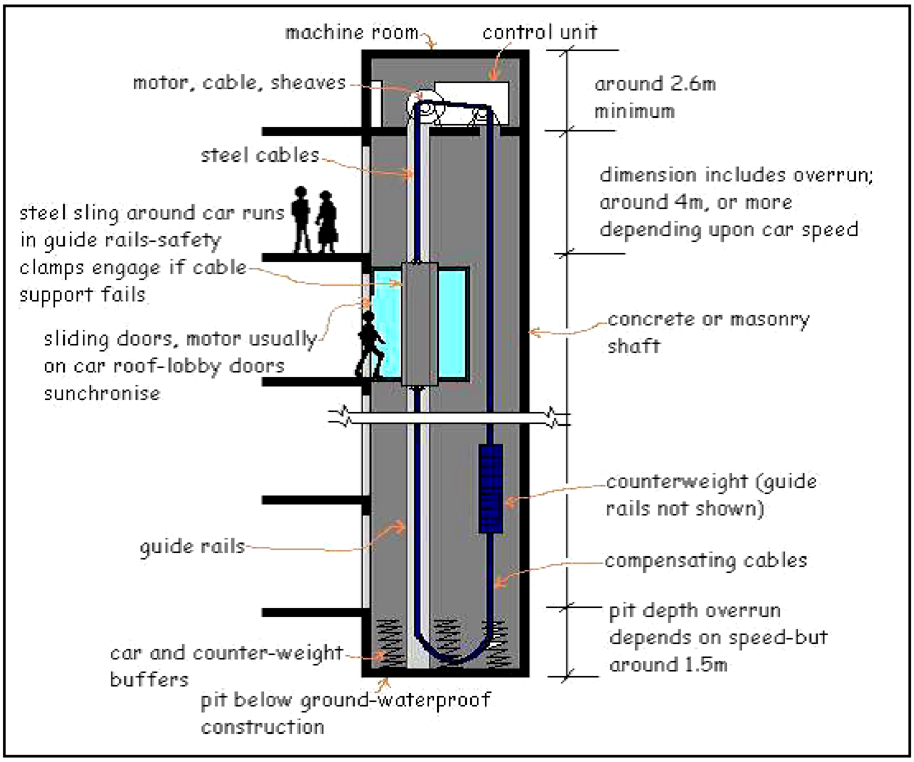


Fig. 2.7: Elevator concept to mitigate the overload problem of the passenger ships, reproduced from Rahman and Rosli (2014).

Fig. 2.8: Mode of failure and form of occurrences of accidents in the waterways, reproduced from Islam et al. (2015).

Islam et al. (2015) investigated the reasons behind the accidents particularly the inland passenger vessels of Bangladesh and suggested some measures that may prevent the accidents. To simplify the causes of inland water transport accidents, the most common form of occurrences were divided into two groups based on the mode of failure as structural failure and stability failure as shown in figure 2.8. The study mentions that when accident occurs due to collision, grounding or fatigue, the structure of vessel fails; and when accident occurs due to overloading or inclement weather, vessel loses its stability in some manner. Structural failure always leads to stability failure, but stability failure may occur without the failure of structure. Accidents may occur with different combinations of all the form of occurrences. The most common combined form in Bangladesh has been overloading with inclement weather as shown in figure 2.9. The data analysis of the major accidents by the study revealed that prevention of passenger vessel accidents will drastically decrease the number of casualties in the inland waterways of Bangladesh where overloading and inclement weather are two repeatedly reported causes of accidents. Besides, it is also stated that, in case of existing traditional design of inland passenger vessels, the ratio of the lateral area above the load water line (exposed to wind) to the underwater part is large and the down-flooding angle is less due to the opening of the engine room. As a result, the stability criteria are satisfied minimally i.e., there remains no margin of safety. The study also stated that an accidental phenomenon can be divided into two phases, namely capsizing and sinking. A vessel that is properly constructed based on a proper design can capsize if the design criteria are not followed. In contrast, prevention of capsizing of vessels will ultimately prevent the sinking of the vessels.

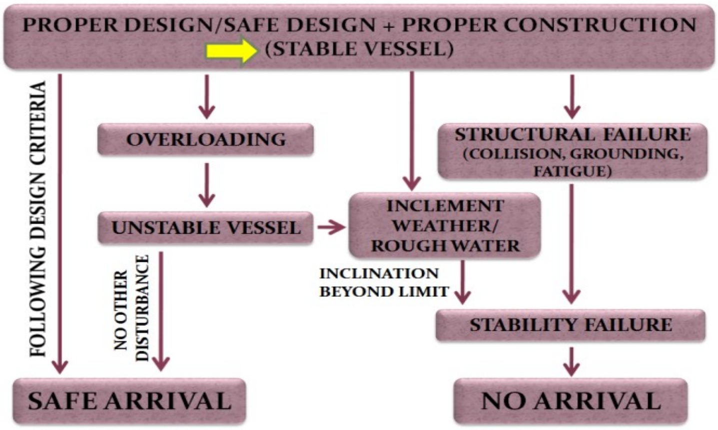


Fig. 2.9: Combination of form of occurrences of accidents, reproduced from Islam et al. (2015).

Rahman (2017) applied the statistical approach to investigate the passenger vessel accidents of Bangladesh during 1983 to 2015. The analysis revealed that the lion's share (42.7%) of accidents involving the passenger vessels occur due to the collision, as shown in figure 2.10. Besides, the majority of fatalities of overall maritime accidents are covered by passenger vessel accidents. The study also revealed that almost 35% of accidents involving the passenger vessels occur during the months of March to May when the violent nor'wester lashes the country frequently.

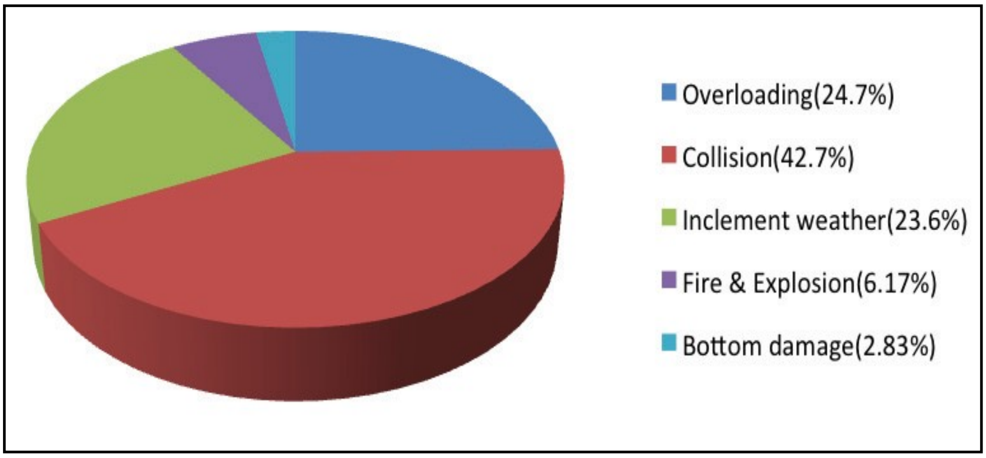


Fig. 2.10: Causes of passenger vessel accidents in Bangladesh, reproduced from Rahman (2017).

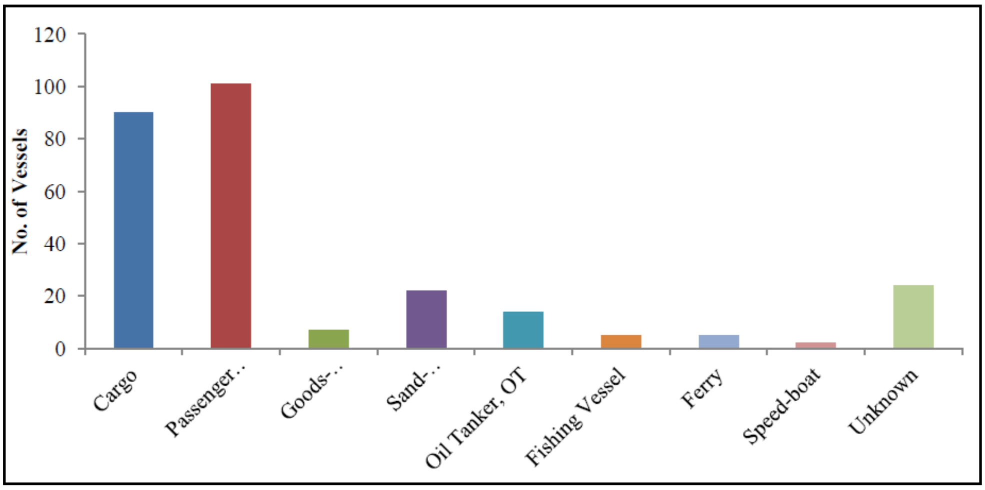


Fig. 2.11: Distribution of vessel types involved in accident, reproduced from Probha (2017).

In a study by Probha (2017) it is revealed that passenger vessels (37%) share the highest percentage of accidents in the inland waterways of Bangladesh during the period 2008 to 2015, as shown in figure 2.11. Besides, the number of accidents occurred during festival periods involved the passenger vessels (63%) more than any other types of vessels. The average casualty per accident was found to be maximum i.e. almost eight on the waterways in comparison to other modes of transports i.e. roads and railways. In addition, the average fatality per accident was also found to be greater in the waterways i.e. almost six in comparison to other modes of transports. It was explained by the author that the reason behind such a high ratio of casualty and fatality in the waterways is due to the higher amount of passenger carrying capacity of the vessels than that of roads and railways. Consequently, a single accident of a passenger vessel on the waterway causes great loss of lives.

A study by Uddin et al. (2017) revealed that the passenger vessels (26.3%) are the second-most dominant type of vessel that experiences accident in the inland waterways of Bangladesh. The study suggested the implementation of the passenger counting system to mitigate the problem related to the overloading of the passenger vessels.

Raiyan et al. (2017) performed a probabilistic analysis based on the event tree method to analyze the inland water transport accidents of Bangladesh. The analysis yielded to the finding that the number of accidents can be reduced considerably if the problem of poor visibility, when the ship is overloaded can be solved. For more quantitative analysis of event tree various data relating to barriers against accident should be taken into consideration. For this purpose, the study suggests that all ships must be provided with Voyage Data Recorder (VDR). This recording can be used for investigation in the initial and pivotal events of accidents. Besides, limitation of data collected from primary source was regarded as the paramount limitation of the study. As a result, the probabilistic analysis made in the study involved moderately low number of realistic incidents.

Rashid and Islam (2017) identified 12 major causes of accidents involving passenger vessels in Bangladesh. By analyzing 5 major passenger launch accidents as case studies, a number of facts were established in the study. Based on those facts, mainly two types of recommendations were put forward to improve the safety of operation of passenger vessels; one is the institutional reformation and the other is the improvement of design and engineering aspects of the passenger ships. Besides, to mitigate the accidents involving the passenger vessels a number of suggested measures are put forward at the end of the study namely proper implementation of inland shipping rules and laws, raising awareness among the passengers, proper weather forecasting, marking of shelter stations in the route, exemplary punishment for corruption, monitoring overloading during festivals, training on emergencies for crews, allocation of resources to concerned departments, enhancement of Department of Shipping and Bangladesh Inland Water Transport Authority (BIWTA).

Rahman (2017a) carried out a risk analysis of inland water transport accidents in Bangladesh by applying the Bayesian network model. The study reported that all passenger vessel accidents can be classified into four categories i.e. collision, overloading, inclement weather, fire and explosion. The study also revealed that the number of passenger vessel accidents is increasing gradually over the years in comparison to accidents by other types of vessels. The casualty due to the accidents involving the passenger vessels is also more because of passengers not being able to come out from the vessel during the accidents.

The discussion above shows that the accidents involving passenger vessel has been a severe problem for a long time. The researchers have also tried to investigate the causes behind these disastrous events and put forward a number of recommendations. However, the in-depth analysis of the factors behind the accidents is not analyzed in those investigations. Therefore, it is needed to study the accident causation models and hazard analysis techniques that can lead to choose a suitable method for in-depth accident investigation and hazard analysis related to inland passenger ship operation in Bangladesh. The next section will briefly discuss the concept regarding accident causation and hazard analysis.

2.5 Overview on Accident Causation and Hazard Analysis

This section presents a brief overview of the ideas regarding the accident causation and hazard analysis. The reader will acquire a preliminary concept regarding the importance of safety analysis of a system from this section.

2.5.1 Overview on the ideas of accident causation

Many researchers have defined the process of accident causation in different ways. The observation by Rasmussen (1997) about the accident is that major accidents generally do not take place as a consequence of simple chains of events or random failures but is represented by the systematic migration of the system states to the higher risk. It was also argued that risk management or safety must be considered as a control problem and it requires a system oriented approach based on functional abstraction rather than structural decomposition. Depending on the nature of hazard source, quite different risk management strategies have evolved across the different hazard domains, as shown in figure 2.12. The study, therefore, argues that a detailed study of control requirements of the dominant hazard sources of a work system is mandatory for risk management. Lim (2008) states that effectively preventing accidents in complex systems requires using accident models that include the social system as well as the technology.

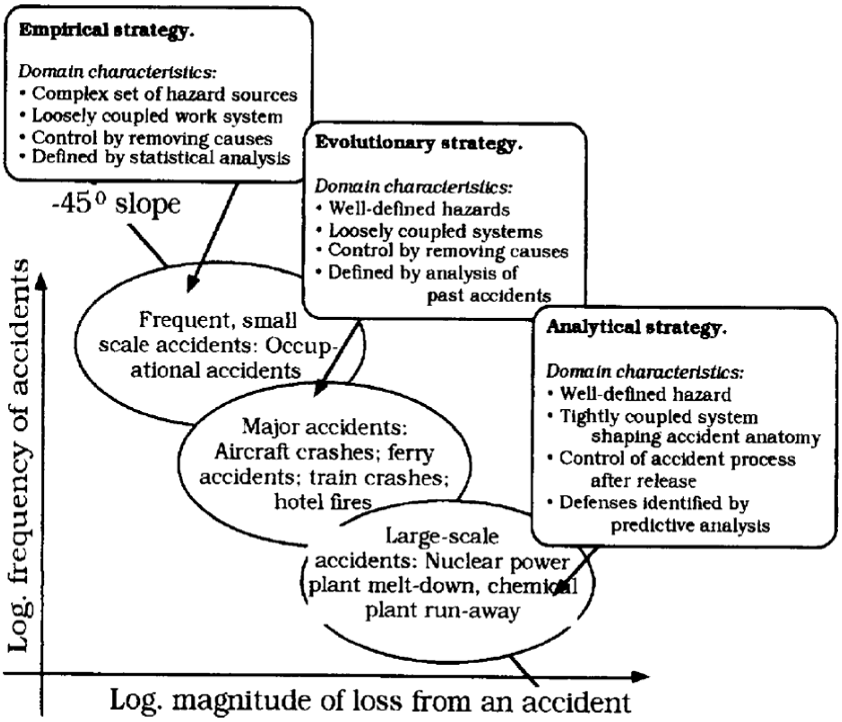


Fig. 2.12: Hazard source characteristics and risk management strategies, reproduced from Rasmussen (1997).

Accidents are most likely to occur in overlap or boundary areas where many controllers (human or automated) control the same process having common boundaries (Leplat, 1987). In both overlap and boundary areas, there remains potential for ambiguity and for conflicts among independent decisions. The responsibility for the control functions in boundary areas is poorly defined in most cases. Leveson (2012) states that the problem often occurs when there is shared control over the same process or at the boundary areas between separately controlled processes. The interface of a system defines this functional boundary of the system components. From the management standpoint, an interface must optimize visibility and control as well as isolate the components that can be implemented separately and for which the responsibility and authority can be delegated (Pickering, 1973).

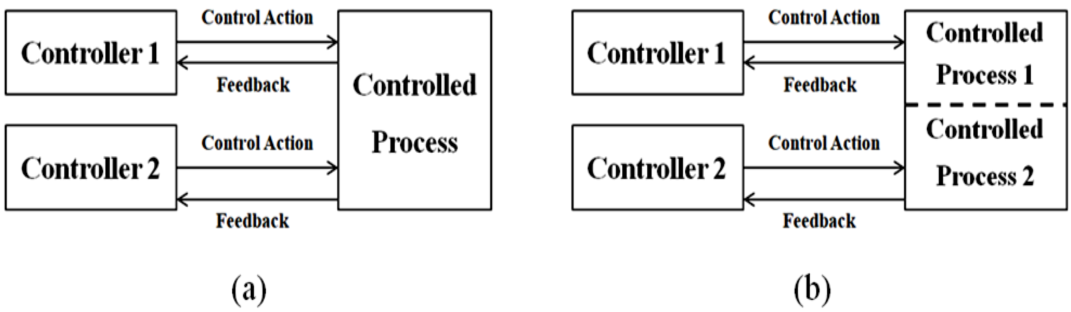


Fig. 2.13: (a) Example of an overlap; (b) Example of a boundary area, adapted from Leveson (2012).

Poorly defined feedback can bring about a reduction in safety in a system (Leveson, 2012). As for example, the workers having the best safety records of the California construction industry were rewarded as an incentive to decrease the number of accidents (Levitt and Parker, 1976). The term best safety record was used to mean the occurrence of least number of incidents. This reward encouraged the workers to withhold the information about minor incidents and near misses. Therefore, those incidents were not investigated to eliminate the root causes. An illusion was created within the industry that the system was becoming safer due to under-reporting of these incidents. Although, the real fact is that the risks were being simply concealed by the workers. The incorrect risk perception by the organization led to not taking the required control actions to decrease the risk. Instead, the reporting of incidents and near misses should have been rewarded to improve the safety of the system. One of the main reasons for lack of reporting is that the information provided by the workers may be used against them or there are other negative impacts such as the need for spending additional time filling out the reports (Leveson, 2012).

It is also needed to consider the context of accident causation in maritime domain that will be helpful for better comprehending of this research. Swift (2004) suggested comprehensive guidelines for the management of the bridge team of a ship. The study demonstrated the procedures of sailing the ship safely by the bridge crews and also the common errors made by them. In the context of the maritime domain, it is mentioned that an accident by its nature is unexpected, but most accidents occur because there is no system in operation to detect and consequently prevent one person making a mistake; a mistake of the type all human beings are liable to make. Del Pozo et al. (2010) have defined the maritime safety as the combination of preventive measures intended to protect the maritime domain against, and limit the effect of accidental or natural danger, harms, damage to the environment, risk or loss.

2.5.2 Hazard analysis

Leveson (2012) states that the hazard analysis can be described as 'investigating an accident before it occurs'. It is also stated that the objective of hazard analysis is to identify the potential causes of accidents, that is, scenarios that can lead to losses, so that they can be removed or controlled in design or operations before any damage or loss occurs.

Ericson (2015) states that the hazard identification is a critical system safety function, and thus the correct understanding and appreciation of hazard theory is critical. Hazard analysis is the basis of system safety. It is performed to identify hazards, hazard effects, and hazard causal factors. It is used to determine system risk, to determine the impact of hazards, and to establish design measures that will mitigate or eliminate the identified hazards. It is also used to systematically examine systems, subsystems, components, software, facilities, personnel, and their interrelationships, with consideration given to logistics, maintenance, training, test, modification, and operational environments. To successfully perform hazard analyses, it is necessary to understand what comprises a hazard, how to recognize a hazard, and how to define a hazard. To develop the skills needed to identify hazards and hazard causal factors, it is necessary to understand the nature of hazards, their relationship to mishaps, and their effect upon system design. The basic reasons why hazards exist are (1) they are unavoidable because hazardous elements must be used in the system, and/or (2) they are the result of inadequate design safety consideration. Inadequate design safety consideration results from poor or insufficient design or the incorrect implementation of a good design. This includes inadequate consideration given to the potential effect of hardware failures, sneak paths, software glitches, human error, and the like. Quite often hazards are inadvertently injected into a system design through design 'blunders', design errors, or lack of foresight. For example, two subsystems may have been independently designed and when combined in a system have unforeseen interface problems that result in a hazard. Fortunately, since hazards are created through the design and development process, this makes them deterministic, predictable, and identifiable. This generates the need for hazard analysis (Ericson, 2015).

2.6 Role of Human-Machine Interaction in Accidents

The human-machine interaction has been causing a significant role in the occurrence of accidents. Leveson (2012) argues that in the case of highly automated systems, an assumption is often made that less training is required. In fact, the requirements of the training go up in automated systems and they alter their nature. Training actually requires being more extensive and comprehensive while using automation. One of the reasons for this requirement is that human operators of highly automated systems not only require a model of the existing process state and the pattern of changing the state, but also a model of the automation and its mode of operation.

Almost all systems contain humans, although engineers are often not trained much about human factors and draw suitable boundaries around the technical components, focusing their attention inside these artificial boundaries (Leveson, 2012). Human factor experts have criticized about the resultant 'technology centered automation', where designers focus only on the technical issues and not on supporting the tasks of the operator (Weiner, 1989). The result is called 'clumsy' automation that increases the chances of human error (Sarter et al., 1997; Billings, 1996; Weiner, 1989). Leveson (2012) argues that engineers can no longer focus only on the technical issues and ignore the social, managerial and even political factors that impact safety if we indeed want to mitigate accidents. They have been assuming that human operators in the system will either acclimatize to whatever is provided to them or will be trained to do the 'right thing'. However, when an accident occurs, the operators are blamed. This approach to safety is responsible for the ineffectiveness of the safety engineering at present. The system design process is required to be started by taking into account the human controller and to continue that perspective all through the development. The best approach to achieve that goal is to engage the operators in the overall design decisions and safety analyses. In most cases, operators are left out of the conceptual design stages and involved later in development. To design a safer system, operators and maintainers must be included in the design process starting from the conceptual development stage and considerations of human error and preventing it should be at the forefront of the design effort.

Leveson (2012) states that humans are increasingly sharing control of systems with automation and gradually moving into positions of higher-level decision making with automation implementing those decisions. These changes are creating new types of human error- such as different types of mode confusion and a novel distribution of human errors, for example, increasing errors of omission versus commission (Sarter and Woods 1995; Sarter et al., 1997). Inadequate communication between humans and machines is becoming an increasingly important factor in accidents (Leveson, 2012). Human behavior is greatly influenced by the environment in which it occurs. A lot of recent accidents that blame operator error as the root cause of accidents could more accurately be labeled as resulting from flaws in the environment in which the operators operate.

2.7 Safety and Reliability

Leveson (2012) states that safety and reliability are different properties. One does not imply nor require the other. A system can be reliable but unsafe. Similarly, it can also be safe but unreliable. To explain the statement the study cites that reliability is often quantified as the mean time between failure. In engineering, the term ‘Reliability’ is defined as the probability that something satisfies its specified behavioral requirements over time and under given conditions, that is, it does not fail (Leveson, 1995). In contrast to that, the term ‘Safety’ is defined as the absence of accidents, where an accident is an event involving an unplanned and unacceptable loss. Leveson (2012) states that to increase the safety of a system, the focus should be on eliminating or preventing hazards, not eliminating the failures. Increasing reliability may decrease safety and increasing safety may decrease reliability. Safety is a system property, not a component property and must be controlled at the system level, not at component level.

In complex systems, accidents often result from interactions among components that are all fulfilling their individual requirements, although none of the components have failed (Leveson, 2012). The report by JPL Special Review Board (2000) reveals that the loss of the Mars Polar Lander was attributed to noise (spurious signals) generated when the landing legs were deployed during the spacecraft’s descent to the surface of Mars. This noise was normal and expected and did not represent a failure in the landing leg system. The onboard software interpreted these signals as an indication that landing had occurred (which the software engineers were told such signals would indicate) and shut down the descent engines prematurely, causing the spacecraft to crash into the surface of Mars. In this case, the landing legs and the software performed correctly (as specified in the requirements) and reliably, but the accident occurred because the system designers did not account for all the potential interactions between landing leg deployment and the descent engine control software. This loss of Mars Polar Lander is a component interaction accident (Leveson, 2012). Such accidents arise in the interactions among system components (electromechanical, digital, human, and social) rather than in the failure of individual components. Therefore, in component interaction accidents there may be no failures and the system design errors giving rise to unsafe behavior are not random events.

Component failure accident is considered as the most important aspect in engineering, although component interaction accidents are becoming more common as the complexity of our system designs increases (Leveson, 2012). In the past, our designs were more intellectually manageable and the potential interactions among components could be thoroughly planned, understood, anticipated, and guarded against (Perrow, 2011). But this is not valid in present times.

2.8 Role of Operators in Accident

After an accident it is simple to see where people have made the mistake, what they should have done or not done, to judge people for missing a piece of information that turned out to be critical, and to see exactly the kind of harm that they should have anticipated or prevented (Dekker, 2007). However, before the event, such insight is difficult and, perhaps, impossible. This psychological phenomenon is called 'hindsight bias'. To avoid hindsight bias it is required to change our focus from what they did wrong to why it made sense for them to act the way they did while analyzing the role of humans in accidents (Leveson, 2012).

The less that is known about an accident, the most likely it will be attributed to operator error (Johnson, 1980). Thorough investigation of severe accidents almost invariably finds the other factors (Leveson, 2012). Perrow (2011) claims that even in some best industries of the world, there is rampant attribution to blame operator error for the accident, to neglect the errors by designers or managers. The study cites that a U.S. Air Force study on aviation accidents representing that the designation of human error (pilot error in this case), is a suitable classification for accidents whose actual cause is uncertain, complex and embarrassing to the organization.

Leveson (2012) cites that the engineers have a tendency to equate people with the machines. Usually, the human failure is treated in a similar way to that of a physical component failure- a deviation from the performance of a specified or prescribed sequence of actions. This definition is equivalent to that of machine failure. However, human behavior is much more complicated than machines. Human factor experts have found that the instructions and written procedures of the organization are almost never followed accurately as the operators try to become more proficient and productive and to manage time pressures (Rasmussen, 1997). Many studies have found that the operators modify the instructions repeatedly even in the extremely constrained and highly hazardous environment of the nuclear power plants (Fujita, 1991; Vicente, 1995; Vicente and Rasmussen, 1992).

2.9 The Focus on Determining Blame

After an accident one of the prime objectives of the investigators is to find that who is to be blamed for the accident. Leveson (2012) argues that blame is not an engineering concept; it is a legal or moral one. In a study by Leveson (2004) regarding aerospace accidents involving software, it was found that most of the accident investigation reports stopped after assigning blame; usually to the operators who interacted with the software, and never got to the root of why the accident occurred. When trying to understand contributions of operators to the accidents, it is more useful in learning how to prevent future accidents by focusing not on what the operator did 'wrong' but on why it made sense for them to behave that way under that context (Dekker, 2007). Leveson (2012) states that most people are not malicious, but simply try to do the best they can under the situations and with the information they have. Understanding why those attempts were not adequate will assist in changing the features of the system and environment, so that, the sincere efforts will become more successful in the future. Focusing on assigning blame contributes nothing toward achieving this goal and may impede it by reducing openness during accident investigations, thereby making it more difficult to find out what actually happened.

A number of studies have found the choice of causes of accidents is dependent on characteristics of the victim and of the analyst (e.g. degree of involvement, hierarchical status and job satisfaction) as well as the relationships between the victim and the analyst and on the severity of accident (Leveson, 2012). Moreover, the lower the position in the hierarchy in an organization, the higher the tendency to blame for accidents on factors linked to the organization; individuals who have a high position in the hierarchy tend to blame the workers for accidents (Leplat, 1987). Accident investigation data on near-miss (incident) reporting suggest that causes for these events are mainly ascribed to technical divergence while similar events that result in losses or accidents are more often blamed on operator error (Edwards, 1981; Kjellen, 1982). Causal identification may also be influenced by the data collection methods (Leveson, 2012). Data are generally collected in the form of textual descriptions of the chain of events of the accident, which tend to focus on obvious conditions or events closely preceding the accident in time and tend to omit less obvious or indirect events and factors. There is no simple solution to this inherent bias. On one hand, report forms that do not specifically ask for non-proximal factors often do not elicit them while, on the other hand, more directive report forms that do request particular information may limit the categories or conditions considered (Kjellen, 1987).

Leveson (2012) argues that there is a difference between an explanation based on goals and based on motives. A goal represents an end state while a motive explains why that end state was selected. Let us consider the hypothetical case where a car is driven too fast during a snowstorm and it slides into a telephone pole. An explanation based on goals for this chain of events might include the fact the driver wanted to get home hurriedly. However, an explanation based on motives might include the fact that guests were coming for dinner and the driver had to prepare the food before they arrived. Similarly, there are two basic reasons for conducting an accident investigation. The first one is to assign blame for the accident. The other reason is to comprehend why it happened so that similar accidents can be prevented in the future. When assigning blame becomes the goal, the backward chain of events considered often ends when someone or something suitable to blame is found. As a result, the chosen initiating event may provide too superficial an explanation of why the accident occurred to prevent future losses.

2.10 Accident Causation Models

A number of accident causation models have been proposed previously by many researchers to explain the accidents. The chronological order of development and classification of accident theories altogether is depicted in figure 2.14.

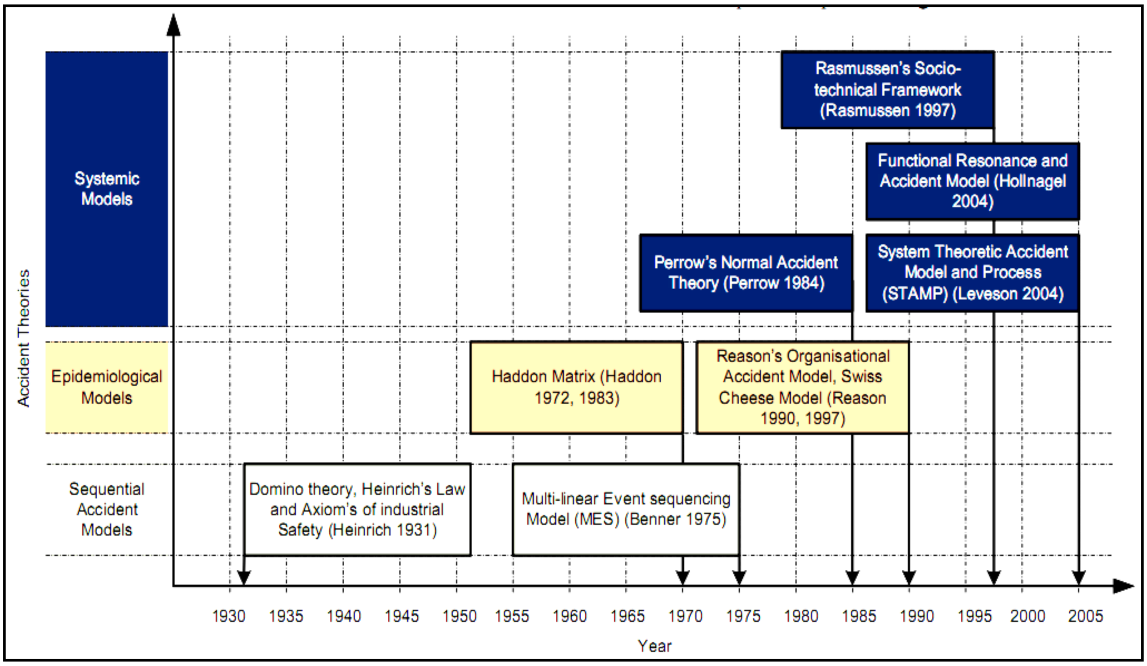


Fig. 2.14: Development of Accident theories in chronological order, reproduced from Awal and Hasegawa (2015).

Leveson (2012) states that a particular type of model, an accident model or accident causality model underlies all efforts to engineer for safety. An accident model provides the foundation for (1) investigating and analyzing the cause of accidents, (2) designing to prevent future losses, (3) assessing the risk associated with using the systems and products we create. These models explain why accidents occur, and they determine the approaches we should take to prevent them.

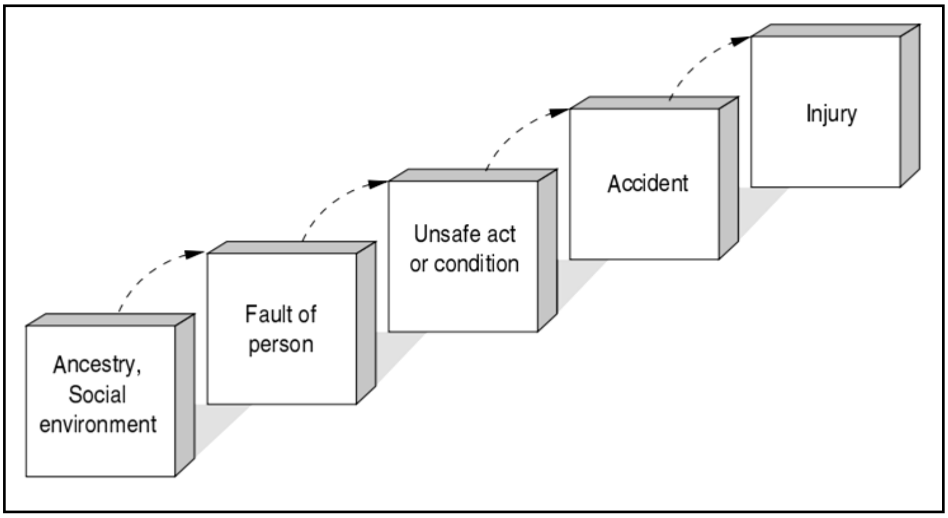


Fig. 2.15: Heinrich's Domino Model of Accidents, reproduced from Leveson (2012).

Heinrich's Domino model, published in 1931, was one of the first published general accident models and was absolutely dominant in shifting the emphasis in safety to human error (Leveson, 2012). Heinrich compared the common sequence of accidents into five dominoes, standing in a row. When the first domino falls, it automatically knocks down its nearby domino and so on until the injury occurs at last. This model states that, in any accident sequence, ancestry or social environment initiates the fault of a person, which results in an accident that ultimately causes an injury.

The theory is mainly focused on assigning blame to the operator. It implies over-emphasis on worker behavior and not enough attention on systems. It is stated by the theory that 88% of all accidents are caused by unsafe acts of people, 10% by unsafe conditions and 2% by acts of God (Hosseinian and Torghabeh, 2012). One of the significant limitations of Heinrich's model is its one-dimensional nature. The accident and injury occur as a sequence of linear chain events, with no other external influences. This theory does not consider options of preventing accidents through means other than removing a factor from the linear event chain. As a result, Restriction to one-dimension event chain limits a safety analyst to focus only on the specified factors. It is not possible for him to consider or discover any other causal factor responsible for the accident.

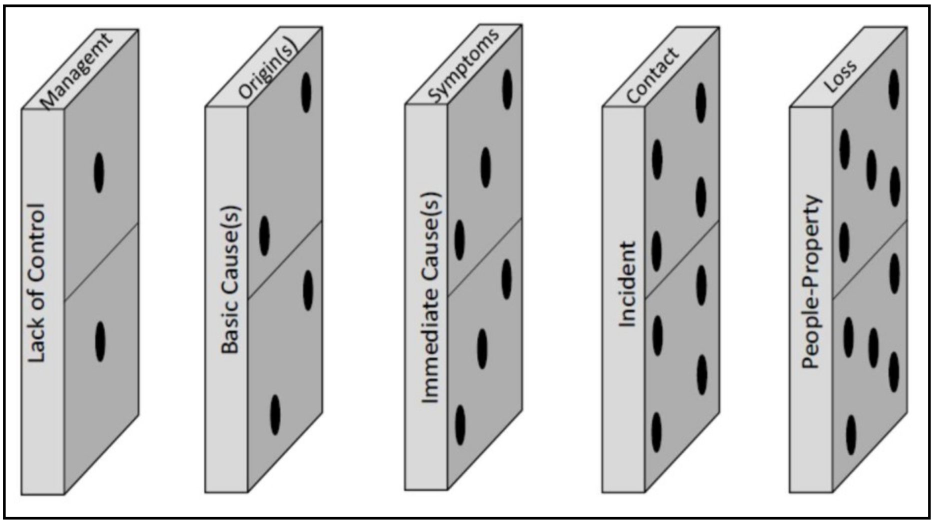


Fig. 2.16: Bird and Lotfus' Domino Model, reproduced from Stukus (2017).

In 1976, Bird and Lotfus (Bird and Lotfus, 1976) extended the basic Domino Model to include management decisions as a factor in accidents. The model is structured in the following way:

1. Lack of control by management, allowing
2. Basic causes (personal and job factors) that lead to
3. Immediate causes (substandard practices or conditions or errors) that are the proximate cause of
4. An accident or incident, which results in
5. A loss.

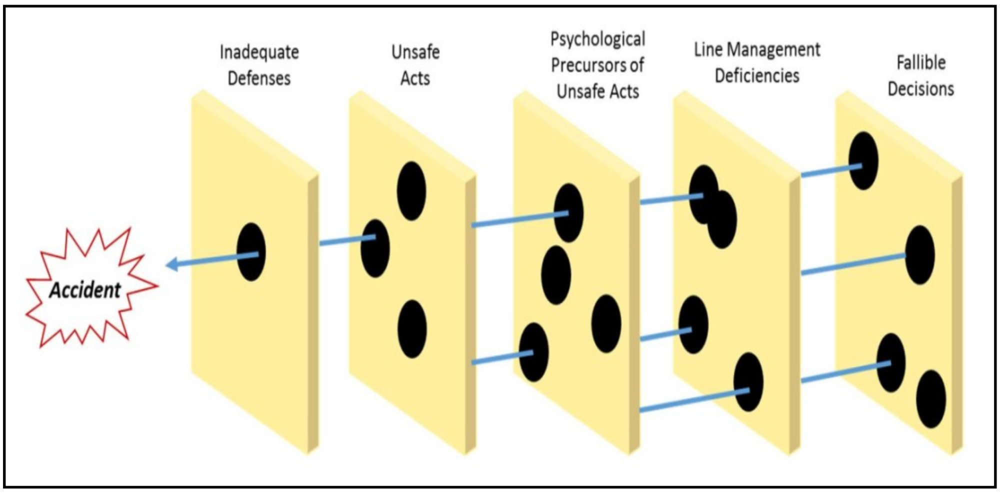


Fig. 2.17: Swiss Cheese Model, reproduced from Reason (2008).

In 1991, James Reason reinvented the Domino Model and named it as Swiss Cheese model, but with layers of Swiss cheese substituted for dominos (Reason, 1990; Reason, 1997). Each layer has some areas of weakness that are penetrable by the hazards. These areas of weakness are shown as gaps or holes; hence bear a resemblance to the 'Swiss cheese'. These holes are not static rather continuously opening and closing. Moreover, the slices are also rotating. These holes are caused by the unsafe acts and latent conditions. These latent conditions are formed by imperfect decisions by the management and psychological precursor of unsafe acts. A loss event is considered to exist within the loss event, which in the Domino model were presumed to occur only from active failures such as unsafe acts (Reason, 1991). However, this model has lots of limitations regarding its nature and explanation of an accident. The holes are considered to line up arbitrarily, which assume that each slice is independent in nature. This idea is extremely unlikely in any real system. That is the nature and rotations of slices are not explained clearly that can match with a real system. Moreover, the model omits the systemic factors i.e. the background behind the creation of the holes on the slices.

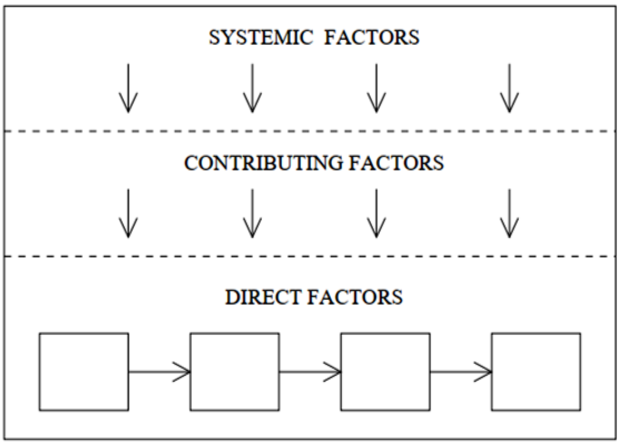


Fig. 2.18: Johnson's Three Level Model of Accidents, reproduced from Leveson (2012).

A number of attempts have been made to include systemic factors into event models, but all of them have significant limitations (Leveson, 2012). The most common approach has been to include hierarchical levels above the event chain as depicted in figure 2.18. William G. Johnson proposed a model and that explained accidents as chains of direct events and causal factors occurred by contributory factors, which sequentially arise from the systemic factors (Johnson, 1980). Johnson also attempted to incorporate the management factors into fault trees (a technique called MORT or Management Oversight Risk Tree), but ended up just providing a general checklist for auditing the management practices. Leveson (2012) argues that, while such a checklist can be very helpful, it presupposes that each error can be predefined and put into a checklist form. This checklist is comprised of a set of questions that are supposed to be asked during an investigation. Initially, Johnson provided hundreds of such questions, and additions have been made to his checklist since it was created in the 1970s. Therefore, the checklist has become larger now. The application of the MORT checklist is viable because the items are so general, but such generalization also limits its usefulness. Therefore, something more effective than the checklist is needed.

Rasmussen and Svedung's model of the socio-technical system involved in risk management has been the most sophisticated of the hierarchical add-ons to event chain (Rasmussen, 1997). They model a hierarchical control structure, with levels for government, regulators and associations, company, management, and staff at the social and organizational level as shown in figure 2.19. At each level, the information flow has been mapped. The model focuses on operations; information from the system design and analysis process is considered as input to the operations process. At all levels, the factors involved are modeled using the event chains, with links to the event chains at the level below. It is notable that, the model still assumes the presence of a root cause and causal chain of events. Therefore, Leveson (2012) argues that a number of new assumptions are needed to make progress in learning how to design and operate safer systems.

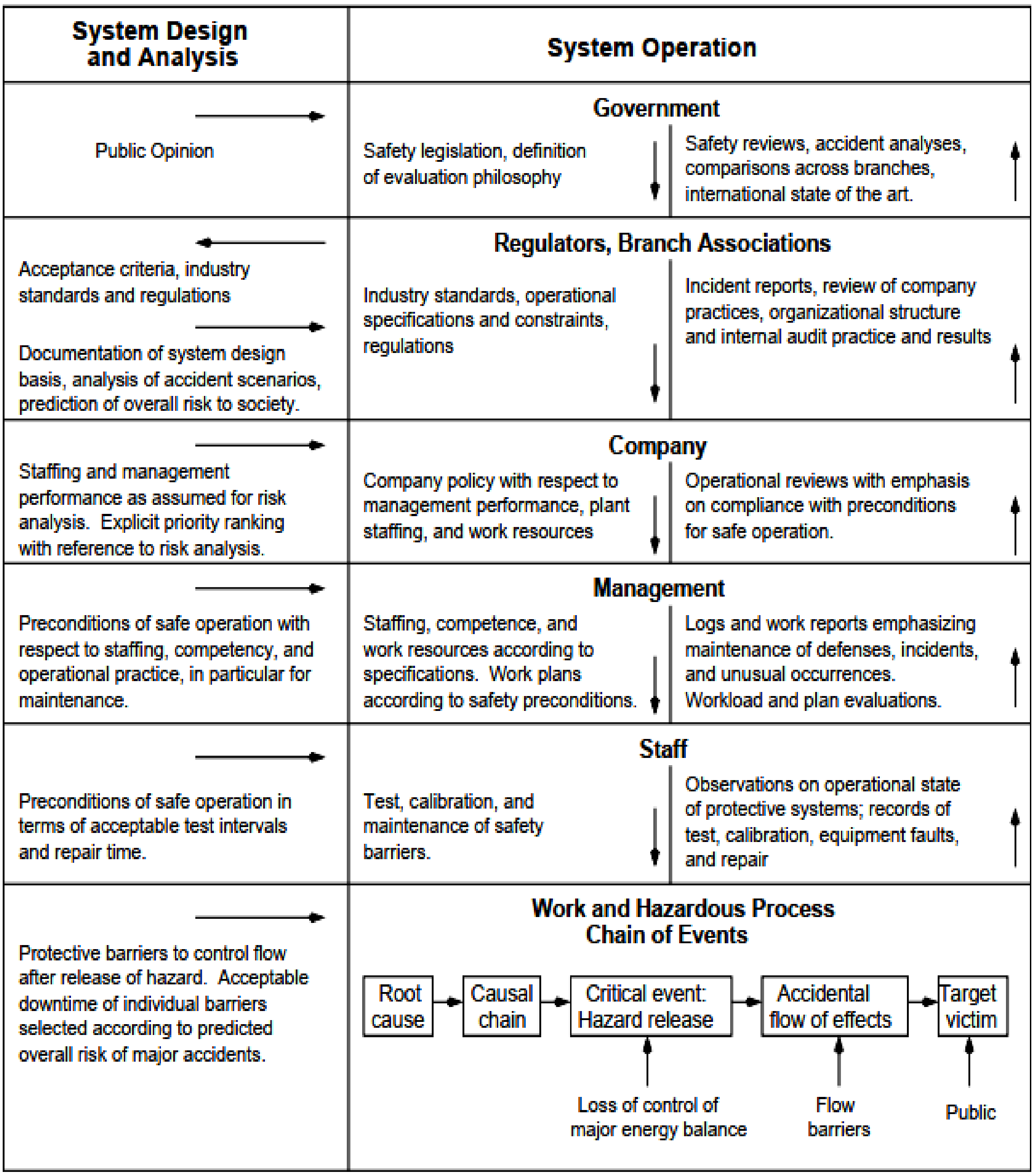


Fig. 2.19: Rasmussen and Svedung's model of risk management, reproduced from Leveson (2012).

2.11 Limitations of Probabilistic Risk Assessment

The probabilistic risk assessment method allows predicting accident by the mathematical approach. However, Leveson (2012) argues that the current methods of probabilistic risk assessment for quantifying the risk that are based on combining probabilities of individual component failures and mutually exclusive events are not suitable for systems controlled by software and humans making cognitively complex decisions. Moreover, there is no effective way to incorporate management and organizational factors, such as flaws in the safety culture, despite many well-intentioned efforts to do so. As a result, these critical factors related to the accidents are often omitted from risk assessment because analysts have no knowledge on how to obtain a 'failure' probability, or alternatively, a number is pulled out of the air for convenience of the assessment. If we had known enough to measure these types of design flaws, it would be better to fix them than to try to measure them.

Leveson (2012) argues that while conducting the probabilistic risk assessment, usually the starting events in the chain are considered as being mutually exclusive. Though this assumption simplifies the mathematics, it may not go with the reality. In the Bhopal accident water spouts, vent scrubber, refrigeration unit, flare tower and various monitoring equipment were all out of operation concurrently. Assigning probabilities to all these apparently unrelated events and assuming independence would make a person to believe that this accident was merely an incident of an once-in-a-lifetime coincidence. A probabilistic risk assessment based on event chain model most likely would have considered these conditions as independent failures and then calculated their coincidence as being so remote as to be beyond consideration. In the renowned Swiss Cheese Model of accident causation based on defense in depth, supports the similar principle that in general 'the chances of such a trajectory of opportunity finding loopholes in all the defenses at any one time is very small indeed' (Reason, 1990). Leveson (2012) states that a closer look at Bhopal and indeed most accidents paints a quite different picture and shows these were not random failure events but were related to engineering and management decisions initiating from common systemic factors.

Leveson (2012) argues that the majority of accidents in well-designed systems involve two or more low-probability events occurring in the worst possible combination. When an attempt is made to predict system risk, people explicitly or implicitly multiply events with low probability (by assuming independence) and come out with impossibly small numbers, though, in reality, the events are dependent. This dependence may be related to common systemic factors that do not appear in an event chain. Machol (1975) terms this phenomenon as the *'Titanic coincidence'*. Watt (1974) defined a related phenomenon as *'Titanic effect'* to explain the fact that major accidents are often preceded by a belief that they cannot happen. It is also stated that the magnitude of disasters decreases to the extent that people believe that disasters are possible and plan to prevent them or to minimize their effects. Leveson (2012) also argues that an additional limitation of probabilistic risk assessment is the emphasis on failure events. The design errors are usually skipped in the assessment and only come into the calculation indirectly through the probability of the failure event. Accidents involving the dysfunctional interactions among non-failing (operational) components i.e. component interaction accidents are usually not considered. Besides, the systemic factors also are not reflected in those risk assessments. The most awful outcome of using probabilistic risk assessment occurs by taking into account only the immediate physical failures. Latent design errors of the system may be ignored and go uncorrected due to overconfidence in the risk assessment.

2.12 The Need for a New Accident Causation Model

The event based models are poor at representing systemic causal factors of an accident such as decision making by the management, structural deficiencies in the organization, and flaws in the safety culture of the organization (Leveson, 2012). Jerome Lederer, the then the director of NASA manned Flight Safety Program for Apollo, wrote "System safety covers the total spectrum of risk management. It goes beyond the hardware and associated procedures of system safety engineering. The non-technical aspects of system safety cannot be ignored" (Lederer, 1986). Too often, however, the non-technical aspects of system safety are ignored (Leveson, 2012).

To label one event (such as a maintenance worker leaving out the slip disk) or even several events as the root cause or the start of an event chain leading to the Bhopal accident is misleading at best (Leveson, 2012). Rasmussen states "the stage for an accidental course of events very likely is prepared through time by the normal efforts of many actors in their respective daily work context, responding to the standing request to be more productive and less costly. Ultimately, a quite normal variation in somebody's behavior can release an accident. Had this 'root cause' been avoided by some additional safety measure, the accident would very likely be released by another point in time. In other words, an explanation of accidents in terms of events, acts, and errors is not very useful for the design of improved systems" (Rasmussen, 1997).

Table 2.2: The basis for a new foundation for safety engineering, reproduced from Leveson (2012).

Traditional Assumption	New Assumption
Safety is increased by increasing system or component reliability; if components do not fail, then accidents will not occur.	High reliability is neither necessary nor sufficient for safety.
Accidents are caused by chains of directly related events. We can understand accidents and assess risk by looking at the chains of events leading to the loss.	Accidents are complex processes involving the entire socio-technical system. Traditional event-chain models cannot describe this process adequately.
Probabilistic risk analysis based on event chains is the best way to assess and communicate safety and risk information.	Risk and safety must be best understood and communicated in ways other than probabilistic risk analysis.
Most accidents are caused by operator error. Rewarding safe behavior and punishing unsafe behavior will eliminate or reduce accidents significantly.	Operator error is a product of the environment in which it occurs. To reduce operator "error" we must change the environment in which the operator works.
Major accidents occur from the chance simultaneous occurrence of random events	Systems will tend to migrate toward states of higher risk. Such migration is predictable and can be prevented by appropriate system design or detected during operations using leading indicators of increasing risk.
Assigning blame is necessary to learn from and prevent accidents or incidents.	Blame is the enemy of safety. The focus should be on understanding how the system behavior as a whole contributed to the loss and not on who or what to blame for it.

An accident model should encourage the analyst to have a broad view of accident mechanisms that expands the investigation beyond the proximate events (Leveson, 2012). It is also mentioned that a narrow focus on physical component failures, operator actions, and technology may lead to ignoring some of the most important factors in terms of preventing future accidents. The study therefore argues that our assumption regarding safety should be modified for effective identification of system faults. Replacing the traditional assumptions regarding safety by the new ones will obviously provide the foundation of a new view of accident causation. Table 2.2 presents the comparison between the traditional assumptions and new assumptions regarding safety.

An assumption of system engineering is that the behavior of each component including events and actions cannot be comprehended without taking into account the role of the components and their interaction within the system as a whole. This basis for systems engineering is based on the principle that any particular system is more than the sum of its parts. It is often proven ineffective to undertake attempts to improve long-term safety of complex systems by investigating and changing the individual components (Rasmussen, 1997).

2.13 Systems Theory, STAMP Model and STPA

The systems approach focuses on the systems taken as a whole, not on the parts being considered separately (Leveson, 2012). It assumes that some properties of the systems can only be treated adequately in their entirety, taking into account all the facets relating the social to the technical aspects (Ramo, 1973). The decompositional analysis cannot identify the causes of accidents including human error, software requirements errors, and system design flaws (Leveson and Thomas, 2018). However, the systems theory treats a system as a whole and not the system components and behavioral events individually. In systems theory terminology, safety is an emergent property that arises by the interaction among the components in a system (Leveson, 2004). This theory treats systems as a hierarchy of organizational levels. Each hierarchical level controls the interaction, behavior and relationships between the next lower level components. The higher levels enforce or impose the safety constraints on the degree of freedom of the behavior of the lower level system components in a system. This concept of constraints is the basis of the accident causation model named Systems Theoretic

Accident Model and Processes (STAMP). It was invented by Professor Nancy Leveson (Leveson, 2004). In STAMP, systems are viewed as interrelated components kept in a state of dynamic equilibrium by feedback control loops (Leveson, 2012). Safety is treated as a dynamic control problem rather than a failure prevention problem (Leveson and Thomas, 2018). There are three basic concepts in STAMP; safety constraints, hierarchical safety control structure and process models (Leveson, 2012).

In STAMP the main concept is not an event, but a constraint. Events leading to losses occur due to the fact that the safety constraints were not imposed effectively (Leveson, 2012). That is the cause of an accident, instead of being explained in terms of a series of events, is viewed as the result of lack of constraints imposed on the system design and on operations, that is, by inadequate enforcement of constraints on the behavior at each level of a socio-technical system (Leveson, 2004). An example of this can be given as: in the operation of an inland ship, one safety constraint is that there must always be a minimum separation distance between any two adjacent ships. Therefore according to the definition given by the STAMP theory, accident (i.e. collision in this case) will occur when this safety constraint is violated.

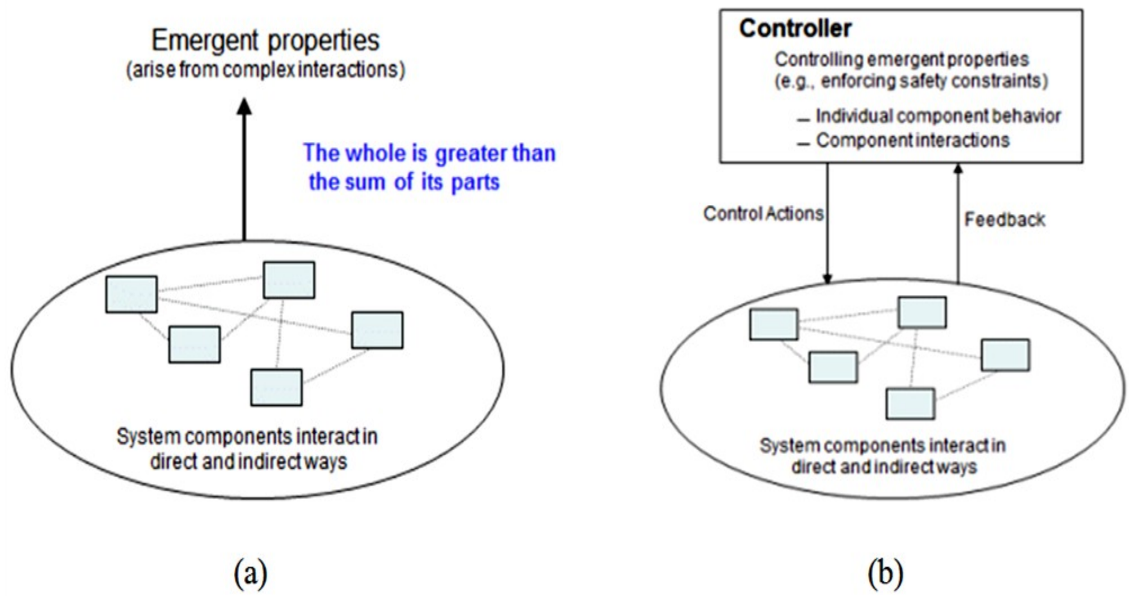


Fig. 2.20: (a) Illustration of emergent properties of a system in the systems theory; (b) Illustration of the feedback control loop of a system in STAMP model, reproduced from Leveson and Thomas (2018).

The STAMP model views a system as being constructed of hierarchical structures. The behavior and activities of any level in a system are controlled by the upper level which imposes some constraints on it. Between the hierarchical levels of each safety control structure, effective communication channels are needed, both a downward reference channel providing the information necessary to impose safety constraints on the level below and an upward measuring channel to provide feedback about how effectively the constraints are being satisfied (Leveson, 2012). The controller uses the feedback for being accustomed to the future control commands to achieve the goals more readily. Therefore a feedback control loop is formed between each level.

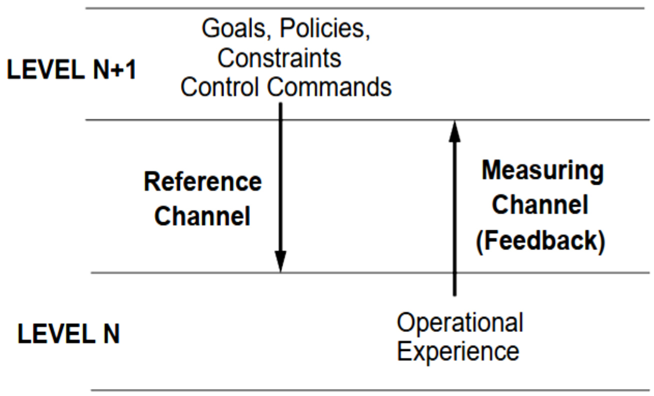


Fig. 2.21: Communication channels between the control levels, reproduced from Leveson (2012).

Accordingly, each component in a system has responsibilities to enforce or follow safety constraints imposed on it by the higher level and together these responsibilities should result in enforcement of overall system safety constraint (Leveson, 2012). At each level of the hierarchical structure, inadequate control may result from missing constraints (unassigned responsibility for safety), inadequate safety control commands, commands that were not executed correctly at a lower level, or inadequately communicated or processed feedback about constraint enforcement. As an example, an operations manager may provide work instructions or procedures to the operators that are unsafe, or the manager may provide correct (safe) instructions but the operators may not follow them properly. The operations manager may not have a proper feedback channel to identify that unsafe instructions are being provided or that his safety-related commands are not being implemented or followed.

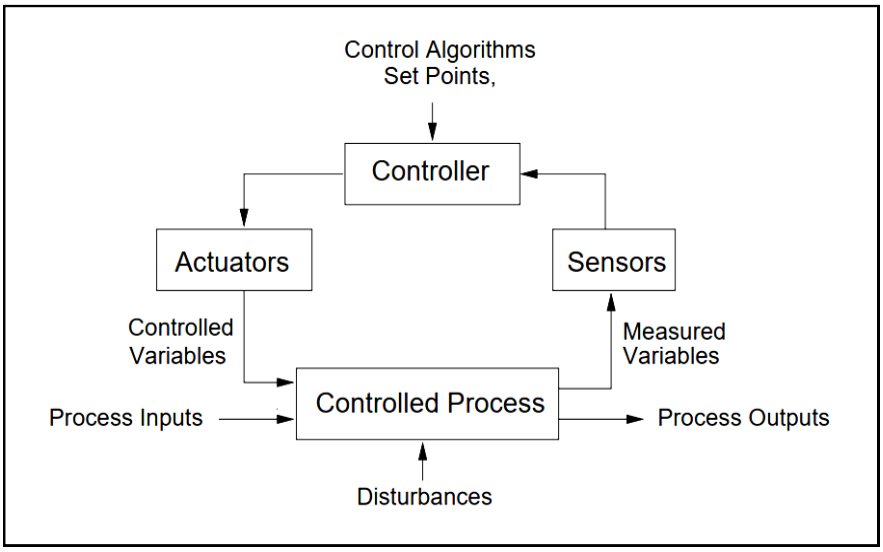


Fig. 2.22: A standard control loop, reproduced from Leveson (2012).

Leveson (2012) states that any controller (human, automated) must have a model of the system or process that they are controlling directly which is called a process model. It is used according to the control algorithm of the controller to maintain the safety constraint. In a human controller, the process model is usually termed as 'mental model'. Whether the model is embedded in the control logic of an automated controller or in the mental model maintained by a human controller, it must contain the same type of information: the required relationship among the system variable (the control laws), the current state (the current values of the system variables), and the ways the process can change state. Accidents can occur when the controller's process model does not match the state of the system being controlled and the controller issues unsafe commands.

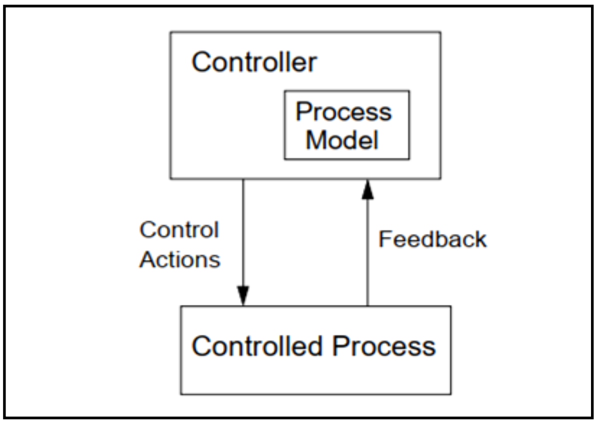


Fig. 2.23: Process model contained within a controller, reproduced from Leveson (2012).

The traditional accident causality models view accidents as being caused by a chain of failure events over time, every event directly leading to cause the subsequent event. On the other hand, the STAMP model views the accident as a result of the violation of safety constraints in a system i.e. ineffectiveness of the controls to enforce the safety constraints (Leveson, 2004). It is also argued that the traditional accident analysis methods often do not analyze the complex causes behind the incidents viz. interaction among human and machines, complex human decision-making and others. In contrast to that, the STAMP model is capable to overcome these limitations by including more complex processes and unsafe interactions among the system components (Leveson, 2012). STAMP works on very complex systems because it works top-down rather than bottom-up (Leveson and Thomas, 2018).

System-Theoretic Process Analysis (STPA) is a hazard analysis technique based on the STAMP accident causality model. STPA is a top-down, system engineering approach to system safety that can be used to generate high-level safety requirements and constraints. The goal of STPA is to identify scenarios leading to identified hazards and thus to losses so that they can be eliminated or controlled.

2.14 Applications of System-Theoretic Process Analysis (STPA)

STPA has been extensively applied to the safety analysis of the spacecraft, aircraft, railway, Offshore Supply Vessel (OSV), chemical plants, automobiles, nuclear and electrical power plants and security of ports, etc. This section presents the major findings of the STPA analysis mainly related to the transportation safety aspect.

Sulaman et al. (2014) applied STPA for the hazard analysis of a safety critical system i.e. the forward collision avoidance system of a vehicle. Based on the findings of the study, it is revealed that STPA is an effective and efficient hazard analysis method for assessing the safety of a safety-critical system from the automotive domain. Ishimatsu et al. (2014) performed STPA hazard analysis on a complex system i.e. Japanese Aerospace Exploration Agency H-II Transfer Vehicle. In a comparison of the results of the STPA method and standard fault tree analysis used in the design and certification of the H-II Transfer Vehicle, it is revealed that STPA found all the hazardous scenarios identified in the fault tree analysis as well as the additional causal factors that had not been identified by fault tree analysis. Besides, STPA can identify possible unsafe interactions among multiple controllers that are caused by conflicting or uncoordinated control actions. It is concluded that the multiple controller problems cannot be captured by the fault tree analysis (Ishimatsu et al., 2014). Dong (2012) applied STPA for an advanced signaling and train control system named Communication based Train Control System in China. The study concludes that STPA is a very comprehensive method for identifying the accident scenarios or loss scenarios.

Williams (2015) conducted a study to apply the STAMP and STPA model for port security. The study concluded that STAMP and STPA model view the security as an emergent complex, socio-technical system property traceable to overarching the port objectives. Therefore, STAMP's broader view of causality and complexity can better address the dynamic and interactive behaviors of social, organizational and technical components of port security (Williams, 2015).

Abrecht and Leveson (2016) conducted a study to analyze the safety of the Offshore Supply Vessels (OSV) that utilizes software-intensive dynamic positioning in support of target vessel escort operations. The analysis assessed the functional relationship between OSV system components that can lead to unsafe control and the violation of existing safety constraints. The results of the analysis show that STPA has identified all of the component failures identified through independently conducted traditional safety analyses of the OSV system. Furthermore, the analysis revealed that STPA finds several additional safety issues that were either not identified or inadequately mitigated through the use of Fault Tree Analysis and Failure Mode and Effect Analysis on this system. It is also discussed that, unlike most other safety analysis techniques, STPA can be used during the concept development stage of system design to design safety into the system from the beginning (Abrecht and Leveson, 2016). Rokseth et al. (2017) applied STPA for hazard identification and assessment of complex automated systems like Dynamic Positioning (DP) systems in the maritime operations. Wrobel et al. (2018) applied the STPA method to analyze the safety of remotely controlled merchant vessel.

Aps et al. (2017) applied STPA to identify system level hazards and potentially unsafe ship speed and maneuvering control actions with respect to Collision Regulations (COLREGs) rules provided by IMO (International Maritime Organization) on the safe speed of ship, safe separation distance among the ships and the traffic separation schemes requirements with the aim of effective hazard control options to enable efficient updating of ship level situation awareness and the enforcement of safety constraints in real-time. The study concludes that STPA has proved to be an effective and efficient method to assess the safety management of a complex safety-critical socio-technical system from the maritime domain. It is also revealed that STPA is an effective novel method to address the dynamic interactions between the integrated human and technical e-navigation components and, in general, are applicable to any navigable sea in the world subject to IMO Collision Regulations (COLREGs) (Aps et al., 2017). Kwon (2016) applied the Causal Analysis based on STAMP or CAST for the analysis of the Sewol-Ho ferry accident in South Korea. The analysis revealed that the systems approach is capable of identifying more causal factors than the traditional approach of accident investigations.

Above discussion shows that STPA is being applied widely in different aspects of applications of science and engineering for successful mitigation of hazards and analysis of accidents to ensure safety. However, this method has not been applied to address the safety issue in the inland water transport of Bangladesh till now. From this perspective, this research is aimed to perform the hazard analysis of inland passenger ship operation in Bangladesh for the first time by applying STPA.

CHAPTER 3

METHODOLOGY

3.1 General

As discussed in the previous chapter, STAMP is a relatively new accident causation model based on systems theory. System-Theoretic Process Analysis (STPA) is the hazard analysis technique based on the STAMP model. This chapter will give a brief overview on the fundamental steps that are needed to perform the hazard analysis based on STPA.

3.2 System-Theoretic Process Analysis (STPA)

STPA (System-Theoretic Process Analysis) is a structured hazard analysis method. To apply the STPA method effectively it is needed to have comprehensive knowledge on the system being considered. Besides, it is also needed to comprehend comprehensively all the steps involved in the analysis.

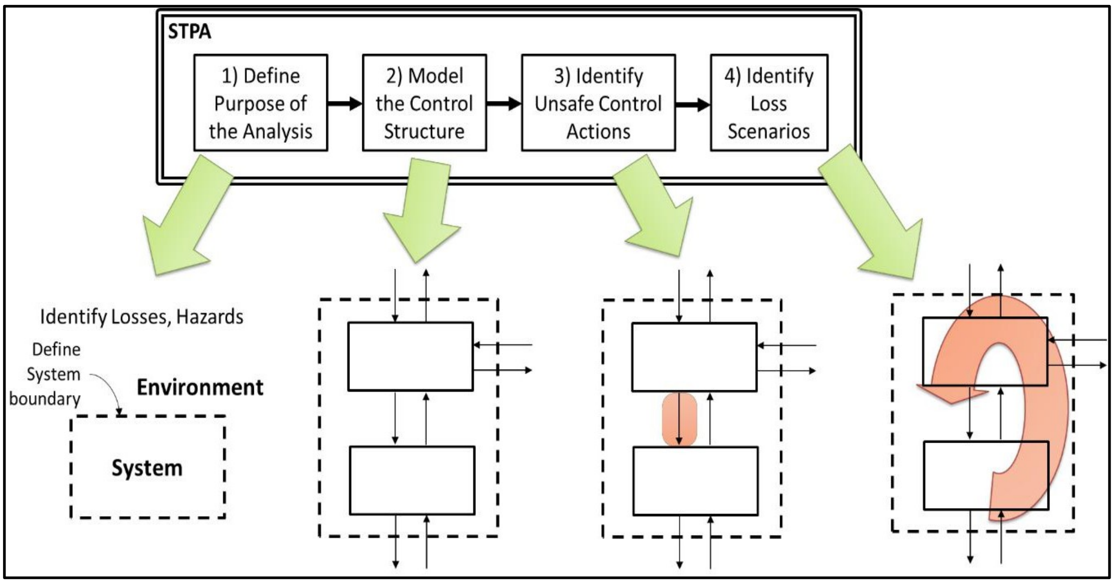


Fig. 3.1: Overview of the STPA method, reproduced from Leveson and Thomas (2018).

There are four basic steps of STPA analysis (Leveson and Thomas, 2018). These are stated below:

i) Define the purpose of the analysis

ii) Model the control structure

iii) Identify Unsafe Control Actions (UCA)

iv) Identify loss scenarios

Figure 3.1 illustrates the overview of the STPA method and figure 3.2 illustrates the steps involved in the STPA method.

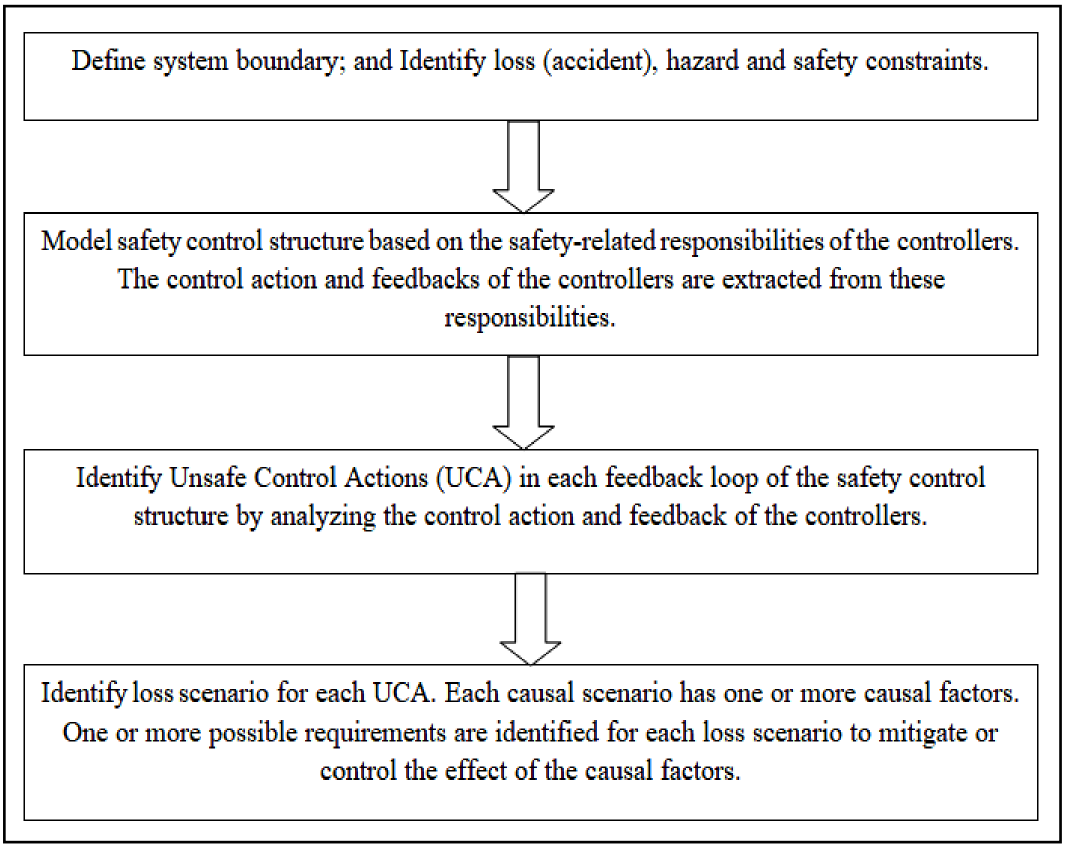


Fig. 3.2: Steps of STPA method.

These steps of STPA are described below.

3.2.1 Define the purpose of the analysis

There are three main parts of defining the purpose of the analysis:

a) Identify losses:

In this part, it is needed to identify the losses that are to be prevented. It involves something of value to the stakeholders. Losses may include a loss of human life or human injury, damage of property, environmental pollution, loss of mission, or any other loss that is unacceptable to the stakeholders (Leveson and Thomas, 2018). An easy way to identify the loss is to translate each value or goal into a loss. Some examples of losses are illustrated below:

L-1: Loss of life

L-2: Damage to the vessel

L-3: Loss of stability of the vessel

b) Identify system-level hazards:

The system-level hazards are needed to be identified in this part. A hazard is a system state or set of conditions that, together with a particular set of worst-case environmental conditions, will lead to a loss (Leveson and Thomas, 2018). Hazards must refer to the factors that can be managed or controlled by system operators and designers. To identify the system-level hazards, at first, it is required to identify the system to be analyzed and the system boundary. A system is a set of components that act together as a whole to achieve some common goal, objective, or end. A system may contain subsystems and may also be part of a larger system.

There are three basic criteria for defining the system-level hazards (Leveson and Thomas, 2018). These are:

- Hazards are system states or conditions (not component-level causes or environmental states).
- Hazards will lead to a loss in some worst-case environmental conditions.
- Hazards should describe the states or conditions to be prevented.

The structure of hazard including an example is shown in Table 3.1.

Table 3.1: The structure of hazard.

Hazard specification =	System	Unsafe Condition	Link to Losses
H-1 =	Ship	violates minimum separation from another ship	[L-1, L-2, L-3]

c) Identify system-level constraints:

After identifying the system-level hazards, it is needed to identify the system-level constraints that must be enforced to prevent the system-level hazards. A system-level constraint specifies system conditions or behaviors that need to be satisfied to prevent hazards and ultimately to prevent the losses

(Leveson and Thomas, 2018). The hazard condition can be inverted to identify the system-level constraints.

The structure of system-level constraints including an example is shown in Table 3.2.

Table 3.2: The structure of system-level constraints.

Safety Constraint =	System	Condition to Enforce	Link to Hazards
SC-1 =	Ship	must not violate minimum separation from other ships or objects.	[H-1]

Besides, constraints can also define how the system must minimize losses in case the hazards do occur (Leveson and Thomas, 2018). For example, if a ship violates the minimum separation then that violation must be detected and measures must be taken to keep the ship safe from collision. This structure of system-level constraints including an example is shown in Table 3.3.

Table 3.3: An alternative structure of system-level constraints.

Safety Constraint =	If hazard occurs,	then what needs to be done to prevent or minimize a loss	Link to Hazards
SC-2=	If the ship violates minimum separation,	then the violation must be detected and measures should be taken to prevent the collision.	[H-1]

3.2.2 Model the control structure

The second step of STPA is to model the hierarchical control structure. A hierarchical control structure is a system model that is composed of feedback control loops (Leveson and Thomas, 2018). An effective control structure will enforce constraints on the behavior of the overall system. One of the major goals of STPA is to analyze the control structure and anticipate how each element might behave in unsafe and potentially unexpected ways.

Leveson and Thomas (2018) state that a hierarchical control structure is composed of control loops like the one shown in figure 3.3. A controller provides control actions to control some process and to enforce a number of constraints on the behavior of the controlled process. The control algorithm represents the controller's decision making process that is used to determine the control actions to provide. The process model is the internal beliefs of the controller that is used to make decisions. It may include the beliefs of the controller about the process being controlled or any other relevant aspects of the system or the surrounding environment. For humans, the process model is usually called a mental model and the control algorithms may be called operating procedures or decision-making rules.

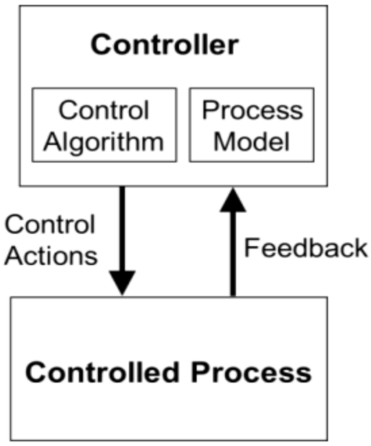


Fig. 3.3: A generic control loop, reproduced from Leveson and Thomas (2018).

Leveson and Thomas (2018) state that a hierarchical control structure usually contains at least five types of elements. These are stated below:

i. Controllers
ii. Control Actions
iii. Feedback
iv. Other inputs to and outputs from components (neither control nor feedback)
v. Controlled processes

After identifying the controllers, system engineers can assign responsibilities to each controller. These responsibilities are a modification of the safety constraints. Control actions for every controller can be defined based on these safety related responsibilities. Feedback should be derived from the control actions and responsibilities by first identifying the process models that controllers will need to make decisions. Then, feedback and other information needed to form accurate process models can be identified (Leveson and Thomas, 2018).

3.2.3 Identify the Unsafe Control Actions (UCA)

After modeling the control structure, the next step is to identify the Unsafe Control Actions. An Unsafe Control Action (UCA) is a control action that, in a particular context and worst-case environment, will lead to a hazard (Leveson and Thomas, 2018). A control action can be unsafe in four ways. These are:

1. Not providing the control action leads to a hazard.
2. Providing the control action leads to a hazard.
3. Providing a potentially safe control action but too late, too early, or in the wrong order.
4. The control action lasts too long or is stopped too soon (for continuous control actions, not discrete ones).

There are three different ways the second type of UCA (Providing the control action leads to a hazard) may occur (Leveson and Thomas, 2018). These are:

a. Consider the contexts in which the control action may never be safe.
b. Consider the contexts in which an insufficient or excessive control action may be unsafe.
c. Consider the contexts in which the direction of the control action may be unsafe.

Every UCA must specify the context in which the control action is unsafe. Any relevant context can be referenced in a UCA, including the environmental conditions, controller states, controlled process states, previous actions, and parameters. Using the words like "while", "when" or "during" in UCA construction is often helpful in developing the context (Leveson and Thomas, 2018). The structure of an Unsafe Control Actions (UCA) including an example is shown in Table 3.4.

Table 3.4: The structure of Unsafe Control Actions (UCA).

Unsafe Control Action=	Controller	Type	Control Action	Context	Link to Hazards
UCA-1=	Master	does not provide	the command for changing course of the ship	when it is needed to avoid contact from any ship ahead.	[H1]

The first part of the UCA is the controller that provides the control action and the second part is the type of unsafe control action (provided, not provided, too early or too late, stopped too soon or applied too long). The third part is the control action or command itself (identified from the control structure). The fourth part is the context discussed above, and the last part is the link to hazards (Leveson and Thomas, 2018).

It is required to define the controller constraints after identifying the Unsafe Control Actions (UCA). A controller constraint specifies the controller behaviors that are needed to be satisfied to prevent the occurrence of Unsafe Control Actions. After identification of UCA, they can be translated into constraints based on the behavior of each controller. In general, each UCA can be inverted to define constraints for each controller (Leveson and Thomas, 2018).

3.2.4 Identify loss scenarios

The last step of STPA is to identify the loss scenarios. A loss scenario describes the causal factors that can lead to the unsafe control actions and to hazards (Leveson and Thomas, 2018).

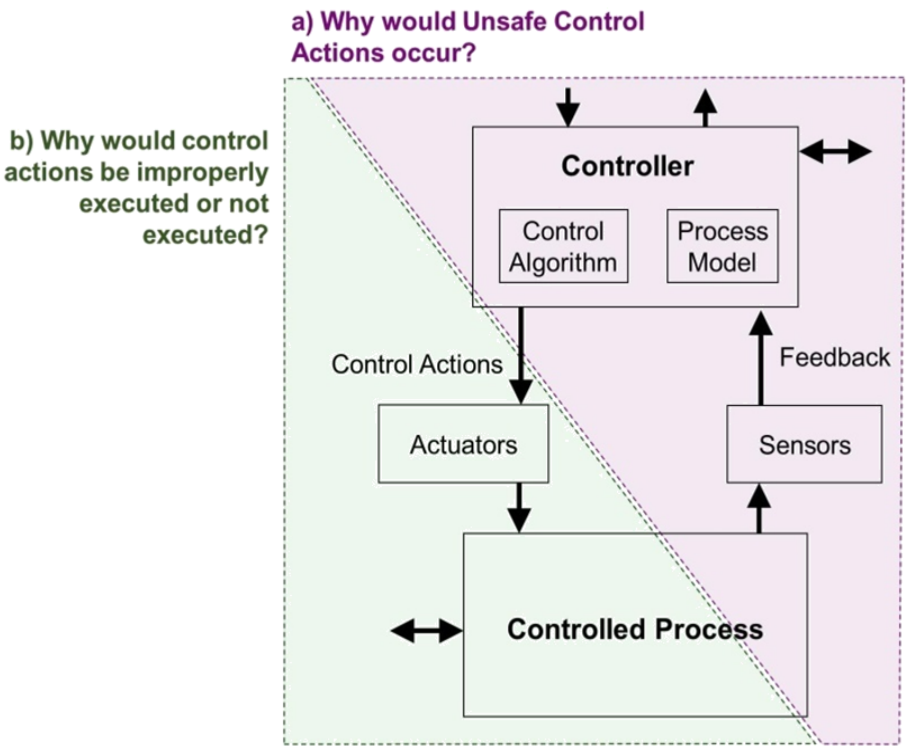


Fig. 3.4: Illustration of two types of scenarios that should be considered during STPA analysis, reproduced from Leveson and Thomas (2018).

There are two types of loss scenarios that should be considered, as shown in figure 3.4. These are:

a) Why would Unsafe Control Actions occur?
b) Why would control actions be improperly executed or not executed, leading to a hazard?
These two types of loss scenarios are described below:

a) Identifying scenarios that lead to Unsafe Control Actions

1. Unsafe Controller Behaviors:

   There are four general reasons for providing an Unsafe Control Actions (UCA) by a controller (Leveson and Thomas, 2018). These are:

   - Failures involving the controller (for physical controllers)
   - Inadequate control algorithm
   - Unsafe control inputs (from other controllers)
   - Inadequate process model

2. Causes of inadequate feedback and information:

   Scenarios related to inadequate feedback and information might involve:

   - Feedback or information not received
   - Inadequate feedback is received

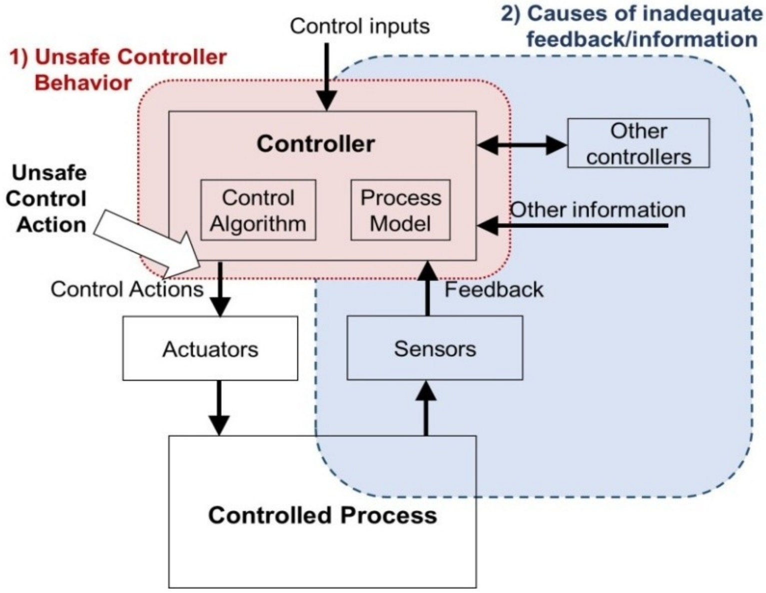


Fig. 3.5: Illustration of scenarios that lead to Unsafe Control Actions, reproduced from Leveson and Thomas (2018).

b) Identifying scenarios in which control actions are improperly executed or not executed

1. Scenarios involving the control path:

   Leveson and Thomas (2018) state that the scenarios involving the control path include:

   - Control action not executed
   - Control action improperly executed

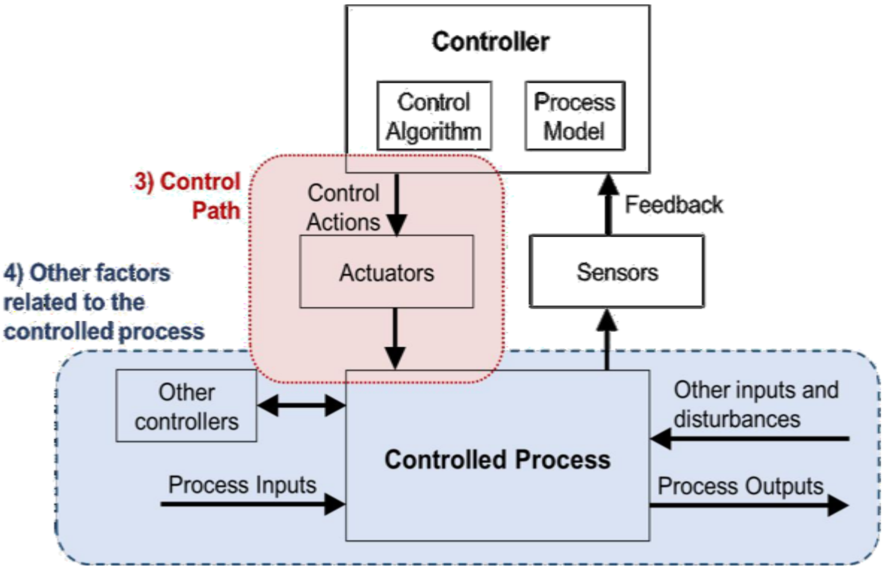


Fig. 3.6: Generic control loop illustrating the scenarios in which the control actions are improperly executed or not executed, reproduced from Leveson and Thomas (2018).

To create these scenarios, at first, a control action should be selected. Then it is needed to identify the factors that can cause improper execution or no eon-execution of the control action. It is also required to identify the way in which the control path could contribute to that behavior (Leveson and Thomas, 2018).

2. Scenarios related to controlled process:

   Similarly, the scenarios involving the controlled process include:

   - Control action not executed
   - Control action improperly executed

To create these scenarios, at first a control action should be selected. Then the factors should be identified that can affect the controlled process to make the control action ineffective (Leveson and Thomas, 2018).

3.3 Model for Human Controller

For human controllers, France (2017) proposed a new model and method to support the creation of robust causal scenarios for the human controllers. The new model is shown in figure 3.7.

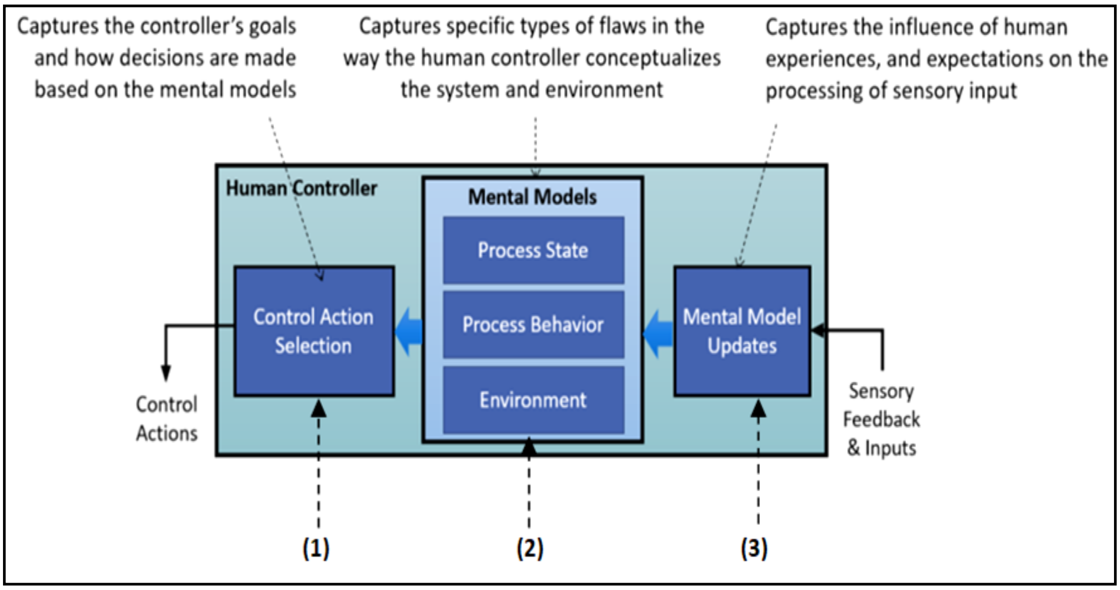


Fig. 3.7: The new engineering for humans model, reproduced from France (2017).

The three numbered components of the model are (1) Control Action Selection, (2) Mental Models, and (3) Mental Model Updates (France, 2017). These three parts correspond to three significant questions that should be considered while creating the causal scenarios for human control actions:

1. How did the operator choose which control action to perform?
2. What does the operator know or believe about the system?
3. How did the operator come to have their current knowledge or beliefs?

Figure 3.8 illustrates the control loop diagram including this new human controller model.

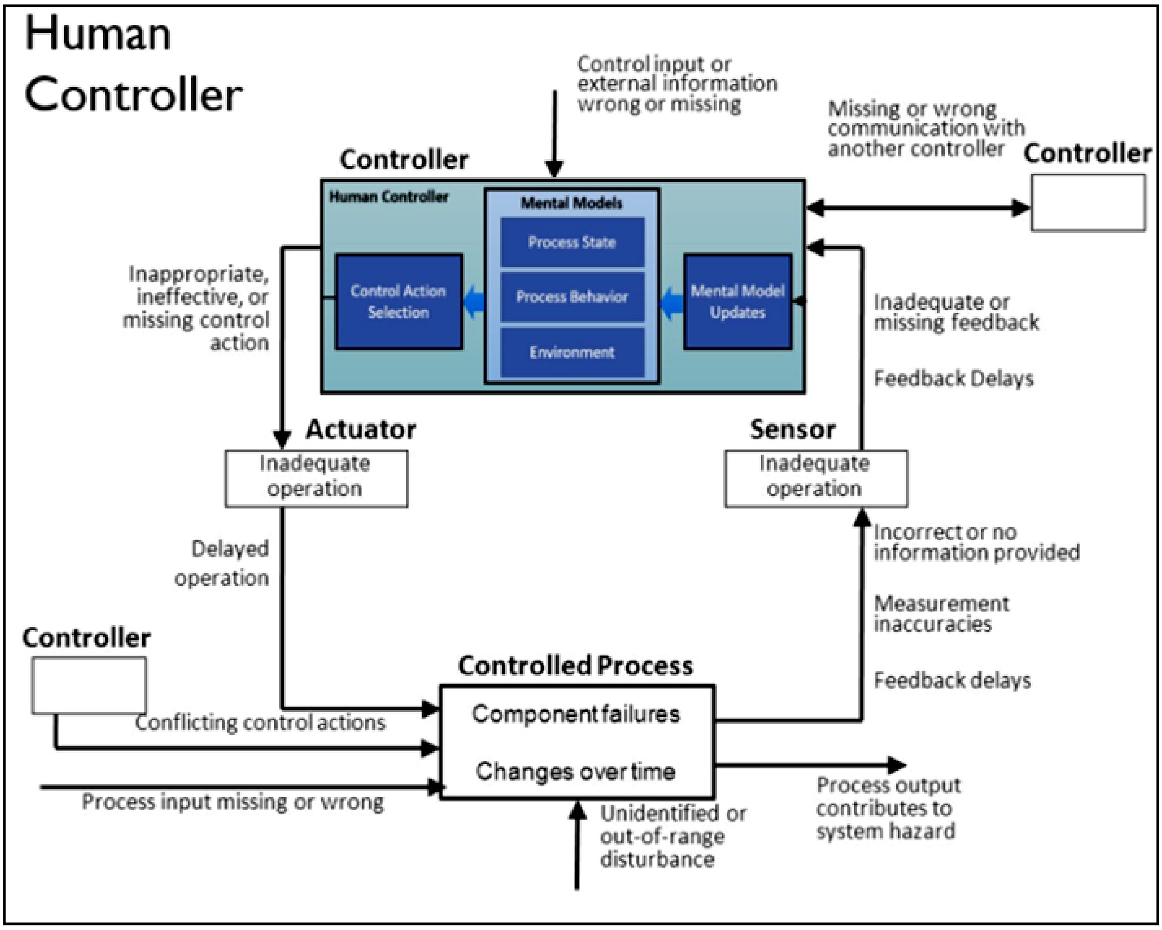


Fig. 3.8: Human controller model in the control loop, reproduced from France (2017).

CHAPTER 4

ANALYSIS

4.1 General

This chapter mainly intends to accomplish the research objectives by performing a statistical analysis of inland water accidents and STPA hazard analysis. Before performing such analysis, the drawbacks of current maritime accident data collection and record-keeping system of Bangladesh will be discussed. The statistical analysis is performed to reveal the contemporary scenario of safety of inland passenger ship operation in Bangladesh. This will reveal the devastating characteristics of passenger vessel accidents in the inland waterways of Bangladesh. It is to be mentioned here that, a statistical analysis is not a pre-requisite to perform the STPA analysis. However, a number of important conclusions can be drawn from the statistical analysis that are helpful to demonstrate the steps of the STPA analysis for safety of inland passenger ship operation in Bangladesh.

4.2 Drawbacks of Maritime Accident Data Collection System in Bangladesh

It has been already mentioned that one of the major limitations of carrying out research on the maritime safety of Bangladesh is the absence of a proper maritime accident data. Due to this drawback, the researchers are unable to conduct in-depth scientific analysis related to the maritime safety of Bangladesh. The Department of Shipping and Bangladesh Inland Water Transport Authority (BIWTA) are the only reliable organizations of Bangladesh to record the data related to maritime accidents. Therefore, the accident data were collected from these two organizations. However, it has been found that the Department of Shipping does not maintain a database for record-keeping of the accident data. The accident data are recorded in a register book where only 10 parameters are listed (Appendix-A). The accident data of all types of vessels are recorded by the Department of Shipping. Besides, in some cases it has been found that a number of parameters of many accidents are missing i.e. not recorded at all. As a result, it is not possible to perform a comprehensive statistical analysis due to this inadequate data in this study. The parameters that are listed in the record book of Department of Shipping are listed below:

i) Date and time of accident
ii) Location of accident
iii) Name of the vessel
iv) Cause of accident
v) Damages due to accident
vi) No. of people died
vii) No. of injured people
viii) No. of missing people
ix) Members of the Maritime Accident Investigation Committee
x) Date of receiving the reports of the Maritime Accident Investigation Committee

The format of record-keeping of accident data by the BIWTA is somewhat different from the Department of Shipping (Appendix-B). The accident data of passenger launches are recorded by this organization. The parameters listed by the BIWTA include:

i) Name and registration number of Launch
ii) Name and address of Launch owner along with the company
iii) Date and time of accident
iv) Dimensions of the launch
v) Cause of the accident
vi) Accident location
vii) Damages due to the accident
viii) No. of people died
ix) No. of injured people
x) No. of missing people
xi) Comments

From the above discussion, it can be said that the current practice of accident record-keeping system needs to be modified. A standard database containing a number of additional accident parameters should be maintained immediately. It will enable a detailed analysis of maritime accidents to reveal the characteristics of the accidents.

Therefore, a typical database structure is developed consisting of 29 different parameters which are grouped in 6 main categories. It is recommended that the Department of Shipping and BIWTA should maintain this database. The database structure is shown in figure 4.1.

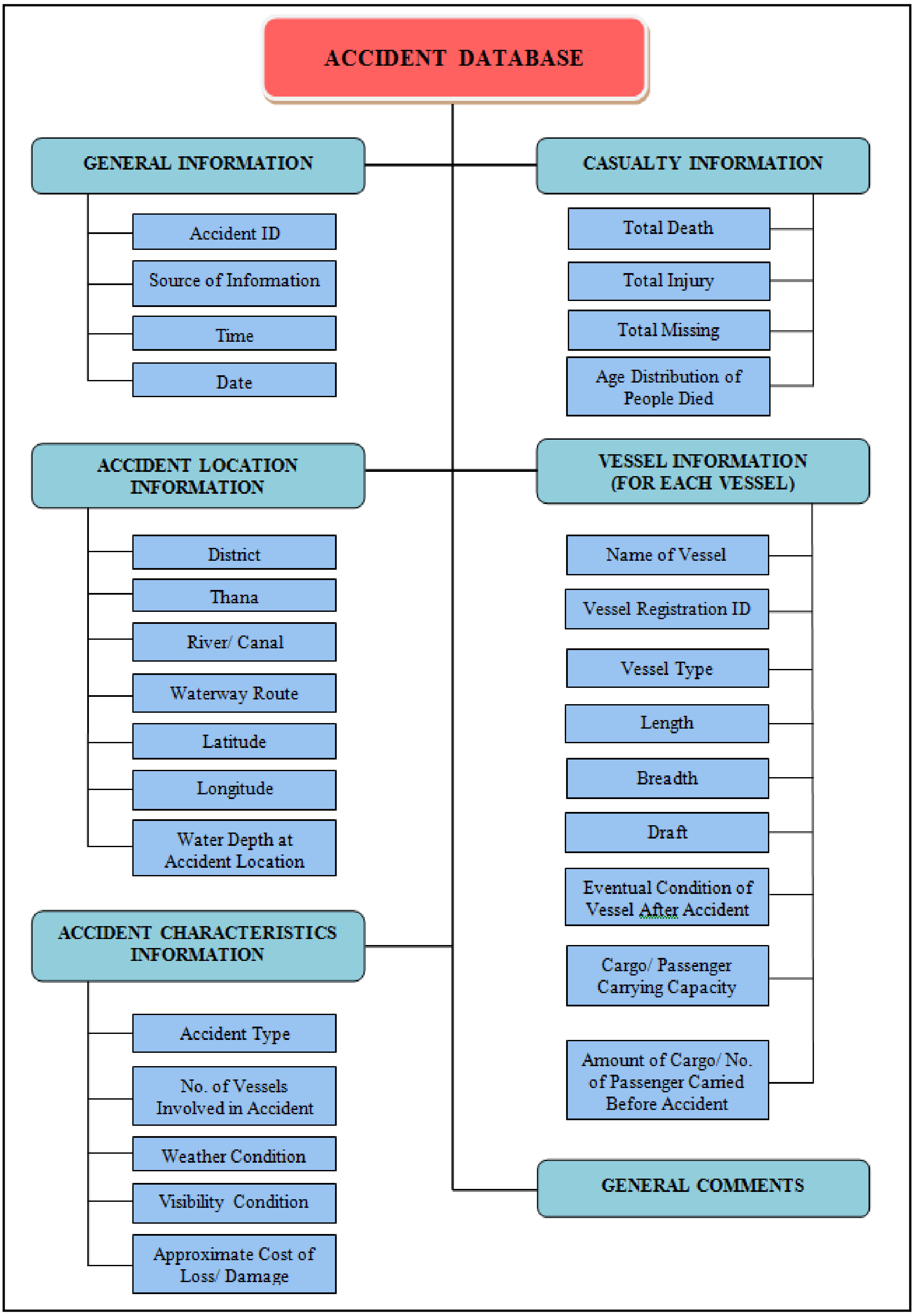


Fig. 4.1: Database structure.

4.3 Statistical Analysis

This section presents the statistical analysis of the accidents involving the passenger vessels in the inland waterways of Bangladesh. Accident data is collected from the Department of Shipping and Bangladesh Inland Water Transport Authority (BIWTA). Passenger vessel accidents from 2005 to 2017 were taken into consideration for the analysis. The types of accident, location of the accident, number of fatalities involved, types of the vessel involved etc. are analyzed to reveal the contemporary scenario of passenger vessel safety.

The year-wise distribution of overall accidents and passenger vessel accidents are represented in figure 4.2. It is seen that the trend of both type accidents resembles almost similar pattern. In addition, there remains almost the same gap between the curves. This gap represents the accidents involving the other types of vessels except the passenger vessels. An interesting fact about the curve is that it is somewhat similar to sinusoidal shape. It needs further extensive research to reveal the facts behind the nature of this curve. Besides, during the years 2009 and 2010, the number of accidents is higher than in any other years.

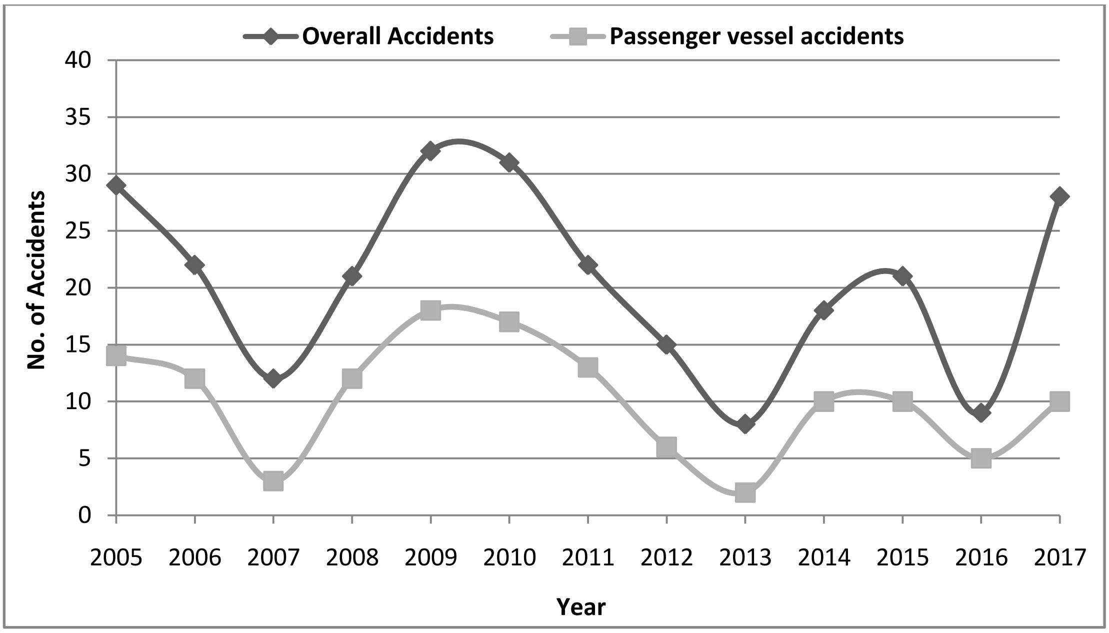


Fig. 4.2: Comparison of year-wise distribution of overall accidents and passenger vessel accidents.

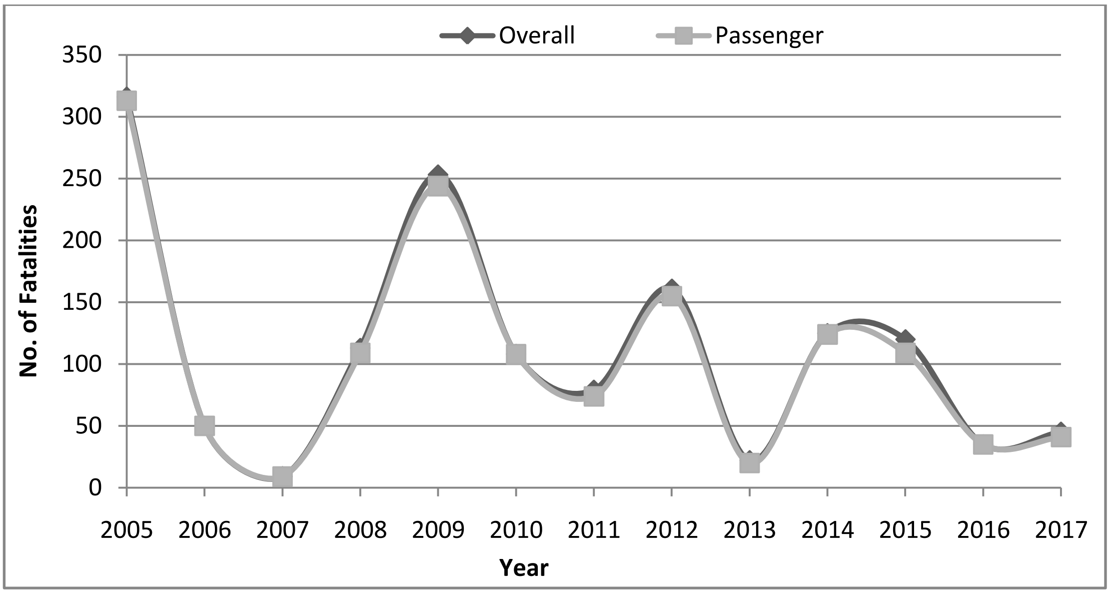


Fig. 4.3: Comparison of year-wise distribution of fatalities involving overall accidents and passenger vessel accidents.

From figure 4.3 it is observed that the number of fatalities involving overall accidents and passenger vessel accidents almost coincides with each other during the period 2005 to 2017. It indicates the devastating consequence of passenger vessel accidents in Bangladesh. It is therefore high time to take immediate action against this curse through the scientific approach.

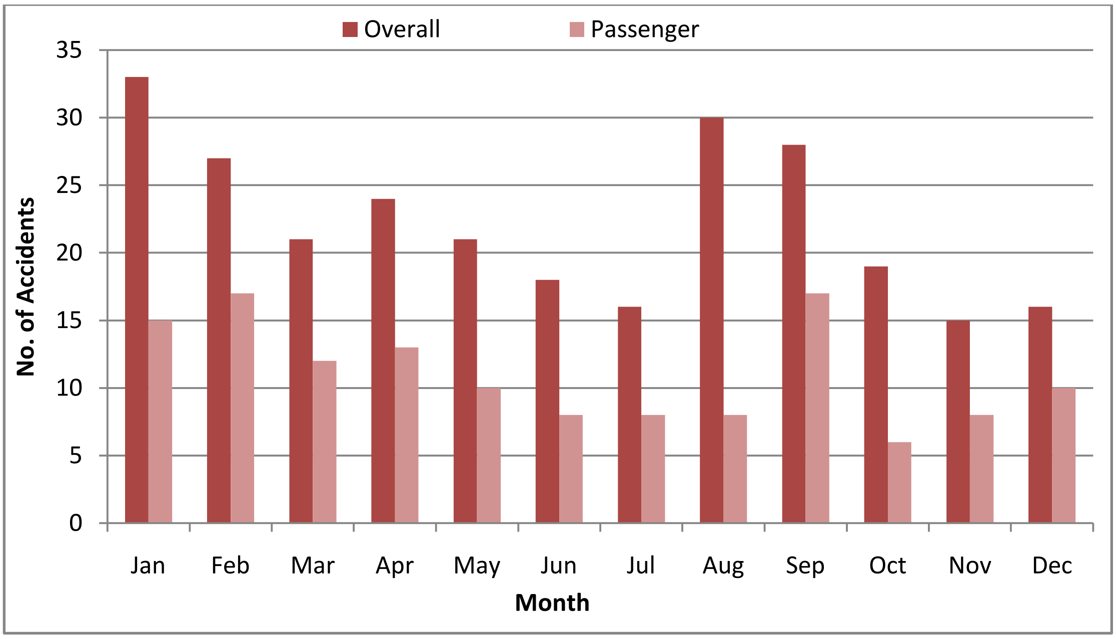


Fig. 4.4: Comparison of month-wise distribution of overall accidents and passenger vessel accidents.

Figure 4.4 illustrates the comparison of the month-wise distribution of accidents between overall accidents and passenger vessel accidents. It is observed that the number of passenger vessel accident in each of the month is nearly half of the number of overall accidents. Besides, it is observed from figure 4.5 that, the number of fatalities involving the passenger vessel accidents in each of the months is nearly equal to the number of fatalities involved with overall accidents. It indicates the severe consequence of passenger vessel accidents in Bangladesh. The number of fatalities is comparatively higher during the months of February, March, April and May. During February, the foggy weather may cause such a high percentage of accidents and fatality. However, during the months of March, April and May the reason behind the high proportion of fatality is mainly due to the effect of Nor'wester.

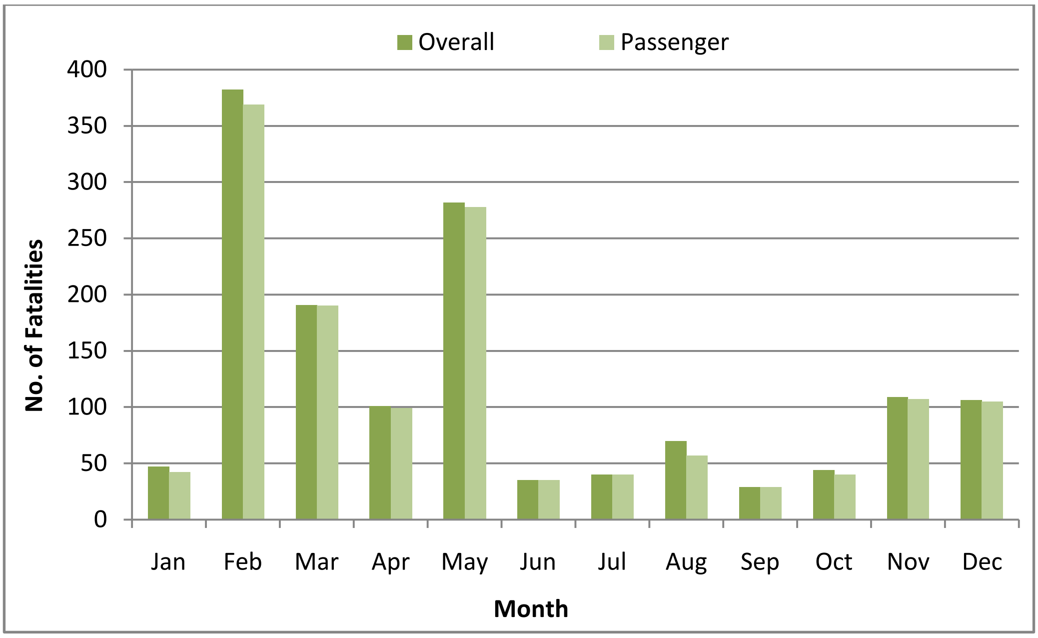


Fig. 4.5: Comparison of month-wise distribution of fatalities involving overall accidents and passenger vessel accidents.

The district-wise distribution of the number of accidents involving the passenger vessels is illustrated in figure 4.6. It is found that most of the accidents occur in the districts namely Barisal, Chandpur, Munshiganj, Shariatpur, Patuakhali. Apart from these districts, Dhaka and Narayanganj districts are also noteworthy for the occurrence of accidents. These two districts fall within the renowned route of Dhaka to Barisal that connects the Capital city Dhaka with the southern part of the country. Therefore, it can be said that most of the accidents occur in the waterway zone of the districts located in the southern zone of the country. This is due to the fact that the main mode of transportation in the southern part of the country is mainly inland water transport. In the northern part of the country, the waterway is not so popular.

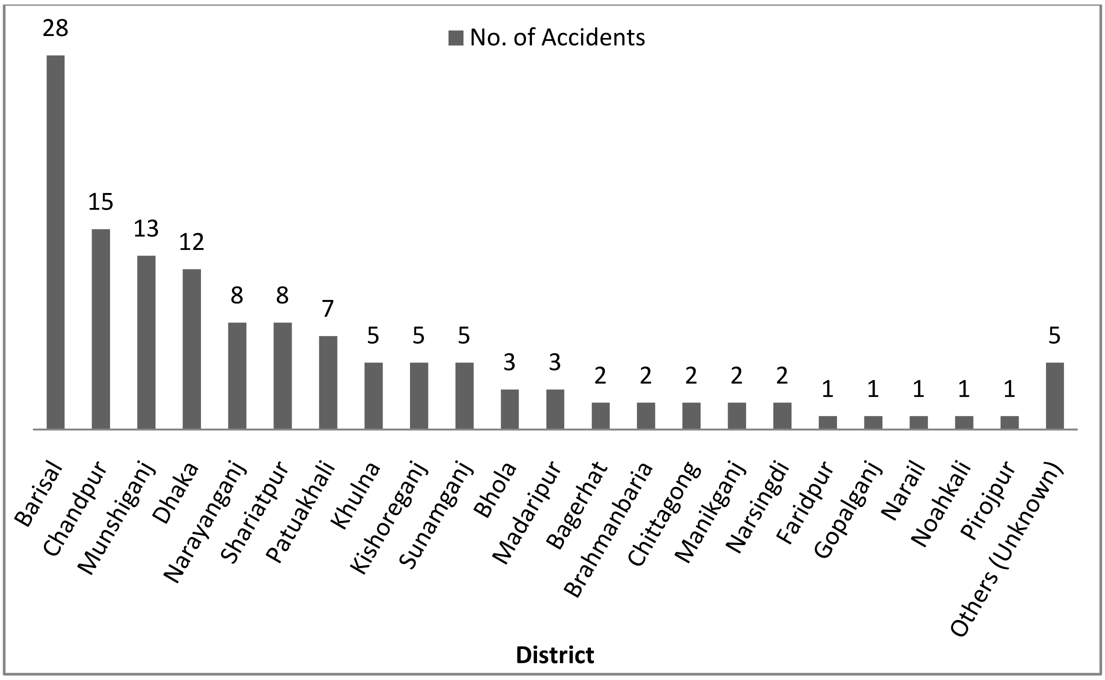


Fig. 4.6: District-wise distribution of number of accidents involving the passenger vessels.

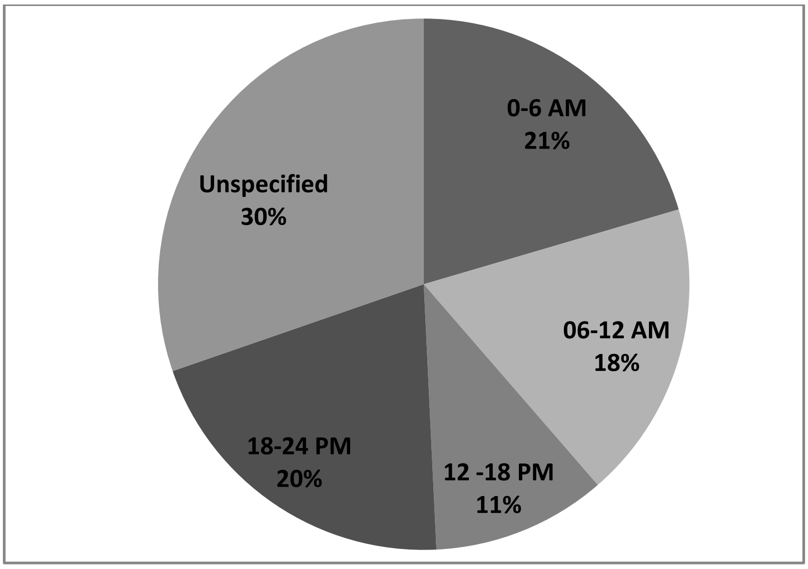


Fig. 4.7: Distribution of passenger vessel accidents on the basis of time.

The distribution of passenger vessel accidents on the basis of time is illustrated in figure 4.7. It is observed that most of the accidents occur during the time range of 0-6 AM and

18-24 PM. During the time range 6-12 AM and 12-18 PM, the number of accidents is comparatively lower. That is the number of passenger vessel accidents occurs mostly during the day time. One of the most important facts is that in 30% cases the time of the accident has been found as not reported in the accident reports. It indicates that the level of accident investigation and reporting is poor in Bangladesh.

The comparison of the number of accidents and casualties between overall accidents and passenger vessel accidents is illustrated in figure 4.8. Although the number of accidents involving the passenger vessels is about half the total number of accidents, the casualty is nearly equal to the overall accidents. That is, the number of fatality, injury and missing due to the accidents of passenger vessels are almost equal to the numbers of the overall accidents. A noteworthy fact is that the people who are reported as missing are usually not found alive later on. Therefore, in the actual term, they can be considered as dead. Considering this fact, the number of overall fatalities is higher than the reported number. Therefore, the mitigation of the passenger vessel accidents can significantly reduce the major proportion of fatalities involved in inland water transport accidents of Bangladesh.

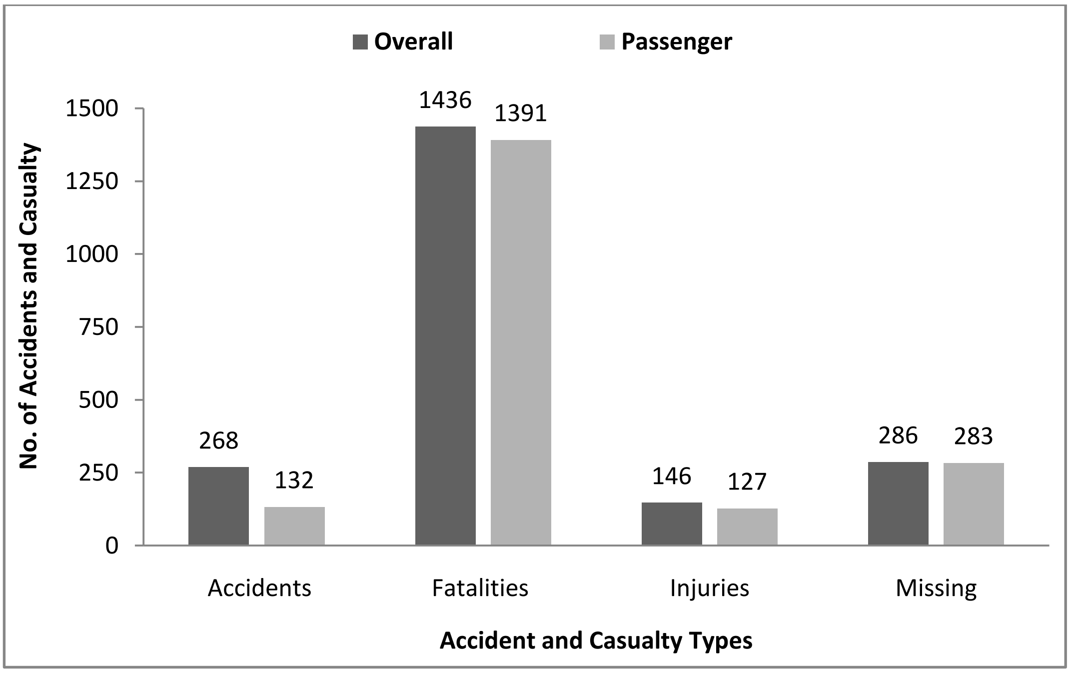


Fig. 4.8: Comparison of number of accidents and casualties between overall accidents and passenger vessel accidents.

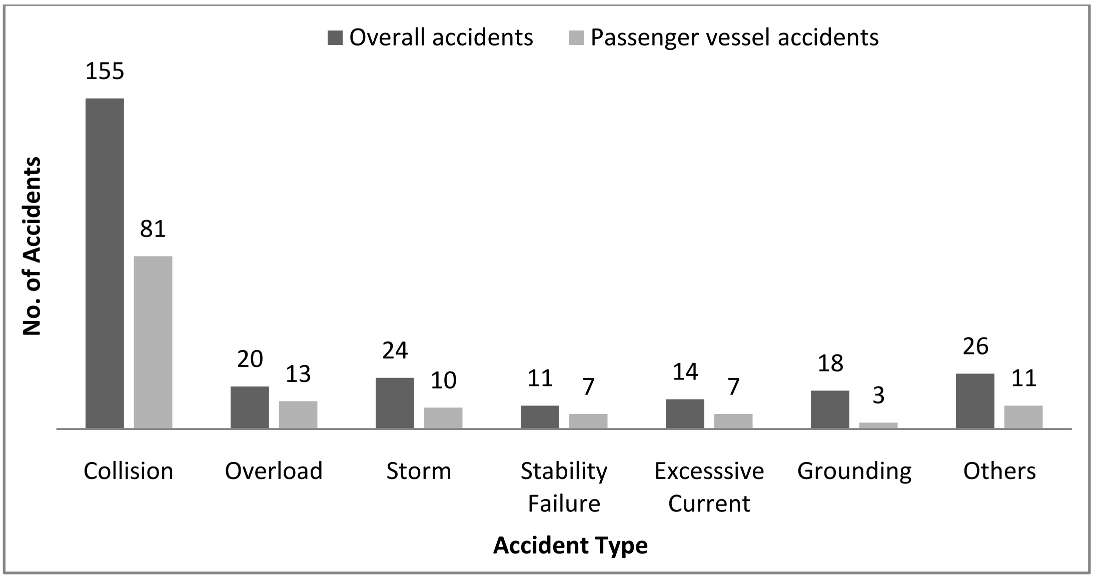


Fig. 4.9: Comparison of accidents on the basis of accident types between Overall accidents and passenger vessel accidents.

Figure 4.9 presents the distribution of accidents on the basis of accident types. It is seen that collision is the leading cause of the accident in the inland waterways of Bangladesh. Therefore, it can be said that mitigation of collision accidents will significantly reduce the number of overall accidents. Furthermore, the involvement of passenger vessels in the collision is also noteworthy. Apart from the collision, the other accident types are overload, storm, stability failure, excessive current, grounding, and others.

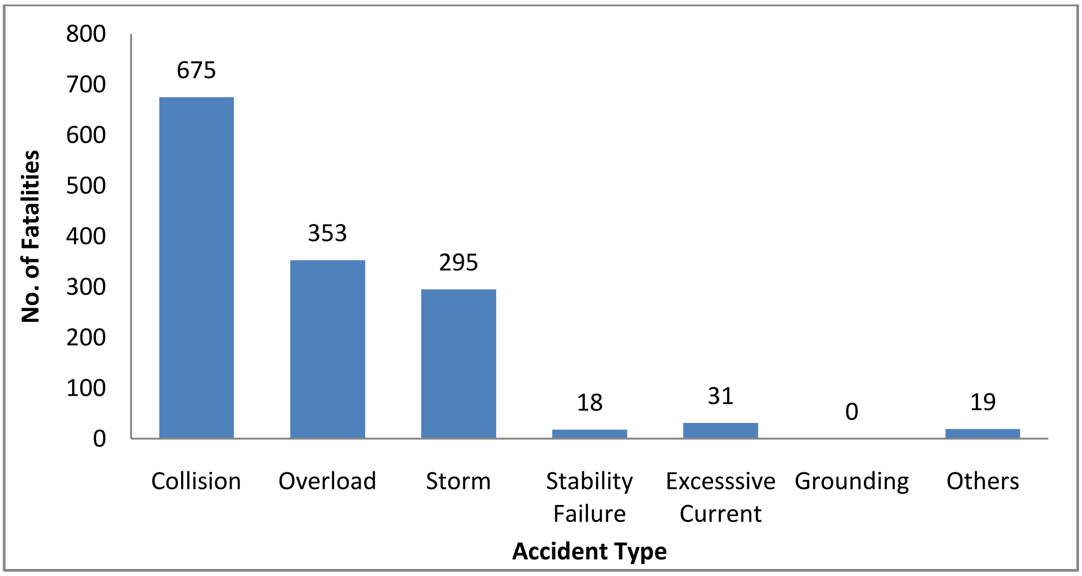


Fig. 4.10: Distribution of fatalities involved in passenger vessel accidents on the basis of accident types.

Figure 4.10 presents the distribution of fatalities involved in passenger vessel accidents on the basis of accident types. It is observed that due to the collision, most of the fatalities involved in the passenger vessel accidents occur. The accident types namely overload and storm also contribute to the significant number of fatalities. Stability failure, excessive current and other accident types cause less number of fatalities involved in passenger vessel accidents.

The fatality per accident factors on the basis of accident types for passenger vessel accidents and overall accidents is illustrated in figure 4.11. It is observed that in case of passenger vessel accidents, the fatality per accident ratio is higher than the overall accidents. This ratio is considerably higher in case of accidents due to overload and storm. The main reason behind such high ratio is that the vessels are foundered after the accident. In addition to that, there is no proper search and rescue operation for the vessels those experience accident. There is also no provision for keeping life jackets in the Inland Shipping Ordinance of Bangladesh, 1976.

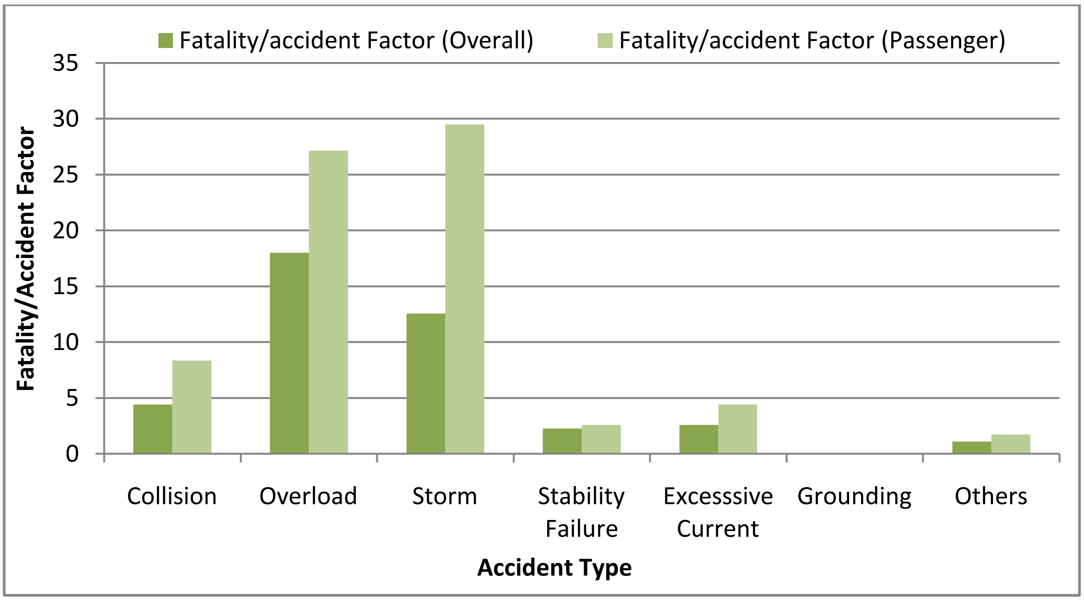


Fig. 4.11: Comparison of fatality per accident factor on the basis of accident type between overall accidents and passenger vessel accidents.

Figure 4.12 illustrates the distribution of types of passenger vessels involved in the accidents. Passenger launch is found to have the highest percentage (56%) of involvement in the accident. The main reason behind such a high percentage is that most of the passenger prefers to move by the passenger launches. Passenger trawler also shares a significant percentage (28%) of accidents in the inland waterways of

Bangladesh. Apart from these, passenger carrying country boats, passenger ferry, passenger steamers and other types of vessels experience the accidents.

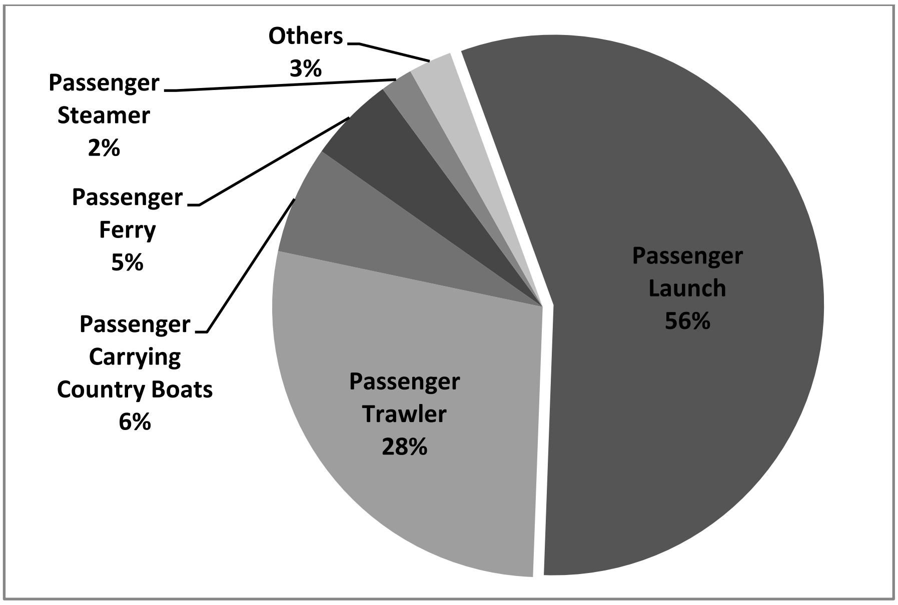


Fig. 4.12: Percentage of types of passenger vessels involved in accident.

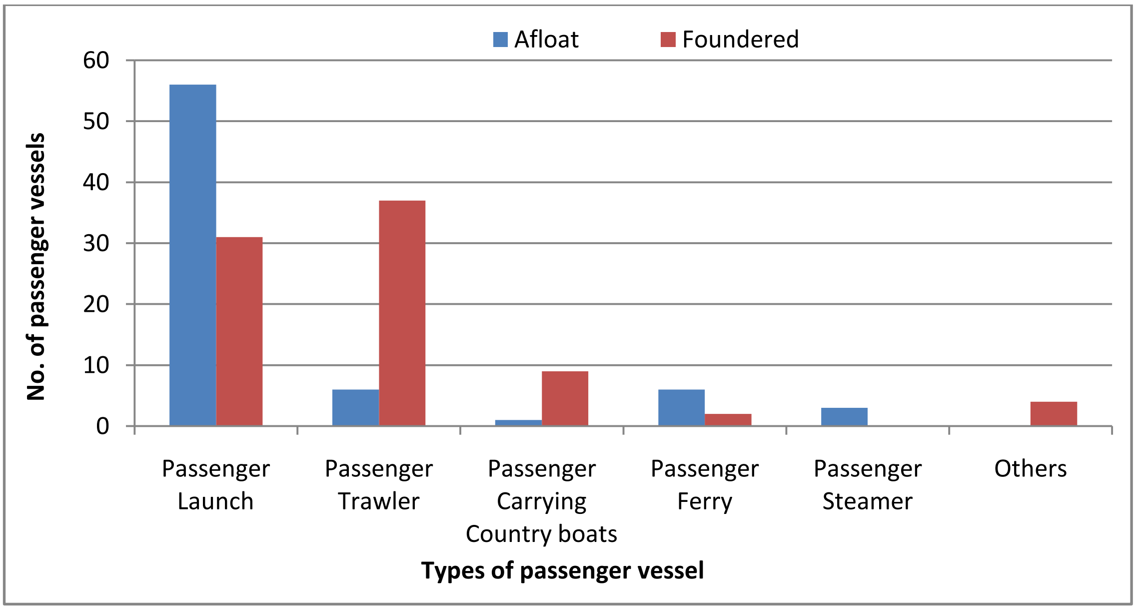


Fig. 4.13: Distribution of ultimate fate of passenger vessels on the basis of types of passenger vessel.

Figure 4.13 illustrates the distribution of ultimate fate of passenger vessels according to the vessel types. The number of foundered passenger launch is approximately half than the number of launches that remain afloat after the accident. In case of passenger trawler, the number of foundered is six times higher than the number of afloat ones.

Similarly, the number of foundered country boats is significantly higher than the number of afloat ones. However, the foundering ratios of passenger ferries, steamers and other vessel types are not so alarming. Therefore, in terms of ultimate fate after the accident, passenger trawlers and country boats are more vulnerable than other types of passenger vessels. The main reasons behind such a high risk of foundering are lack of stability due to improper design, unskilled operators, overloading, undisciplined movement etc.

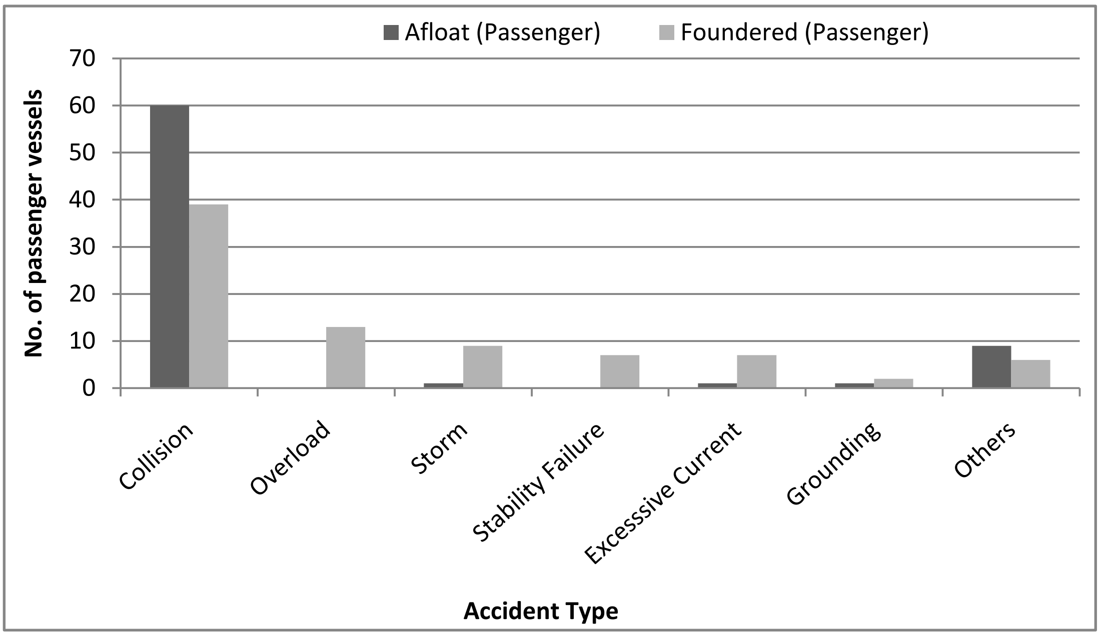


Fig. 4.14: Distribution of ultimate fate of passenger vessels on the basis of accident types.

The distribution of the ultimate fate of passenger vessels according to accident types are illustrated in figure 4.14. It is observed that after collision the number of vessels remaining afloat is greater than the number of the foundered vessels. Accident due to the collision occurs between two or more vessels and the vessel which is hit badly is foundered in general. In some cases, when the collision is not severe, both the vessel may remain afloat. Therefore the number of vessels remaining afloat is greater than the number of foundered vessels. However, accidents due to overload, storm, stability failure, excessive current, grounding have higher proportions of the foundered vessel than the afloat vessels.

The distribution of fatalities on the basis of different types of passenger vessels that are foundered is illustrated in figure 4.15. It is found that the passenger launch is the most vulnerable type of passenger vessel in Bangladesh. In many times it has been observed that, the accident of a single passenger launch caused the loss of several hundreds of human lives that shocked the whole world. Following the passenger launch, the passenger trawler is the second most contributing type of vessel for fatalities. This type of passenger carrying watercraft is mainly designed for traveling a short distance. Almost every trawler is mechanized as each of them has an engine. But as it has no proper navigational equipment and the operators are not well trained, so the risk of an accident is significantly higher. The passenger carrying country boats are of two types, e.g. mechanized and non-mechanized. These boats are mainly used for crossing the river and traveling for a very short distance. Due to lack of proper maneuvering equipment, the boats sometimes face accidents with the larger vessels and trawlers. Passenger ferry, steamers and other types of vessels are not significant in terms of causing fatality.

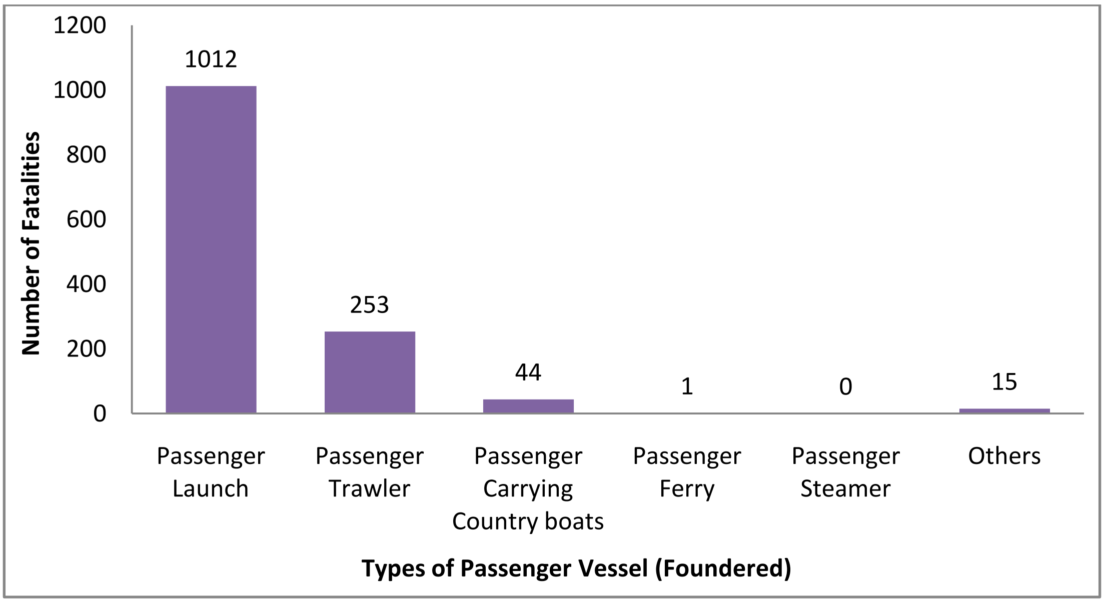


Fig. 4.15: Distribution of fatalities on the basis of types of passenger vessels that are foundered.

During the analysis, it has been found that after 2015 there has been no occurrence of any disastrous passenger launch accident in the inland waterways of Bangladesh. Based on this fact, it can be said that the safety scenario has improved than in previous times. However, without improving the system safety it cannot be assured that the accident will not happen. Therefore, our focus should be on further improving safety from the present situation.

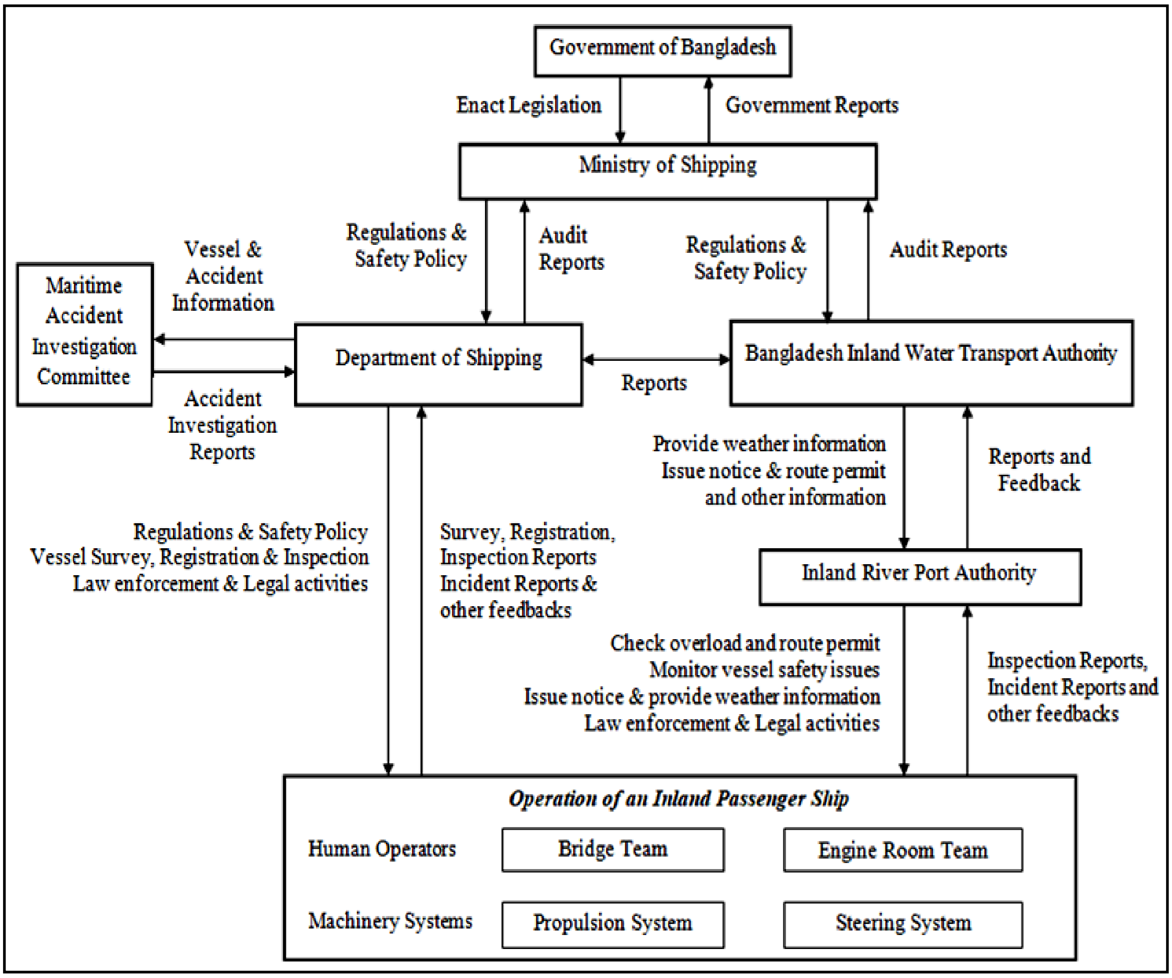


Fig. 4.16: Organizational safety control structure of inland passenger vessel operation in Bangladesh.

4.4 Hazard Analysis by STPA Method

This section presents the hazard analysis of inland passenger ship operation in Bangladesh by the STPA (System-Theoretic Process Analysis) method. The generic organizational safety control structure of the operation of an inland passenger ship of Bangladesh is illustrated below in figure 4.16. This structure is modeled by taking into account the safety-related responsibilities. The Ministry of shipping regulates safety policies as enacted by the Government of Bangladesh. The Department of Shipping regulates the major legal aspects (i.e. vessel survey, registration, law enforcement, marine court etc.) and conducts the accident investigation. On the other hand, Bangladesh Inland Water Transport Authority (BIWTA) handles the operational and maintenance related issues i.e. issue river notice and weather information, grant route permit, check loading condition of the ship, monitor safety issues, maintain sufficient navigability of the waterway route and minor legal issues etc. These functions are conducted through the inland river port authorities of all river ports. In this way, the safety of the operation of an inland passenger ship is ensured by this organizational structure. The STPA method is capable of identifying the Unsafe Control Actions (UCA) at the organizational level by analyzing this organizational safety control structure. However, the focus of this analysis does not delve into the identification of unsafe control actions at the organizational level. Rather, the objective is only focused on the operation of the inland passenger ship in Bangladesh.

The STPA hazard analysis of this study is mainly involved in the operation of the inland passenger vessel. The system considered here is the passenger vessel. However, the safety of the passenger vessel is also related to other external factors. For example, the unsafe operation of other types of vessels may be a threat to the safe operation of the passenger vessels. Because, a passenger vessel may follow all rules and guidelines to move safely; however, the unsafe operation by a sand carrying cargo vessel may pose risk on it. The cargo vessel may not operate by following the rules and regulations properly. As a result, it may collide with the passenger vessel. Besides, some aspects of the waterway route may also be the source of risk for the passenger vessel. These may include lack of adequate navigational aids, lack of navigability, and absence of adequate shelter zone (a specific zone designed for staying a vessel during inclement weather) on the waterway route. Making a waterway safe from these external factors is the responsibility of the relevant government organization i.e. Ministry of Shipping of Bangladesh. Therefore, for ensuring the safe operation of the inland passenger vessel, all the factors related to the operation of the other types of vessels and waterway routes should be taken into consideration.

It has been already mentioned that the passenger vessel accidents share the major proportion of fatality of the overall maritime accidents in Bangladesh. Therefore, the mitigation of passenger vessel accidents will significantly reduce the death toll due to the accidents in the inland waterways. Among the passenger vessels, the passenger launch is most popular among the people of Bangladesh. Usually, a passenger launch travels in the long-route and is designed to carry a higher number of passengers than other types of passenger vessels in Bangladesh. The most important fact is that, in most of the accidents of the passenger vessels where a significant number of passengers died in each of the accident, the passenger launches are found to be the most contributing type of vessel. Moreover, most of the accidents of the passenger vessels are caused by the passenger launch. Considering these issues, a passenger launch is considered for the STPA analysis.

There are mainly 5 classes of inland vessels in Bangladesh. Among those classes, the 1st class vessels are the inland passenger vessels having a minimum load water line length of 20 meter. These vessels are permitted to move in the inland routes during the day and night time.

Table 4.1: Minimum safe number of operators inside the inland passenger vessel.

Designation of operators inside the passenger ship	**Minimum safe number of operators**
1st Class Master	1
2nd Class Master	1
Crew	8
Inland Marine Engineer	1
1st Class Driver	1
Greaser	3

The number of minimum safe number of operators inside an inland passenger vessel based on the engine power is defined in the Inland Shipping Rules of Bangladesh, 2001 [Zulfikar, 2005]. A 1st class inland passenger vessel having the registered engine power of 1120kw and above is considered for the STPA analysis. The minimum safe number of operators inside this type of inland passenger vessel is shown in Table 4.1.

Table 4.2 shows the designation of operators inside the ship for an ideal case against the operators based on the Inland Shipping Rules, 2001 of Bangladesh. For the simplicity of STPA hazard analysis, the designation of operators inside the ship for an ideal case is considered here.

Table 4.2: Designation of operators inside passenger vessel

Designation of the operators inside vessel based on Inland Shipping Rules, 2001 of Bangladesh	**Designation of the operators inside vessel for an Ideal Case**
1st Class Master	Master
2nd Class Master	OOW
Crew (only one)	Helmsman
Crew (others)	Crew
Inland Marine Engineer	Inland Marine Engineer
1st Class Driver	Driver
Greaser	Greaser

In order to apply the STPA method, the operation of an inland passenger ship i.e. passenger launch is considered for the following phases:

I. Passenger ship safety during the stay at inland river terminal.

II. Passenger ship safety during the voyage.

This phase has the following sub-phases:

a) Master acting as the conning officer
b) Officer Of the Watch (OOW) acting as the conning officer
c) Anchoring operation of the ship
d) Anchored condition of the ship
e) Pilot acting as the conning officer
f) Mooring or unmooring operation of the ship

These two phases are briefly illustrated in figure 4.17.

These two phases are analyzed by the STPA method below:

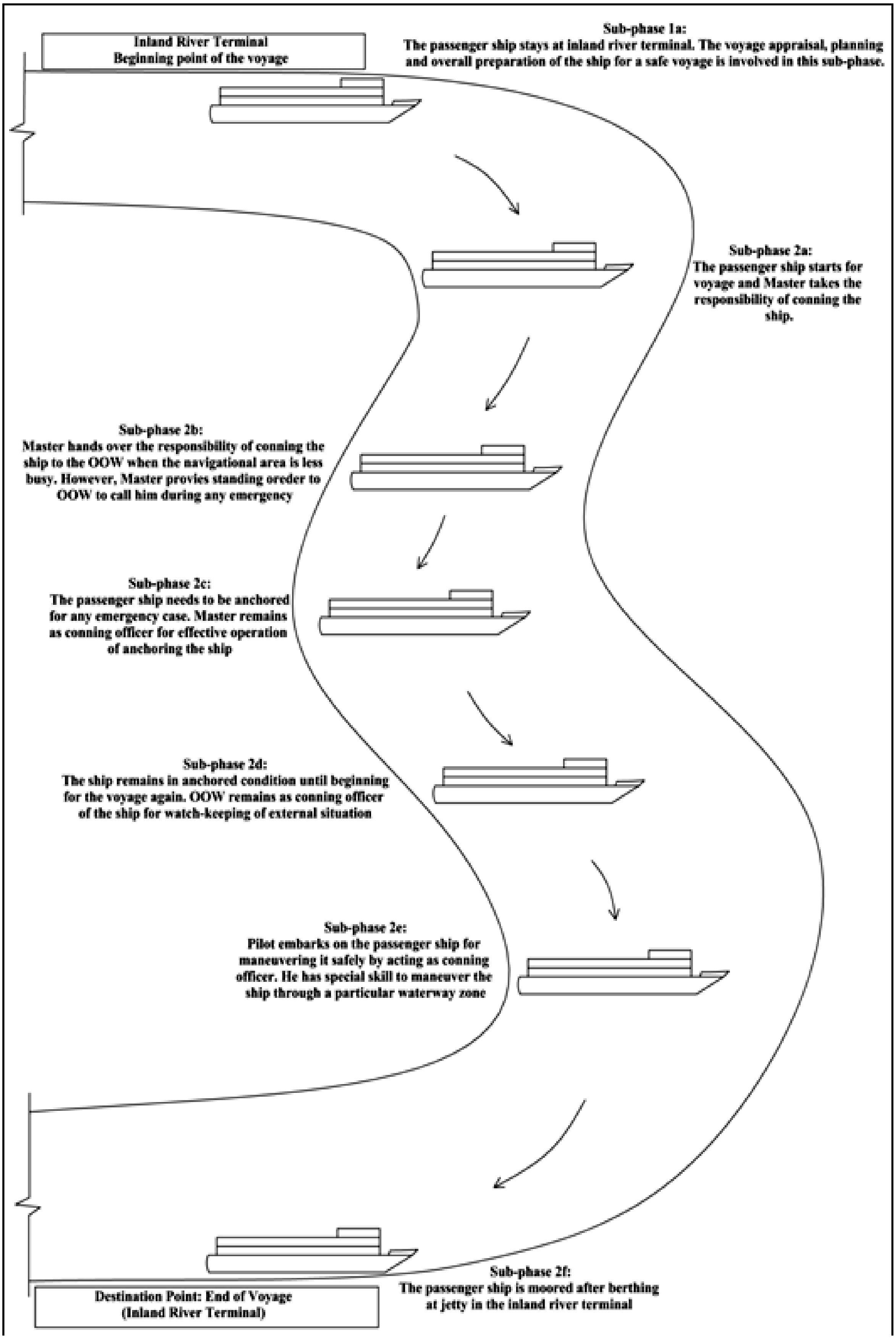


Fig. 4.17: Illustration of different sub-phases of operation of an inland passenger ship.

4.4.1 Phase 1-ships' stay at inland river terminal

The losses relevant to this phase are defined as follows:

A1: Loss of life or serious injury to people.

A2: Damage to the ship or objects outside the ship occurs.

A3: Ship is capsized (due to losing stability during the stay at the terminal or after leaving terminal).

The hazards relevant to this phase are defined as follows:

h1: Passengers of the ship are subjected to insufficient supervision and guidance regarding safety by the crews of the ship. [A1]

h2: Voyage preparation and planning is performed inadequately. [A1, A2]

h3: Ship is overloaded. [A1, A3]

h4: Ship exceeds the maximum acceptable (designed) limit of list/trim. [A1, A2, A3]

The safety constraints relevant to this phase are defined as follows:

sc 1: Passengers of the ship must be subjected to proper supervision and guidance regarding safety by the crews of the ship. [h1]

sc 2: Voyage preparation and planning must be performed adequately before the voyage. [h2]

sc 3: Ship must not exceed the maximum acceptable (designed) limit of loading condition. [h3]

sc 4: Ship must not exceed the maximum acceptable (designed) limit of list/trim. [h4]

4.4.1.1 Sub-phase 1a-ships' stay at inland river terminal

Voyage planning and overall preparation of the inland passenger ship are included in this part of the operation of the ship. All zones of the ship i.e. bridge deck, other decks, engine room and anchor station etc. needs to be checked very carefully so that the safety of the ship is ensured before the voyage. Voyage planning is a procedure to develop a complete description of a vessel's voyage from start to finish. A vessel's voyage planning involves four major steps. These steps are appraisal, planning, execution and monitoring. The appraisal step includes collecting and assessing all relevant information that are needed for the intended voyage. Collecting all river notices, weather update information, tidal depth level information etc. are some noteworthy activities for the appraisal of an inland ship. The planning step includes developing a voyage plan on the basis of the outcome of the appraisal step. It also includes the approval of the plan by the master of the ship after having a discussion. The execution step involves briefing the bridge team on the decisions of the planning step and navigating the vessel according to that plan. The final step of voyage planning includes checking the advancement of the vessel against the decided plan. The first two steps i.e. appraisal and planning are to be performed by Officer Of the Watch (OOW) during the stay of the ship at the inland river terminal. Therefore the activities related to these two steps are mainly regarded as the responsibilities of OOW. The safety related responsibilities, control action, feedback and communication of all crews during this sub-phase are presented in Table 4.3.

Table 4.3: Safety related responsibilities of the crews during the ship's stay at inland river terminal.

Designation of Crew	Safety Related Responsibilities
Conning officer (Master)	• To announce the safety message to the passengers of the ship. • Keep communication and take feedback regarding all activities performed by crews and other personnel that should be performed before commencing the voyage.
OOW (Officer Of the Watch)	• To collect all information sources (e.g. marine charts, catalogues, books, tables, notices etc.) • Identification of a safe track by taking into consideration of no-go areas, determination of margin of safety of draft (and relevant speed to avoid squat effect) around the no-go areas depending on available tidal stream and handling characteristics of the passenger ship. • Switching on all electronic navigational instruments (radar, GPS, VHF, echo sounder, VTS, Gyroscope, magnetic compass, navigational lights and horn and other equipment) and confirmation of its proper operating mode. • Check steering system of the ship. • Check navigation and signal lights and test the horn/siren. • Report to the conning officer (Master) after completing the departure checklist of the bridge.

Inland River Port Traffic Inspector	• Count and examine the number of passengers onboard to check loading condition of the ship so that it is ensured that the ship is not overloaded. • To give permission to leave the ship from terminal for the voyage after checking that the ship is not overloaded.
Crew W	• Supervise embarkation or disembarkation of passengers so that they can embark or disembark safely. • To inform or give feedback to the conning officer (Master) regarding embarkation or disembarkation of passengers or any other relevant problem.
Crew X	• Supervise loading or unloading process of cargo and freights on the passenger ship. • To inform or give feedback to the conning officer (Master) regarding loading or unloading process or any other relevant problem.
Crew Y	• To check the operational readiness and the stowage condition of life-saving appliances. • Inform or give feedback to the conning officer (Master) regarding the present condition of life-saving appliances or any other relevant problem.
Crew Z	• Check weather condition (present & forecasted), changes of current and tide level conditions. • Conduct mooring patrol to check the condition of mooring ropes based on the external environmental conditions. • Inform or give feedback to the conning officer (Master) regarding any problem related to mooring condition of the ship.
Inland Marine Engineer	• Ensure that all the machinery and equipment inside the engine room functions in an effective way in order to support safe navigation of the ship. • Confirmation report to the conning officer (Master) after complete preparation of the engine room for the voyage • Brief the other the engine room crews for the planning of the engine room work schedules and requirements during the voyage.
Driver	• To check the machinery to ensure that all the equipment, instruments and safety systems can start functioning safely and within the specified parameters. • Report to Inland Marine Engineer after completing the departure checklist of the engine room.

Greaser	• Monitor the machinery equipment, check gauges, record readings and keep an engine room log. • Help the inland marine engineer and driver in the start-up of the engine room machinery and equipment. • Clean the spilt oils, greases and lubrication oils, bilge water etc. in the engine room. • Help Driver to complete the engine room checklist before the voyage.

The Control Actions of this sub-phase are presented in Table 4.4.

Table 4.4: Control Actions of the sub-phase ships' stay at inland river terminal.

ID	Control Action path	Description of Control Action
1	Conning officer (Master)→ Passengers of the ship	• Announce the safety message to the passengers
2	OOW → Navigational instruments	• Perform appraisal and planning for voyage • Check navigational instruments
3	Inland river port traffic inspector → Passengers	• Check the loading condition of the ship
4	Crew W → Passengers	• Supervision of embarkation or disembarkation of passengers
5	Crew X → Freights of the passenger ship	• Supervision of loading or unloading process of cargo and freights
6	Crew Y → Life-saving appliances	• Check the operational readiness and stowage condition of the life-saving appliances
7	Crew Z → Mooring system	• Check the condition of mooring ropes
8	The engine room crews → The engine room machinery	• Check the engine room machinery

The Feedbacks of this sub-phase are presented in Table 4.5.

Table 4.5: Feedbacks of the sub-phase ships' stay at inland river terminal.

ID	Feedback path	Description of Feedback
A	Passengers → Conning officer (Master)	• Verbal feedback regarding any safety issue
B	Navigational instruments → OOW	• Visual sensory feedback • Auditory sensory feedback
C	Passengers → Inland river port traffic inspector	• Visual sensory feedback
D	Passengers→ Crew W	• Visual sensory feedback
E	Freight movement → Crew X	• Visual sensory feedback
F	Life saving appliance → Crew Y	• Visual sensory feedback
G	Mooring system → Crew Z	• Visual sensory feedback
H	Propulsion System → The engine room Crew	• Visual sensory feedback • Auditory sensory feedback • Tactile feedback • Machinery and Propulsion system status/information
I	OOW → Conning officer (Master)	• Verbal feedback about the completion of departure checklist of the bridge deck
J	Inland river port traffic inspector → Conning officer (Master)	• Verbal feedback about safe loading condition of the ship
K	Crew W → Conning officer (Master)	• Verbal feedback about passenger embarkation process
L	Crew X → Conning officer (Master)	• Verbal feedback about freight loading or unloading process
M	Crew Y → Conning officer (Master)	• Verbal feedback about the completion of the checklist of operational readiness of all life saving appliances
N	Crew Z → Conning officer (Master)	• Verbal feedback regarding any issue related to the mooring system of the ship
O	Engine room crew → Conning officer (Master)	• Verbal feedback about the completion of departure checklist of the engine room
P	External environment → Crew Z	• Visual sensory feedback

The Communications of this sub-phase are presented in Table 4.6.

Table 4.6: Communications of the sub-phase ships' stay at inland river terminal.

ID	Description of Communication
xx	Communication among the engine room crews

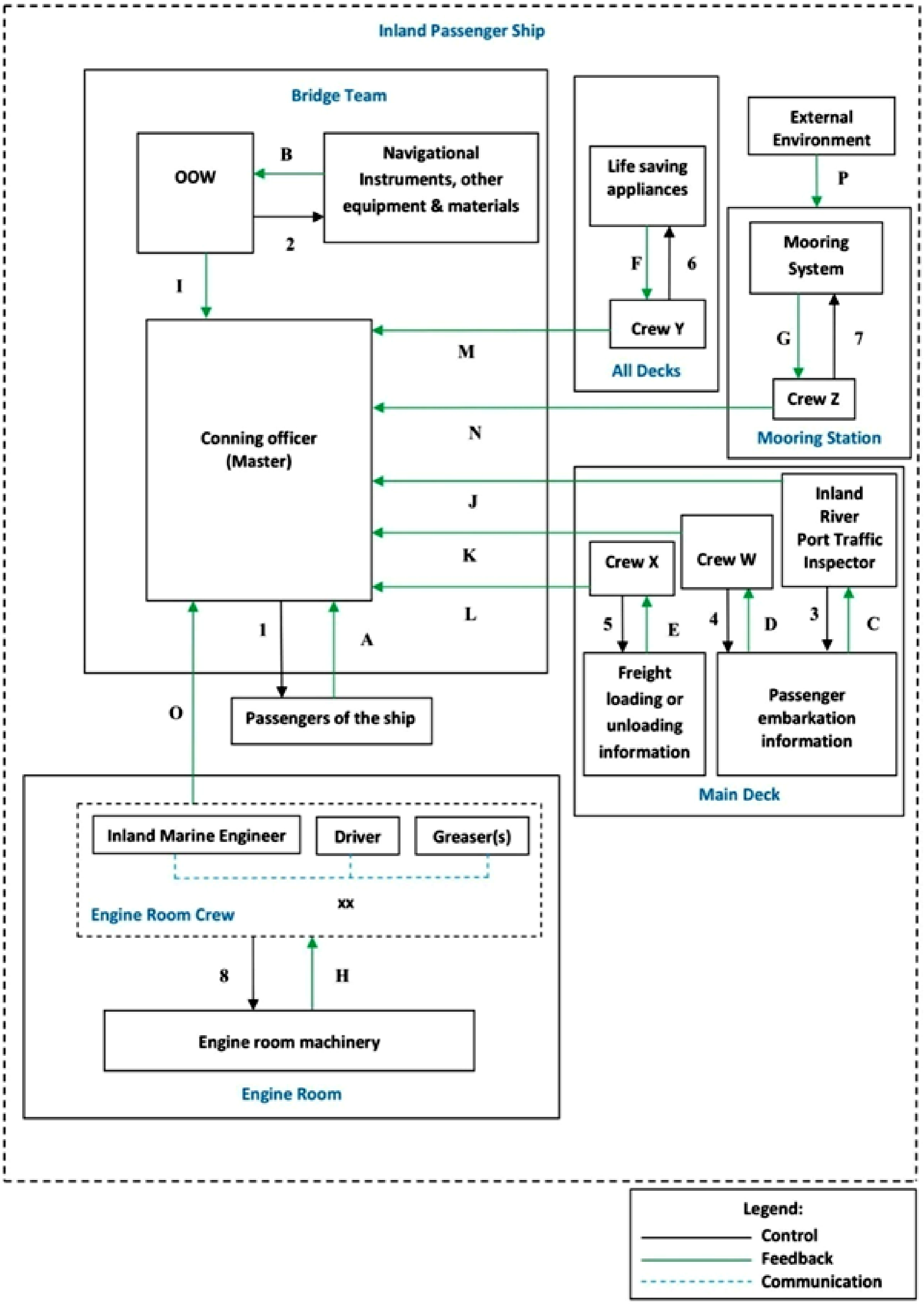


Fig. 4.18: Functional control structure of an inland passenger ship during the sub-phase of ships' stay at inland river terminal.

The Unsafe Control Actions of this sub-phase are presented in Table 4.7.

Table 4.7: Unsafe Control Actions of the sub-phase ships' stay at inland river terminal.

Controller	Control Actions (CA)	Not providing CA causes hazard	Providing CA causes hazard	Wrong timing/Order of CA causes hazard (applied too early or too late)	CA stopped too soon/applied too long
Conning officer (Master)	**Announce safety message to the passengers**	N/A	**UCA 1a-1:** The conning officer (Master) announces the safety message to the passengers with insufficient information before the voyage. [h-1]	N/A	N/A
OOW	**Perform appraisal and planning for voyage**	N/A	**UCA 1a-2:** OOW performs the appraisal and planning for voyage inadequately before the voyage. [h2]	N/A	N/A
OOW	**Check navigational instruments**	N/A	**UCA 1a-3:** OOW checks navigational instruments incompletely before the voyage. [h2]	N/A	N/A

Inland River Port Traffic Inspector	**Check the loading condition of the ship**	N/A	**UCA 1a-4:** Inland River Port Traffic Inspector checks the loading condition of the ship without following exact procedure before the voyage. [h3]	**UCA 1a-5:** Inland River Port Traffic Inspector starts to check the loading condition of the ship too late from the scheduled time before the voyage. [h3]	N/A
Crew W	**Supervision of embarkation or disembarkation of passengers**	N/A	N/A	**UCA 1a-6:** Supervision of embarkation or disembarkation of passengers by crew W is started too late from the scheduled time while the passengers are being embarked on or disembarked from the ship. [h1]	N/A
Crew X	**Supervision of loading or unloading process of cargo and freights**	N/A	N/A	**UCA 1a-7:** Supervision of loading or unloading of cargo and freights by crew X is started too late from the scheduled time during the loading or unloading of cargo and freights. [h4]	N/A

Crew Y	**Check the operational readiness and stowage condition of the life-saving appliances**	N/A	**UCA 1a-8:** Checking the operational readiness and stowage condition of life-saving appliances by crew Y is performed without following exact procedure before the voyage. [h2]	N/A	N/A
Crew Z	**Check conditions of mooring ropes**	**UCA 1a-9:** Checking the conditions of mooring ropes by crew Z is not done during change of the draft of the ship or due to any external influence. [h2]	N/A	N/A	N/A
The engine room crews	**Check the engine room machinery**	N/A	**UCA 1a-10:** Checking the engine room machinery by the engine room crews is performed without following standard procedure before the voyage. [h2]	N/A	N/A

The Controller constraints of this sub-phase are given below:

SC 1a-1: The conning officer (Master) must announce the safety message with sufficient information to the passengers before the voyage. [UCA 1a-1]

SC 1a-2: OOW must perform the appraisal and planning for voyage properly before beginning the voyage. [UCA 1a-2]

SC 1a-3: OOW must check all the navigation instruments properly before the voyage. [UCA 1a-3]

SC 1a-4: Inland River Port Traffic Inspector must begin to check the loading condition of the ship at the scheduled time and be performed properly using sufficient time before the voyage. [UCA 1a-4, UCA 1a-5]

SC 1a-5: Supervision of embarkation or disembarkation of passengers by crew W should begin at the right time and continue throughout the whole period while the passengers are being embarked on or disembarked from the ship. [UCA 1a-6]

SC 1a-6: Supervision of loading or unloading of cargo and freights by crew X should begin at the right time and continue throughout the whole period during the loading or unloading of cargo and freights. [UCA 1a-7]

SC 1a-7: Checking operational readiness and stowage condition of life saving appliances by crew Y should be done properly by following the exact procedure before the voyage. [UCA 1a-8]

SC 1a-8: The conditions of mooring ropes must be checked by the crew Z during the change of draft of the ship or during any external influence. [UCA 1a-9]

SC 1a-9: The engine room crews should check all the engine room machinery properly following the standard procedure before the voyage. [UCA 1a-10]

The analysis of the Causal Scenarios is presented below:

<u>Unsafe Control Action-UCA 1a-1:</u> The conning officer (Master) announces the safety message to the passengers with insufficient information before the voyage. [h1]

Scenario 1a-1:

The most important aspect of safety in the passenger ship is ensuring the safety of all the passengers. All passengers must know the personal safety issues like the locations and operating procedure of the life-saving appliances, evacuation procedure after the announcement of evacuation, etc. It is the responsibility of the conning officer (Master) to announce these important issues to all of the passengers of the ship before commencing the voyage so that during the distress condition passengers can evacuate safely within shortest possible time. However, the conning officer (Master) announces the safety message to the passengers before the voyage with inadequate information (vague or unexplained) due to the fact that the safety message is not updated or reviewed for a long time.

Possible Requirements for scenario 1a-1:

1. The safety message should be updated with adequate information.
2. The announcement of the safety message should not only contain contents, but also the sequences of the safety issues.

<u>Unsafe Control Action-UCA 1a-2:</u> OOW performs the appraisal and planning for voyage inadequately before the voyage. [h2]

Scenario 1a-2:

Before the voyage, it is necessary for the OOW to plan for the voyage by collecting all necessary information, documents, handbook, charts, catalogues, tables, meteorological information and river notices etc. It includes the identification of safe track by taking into consideration of no-go areas, determination of margin of safety of draft (and relevant speed to avoid squat effect) around the no-go areas depending on the handling characteristics of the ship. The completion of a safe voyage mainly depends on this appraisal and planning that is done before the voyage. In the inland waterways, the route remains similar for a particular passenger ship. So it becomes easier for the OOW to plan for the voyage as most of the jobs remain quite similar to previous planning. However, the OOW does not perform the appraisal and planning for the voyage properly. This may be due to the fact that OOW thinks that he has been performing the appraisal and planning for the voyage for many years. So, it is not necessary to perform it properly before every voyage. He has an incorrect mental model that as all the information are available to him, any correction or change of decision can be made during the voyage instantly. A scenario can be considered that OOW receives a river notice regarding the location of danger in a particular zone of waterway route. However, he ignores to fix that particular position in chart thinking that the zone is familiar to him and understands the location of danger. Therefore, he decides that it can be evaded during the voyage. This incorrect mental model is developed within him for successfully completing any voyage previously without any danger.

Possible Requirements for scenario 1a-2:

1. OOW must complete the steps of appraisal and planning for the voyage properly. Regular training, including some case studies of maritime accidents related to the improper appraisal and planning for the voyage is essential to develop the importance of this vital procedure within him.
2. The conning officer (Master) should not take a final feedback only. Rather, he should take frequent feedback from OOW regarding the appraisal and planning for the voyage.

Scenario 1a-2u:

The conning officer (Master) has allocated less time for appraisal and planning for the voyage to the OOW. This may be due to the fact that the conning officer (Master) sets the time limit based on his own assumption; but not on the capability of the OOW. So, OOW rushes through the checklist procedure and skips some minor steps of the appraisal and planning for the voyage.

Possible Requirements for scenario 1a-2u:

1. The conning officer (Master) should realize that the capability of any senior and junior officer is not the same. Therefore, he should not set any time limit appraisal and planning for the voyage that may be short for OOW to complete it properly.

2. OOW must inform the conning officer (Master) regarding any problem he is facing. He should never hesitate to do so, as the responsibility of any crew on board is very crucial for the safety of the passenger ship.

Unsafe Control Action-UCA 1a-3: OOW checks navigational instruments incompletely before the voyage. [h2]

Scenario 1a-3:

The safe voyage depends on the safe operation of the navigation and maneuvering equipment and its effective use. So, it is very important to check the operability of the instruments so that there remains no problem during the voyage. This includes switching on all navigation instruments and confirmation of the proper operating mode. Moreover, the navigation and signal lights should be checked and horn or siren should be tested properly before the voyage. It is the responsibility of OOW to check all those items properly by following a checklist. However, the OOW does not check the items properly for having an incorrect mental model due to the following reasons:

1. OOW has self-complacency that some instruments are reliable to remain in satisfactory condition. This is because he has a belief that the highly technical electronic navigational aids don't make errors. Therefore, he doesn't check all the items and just gives a tick to all the items in the checklist that is to be submitted to the conning officer (Master).

2. OOW checks the major items and skips the minor items. This is because he has seen that there occurred no problem in previous when he could not check all items of navigational instruments.

Possible Requirements for scenario 1a-3:

1. OOW should accept that keeping any navigational instruments in unchecked condition may cause any significant hazard at any time during the voyage. He should also admit that highly technical electronic aids can give a wrong reading in some cases. Proper knowledge about errors of navigational instruments and the importance of checking those before voyage should be learned through proper training.

2. The navigational instruments must not be able to be activated unless all required setup procedures are accomplished correctly.

3. Before the navigational instruments are activated, the OOW must have an opportunity to review all input setup parameters and verify their correctness.

4. Independent verification should be used to ensure that all checklist procedures are accomplished prior to commencing the voyage.

Scenario 1a-3u:

Before commencing the voyage, OOW checks the navigational instruments incompletely and signs off the items in the checklist. This is due to the fact that he has been allocated with less time to check the items.

Possible Requirements for scenario 1a-3u:

1. OOW should be allocated adequate time before the voyage to check the navigational items.

2. OOW should never sign off on the items in the checklist without properly checking those items.

Unsafe Control Action-UCA 1a-4: Inland River Port Traffic Inspector checks the loading condition of the ship without following exact procedure before the voyage. [h3]
Scenario 1a-4:

The inland river port traffic inspector is entrusted with the task of checking the load condition of the passenger ship. He does so by counting the number of passengers being embarked upon the ship. However, he performs the counting and examining the process of the passengers to check the loading condition of the ship (whether overloaded or not) by assuming a number of overall passengers without physically counting the actual number of passengers. He does so due to the fact that there has been a long practice of doing such check (existence of unsuitable procedures).

Possible Requirements for scenario 1a-4:

1. The automatic passenger counting system should be installed at the entry point of the passenger ship. This will allow counting the number of passengers automatically and will signal the overload condition of the ship when the specified number of passengers is crossed.

2. To ensure proper counting, the specified zone of every passenger can be marked by drawing a rectangular box on the main deck (for passengers remaining on the main

passenger deck). This will allow cross-checking the number of passengers very quickly and effectively.

<u>Unsafe Control Action-UCA 1a-5:</u> Inland River Port Traffic Inspector starts to check the loading condition of the ship too late from the scheduled time before the voyage. [h3]

Scenario 1a-5:

If the inland river port traffic inspector is given the responsibility of checking the loading condition of several ships within a very short period, then without completing the overload check procedure of one ship, he has to move to another ship (due to the shortage of manpower of regulatory bodies). Thus, he stops counting the passengers of one ship (without counting properly) and moves to another ship. Therefore, he has to start the procedure of checking the load condition (whether overloaded or not) of a particular ship too late for being burdened with excessive task. Lack of proper management and planning has led to this unsafe control action.

Possible Requirements for scenario 1a-5:

1. A sufficient number of inland river port traffic inspector should be recruited to ensure proper checking and examining of load condition (whether overloaded or not) of the passenger ship.
2. An inland river port traffic inspector should not be given responsibility to check a number of ships within a very short time. He should take sufficient time to check the loading condition of a ship.

<u>Unsafe Control Action-UCA 1a-6:</u> Supervision of embarkation or disembarkation of passengers by crew W is started too late from the scheduled time while the passengers are being embarked on or disembarked from the ship. [h1]

Scenario 1a-6:

The safety of passengers starts from the embarkation upon the ship. So, it is very important to ensure that a passenger embarks on the ship safely. Especially the children, old, sick and disabled people need special guidance from the crew at the entrance of the main passenger deck. This is because they may fall down or get hurt while entering the ship. However, the crew starts the supervision too late for being requested by any crew or officer to assist in any other important task at that moment (lack of proper management & planning).

Possible Requirements for scenario 1a-6:

1. The conning officer (Master) should maintain a proper standing order that no crew should be diverged to perform any undefined task.

2. The conning officer (Master) should give necessary instructions or guideline before sending the crew to the task of supervision. Moreover, he should take feedback from the crew instantaneously during the embarkation or disembarkation of passengers.

3. A camera should be installed at embarkation point to monitor the embarkation or disembarkation of passengers to be checked visually by the conning officer (Master) from the bridge.

4. At present, there is no proper facility of proper and safe embarkation or disembarkation of passengers into the ship in the inland river terminals of Bangladesh. So a safe gangway should be set to the passenger ship for that purpose.

5. The present practice of the nose berthing of the passenger ships should be avoided in the inland river terminals of Bangladesh.

<u>Unsafe Control Action-UCA 1a-7:</u> Supervision of loading or unloading of cargo and freights by crew X is started too late from the scheduled time during the loading or unloading of cargo and freights. [h4]

Scenario 1a-7:

Proper and balanced distribution of load is essential to maintain the stability of any ship. Otherwise, the ship may experience an unsafe condition of list or trim that may cause any hazard e.g. the ship may contact with pontoon when trimmed by the bow. Therefore, it is very important that a crew must check the loading or unloading process of cargo and freights. However, he starts the operation too late for being requested by any crew or officer to assist in any other job (lack of proper management & planning).

Possible Requirements for scenario 1a-7:

1. The conning officer (Master) should maintain a proper standing order that no crew should be diverged to perform any undefined task. Moreover, the conning officer

(Master) should take feedback from the crew instantaneously during the loading or unloading of cargo and freights.

2. The conning officer (Master) should give necessary instructions or guideline before sending the crew to the task of supervision. Moreover, he should take feedback from the crew instantaneously during the loading or unloading of cargo and freights.

3. An automatic list or trim checker should be installed to alarm when it crosses the safe limit that is specified previously. This will help the conning officer (Master) to check continuously the stability condition of the ship during the loading or unloading stage.

Unsafe Control Action-UCA 1a-8: Checking operational readiness and stowage condition of the life-saving appliances by crew Y is performed without following the exact procedure before the voyage. [h2]

Scenario 1a-8:

Whenever any ship is under distress condition, the life-saving appliances (life jacket, life buoy etc.) are used to save the lives of the people. However, if those appliances are not in working order then the people may not be able to save their lives. Moreover, if the life-saving appliances are stowed very tightly then these cannot be freed to use within a very short time during distress condition. Therefore, before commencing the voyage it is very important to check properly with the proper functioning ability of the appliances to ensure that these are ready for immediate use. However, the crew responsible for this duty does not check the items properly due to the fact that he is given inadequate time for checking the life-saving appliances. Therefore, he rushes through the procedure of checking the condition of life saving appliances to stay on schedule.

Possible Requirements for scenario 1a-8:

The crew should be given adequate time to check the condition of life-saving appliances. Moreover, he should be briefed properly by the conning officer (Master) before checking.

Scenario 1a-8u:

The crew has an incorrect mental model that the condition of the life-saving appliances is good (though in fact it is not). The reasons behind this flawed mental model could include:

1. The crew thinks that the life-saving appliances are being regularly checked before every voyage and thus it is not necessary to go through the complete procedure to check the items as he has the incorrect belief that the condition of such items cannot be deteriorated within this short time.
2. The crew checks the life-saving appliances improperly for having insufficient knowledge.

Possible Requirements for scenario 1a-8u:

Regular training and safety drills should be arranged for the crews to learn the techniques of checking the operational readiness and stowage condition of the life-saving appliances effectively. Moreover, he must accept that the condition of life saving appliances may deteriorate at any time.

<u>Unsafe Control Action-UCA 1a-9:</u> Checking the conditions of mooring ropes by crew Z is not done during change of the draft of the ship or due to any external influence. [h2]

Scenario 1a-9:

During the stay at inland river port, the ship is moored at the jetty by the mooring ropes. Throughout that period the change of draft of the ship may occur due to change of tide level and loading or unloading operation of ship. Moreover, due to excessive wind or high water wave caused by the motion of the nearby passing ship can cause significant motion of the ship. In all these cases, it is important to check the condition of mooring ropes (whether in excessive tension or not). If this is not checked in due time the mooring rope may part and serious damage to the ship or human injury can occur. So, it is the responsibility of the crew in charge to check the condition of mooring rope when there is any change of tide level. However, he cannot check the conditions of mooring lines or ropes in due time for being involved in any other task requested by any other crew or officer (lack of proper management & planning).

Possible Requirements for scenario 1a-9:

The crew assigned for checking conditions of mooring lines should not involve him in any other task whenever he needs to check the items. He should inform the conning officer (Master) regarding the condition of mooring ropes in due time.

<u>Unsafe Control Action-UCA 1a-10:</u> Checking the engine room machinery by the engine room crews is performed without following standard procedure before the voyage. [h2]

Scenario 1a-10:

Before commencing the voyage it is important to check all the machinery items by the engine room crews. The crews should complete the departure checklist by checking each and every machinery item. However, the engine room crew does not check all the items (some items remain unchecked) or check incompletely or inadequately due to the fact that he has inadequate knowledge on machinery preparation before the voyage.

Possible Requirements for scenario 1a-10:

1. The engine room crews should be trained regularly about checking the machinery items properly.
2. Inland Marine Engineer should evenly distribute the task among all crews to check the machinery items before commencing the voyage. He should also involve himself in the machinery check operation to work as a team for effective preparation of the engine room before the voyage.

Scenario 1a-10u:

The engine room crews are allocated with less time for checking the engine room machinery before the voyage. This may occur due to the fact that the voyage time has been advanced without prior notice.

Possible Requirements for scenario 1a-10u:

1. The engine room crews should be noticed well early about the voyage time.
2. Master should not start the voyage without complete preparation of the engine room machinery.

4.4.2 Phase 2-voyage condition of the ship

The losses relevant to this phase are defined as follows:

L1: Loss of life or serious injury to people.

L2: Damage to the ship or objects outside the ship.

L3: Ship is capsized.

The hazards relevant to this phase are defined as follows:

H1: Ship violates minimum separation from other ship. [L1, L2]

H2: Ship violates minimum separation from any stationary object or underwater object. [L1, L2]

H3: Loss of ship control. [L1, L2]

H4: Ship enters into dangerous area/ region. [L1, L3]

H5: Fire occurs inside the ship. [L1, L2]

The safety constraints relevant to this phase are defined as follows:

SC 1: Ship must not violate minimum separation from other ship. [H1]

SC2: Ship must not violate minimum separation from any stationary object or underwater object. [H2]

SC 3: If control over the ship is lost, then it must be detected and measures should be taken to regain control over the ship. [H3]

SC 4: Ship must not enter into a dangerous area/ region. [H4]

SC 5: The ship must be maintained properly so that the occurrence of fire is prevented. [H5]

The voyage condition phase of the ship has the following sub-phases:

a) Master acting as the conning officer
b) Officer Of the Watch (OOW) acting as the conning officer
c) Anchoring operation of the ship

d) Anchored condition of the ship

e) Pilot acting as the conning officer

f) Mooring or unmooring operation of the ship

All these sub-phases are analyzed by the STPA method below:

4.4.2.1 Sub-phase 2a- Master acting as the conning officer

The master of the passenger ship remains as the conning officer of the ship during commencing the voyage, end of the voyage and in some waterway zones where special caution regarding maneuvering of the ship is needed. In this case, the safety related responsibilities, control action, feedback and communication of all crews inside the ship are presented in Table 4.8.

Table 4.8: Safety related responsibilities of the crews during the sub-phase of master acting as the conning officer of the ship.

Designation of Crew	Safety Related Responsibilities
Conning officer (Master)	• Responsible for ensuring the overall safety of the ship. • Keep communication and provide commands to bridge team members and the engine room crews. • Ensure safe motion, navigation and maneuvering of the ship by giving the proper navigational command to the helmsman. • To monitor the steering operation of helmsman after the verbal command. • Take decisions regarding maneuvering from the communication made to the conning officer (Master) of the nearby moving ship via VHF (engaged in traffic negotiations with other ships). • Control engine rpm (either manually or by giving command to the engine room team).
Helmsman	• To control the direction of ship's heading and steering as per the command of the conning officer (Master). He should repeat any verbal commands to verify that the command is heard and understood clearly by the conning officer (Master). • Steers the ship physically and maintains a proper course by executing all rudder commands properly.

OOW (Officer Of the Watch)	• Operate radar for proper maneuvering of the ship (to identify any ship or obstruction ahead). • Visual fixing of the position of the ship by checking paper charts, GPS and gyroscope. • Monitor or check the status of echo sounder to check the water depth. • To inform the conning officer (Master) about the presence of any nearby ship or other form of obstruction ahead. • Inform the conning officer (Master) about necessary information collected from navigational instruments and charts. • Challenge the conning officer (Master) for seeking clarification of any decision or command.
Inland Marine Engineer	• Maintain the required power, engine and propeller rpm as commanded by the conning officer (Master). • Ensure that all the machinery and equipment inside the engine room are functioning in an effective way in order to support safe navigation of the ship.
Driver	• Perform all the routine checks in the engine room • Make sure that all the machinery and safety systems are functioning safely and within the specified parameters. • Take necessary actions to recover all leaks and damages as early as possible.
Greaser	• Monitor all machinery equipment, check gauges, record readings and keep an engine room log. • Clean the spilt oil, greases and lubrication oils, bilge water, etc. in the engine room in due time.

The Control Actions of this sub-phase are presented in Table 4.9.

Table 4.9: Control Actions of the sub-phase of Master acting as the conning officer.

ID	Control Action path	Description of Control Action
9	Helmsman → Steering System	• Rudder (steering) command.
10	Conning officer → Helmsman	• Command to change the course of the ship • Monitor the steering operation of helmsman
11	Conning officer → Engine room Crew	• Command to increase propeller rpm • Command to decrease propeller rpm • Command to stop propulsion system
12	Conning officer → Propulsion System	• Propulsion command (controlled from the bridge)
13	OOW → Navigational instruments	• Visual fixing of position of the ship • Operate radar • Monitor or check status of echo sounder
14	OOW → Conning officer	• Inform the conning officer (Master) about the presence of any nearby ship or other forms of obstruction • Challenge the conning officer (Master) for seeking clarification of any command.
15	Engine room crew → Propulsion System	• Measurement of tank levels and check temperature and pressure at specified locations • Cleaning operation to keep machinery space free from accumulation of spilt oil • Sharing of information detected by five senses

The Feedbacks of this sub-phase are presented in Table 4.10.

Table 4.10: Feedbacks of the sub-phase of Master acting as the conning officer.

ID	Feedback path	Description of Feedback
a	Steering System → Helmsman	• Visual sensory feedback • Proprioceptive feedback • Steering system status/ information
b	Helmsman → Conning officer	• Verbal feedback (confirmation before executing rudder command)

c	Engine room crew → Conning officer	• Verbal feedback about propulsion and machinery status and information
d	Propulsion System → Conning officer	• Visual sensory feedback • Proprioceptive feedback • Propulsion system status/information
e	Navigational instruments → OOW	• Visual sensory feedback • Auditory sensory feedback • Proprioceptive feedback
f	Conning officer → OOW	• Verbal feedback
g	Propulsion System → Engine room crew	• Visual sensory feedback • Auditory sensory feedback • Tactile feedback • Machinery and Propulsion system status/information
h	Navigational instruments → Conning officer	• Visual sensory feedback • Auditory sensory feedback
i	Passengers of the ship → Bridge team members	• Feedback about discomfort or any other problem
j	External environment → Bridge team members	• Visual sensory feedback • Auditory sensory feedback • Proprioceptive feedback

The Communications of this sub-phase are presented in Table 4.11.

Table 4.11: Communications of the sub-phase of Master acting as the conning officer.

ID	Description of Communication
xx	Communication among the engine room crews
yy	Communication between the conning officer (Master) and bridge team of another ship (via VHF telecommunication system)

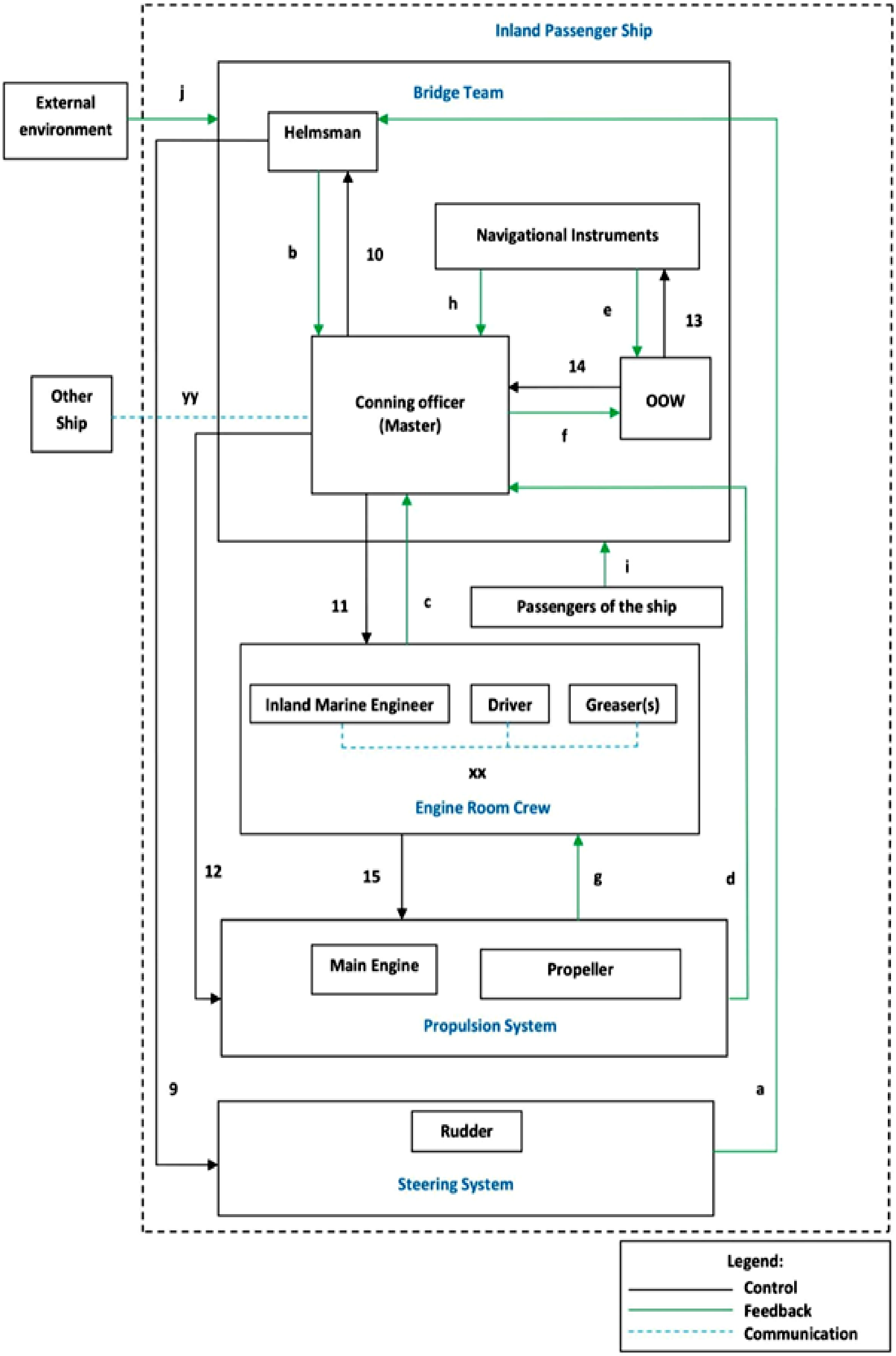


Fig. 4.19: Functional control structure of an inland passenger ship during the sub-phase of Master acting as the conning officer.

The Unsafe Control Actions of this sub-phase are presented in Table 4.12.

Table 4.12: Unsafe Control Actions of the sub-phase of Master acting as the conning officer.

Controller	Control Actions (CA)	Not providing CA causes hazard	Providing CA causes hazard	Wrong timing/Order of CA causes hazard (applied too early or too late)	CA stopped too soon/applied too long
Helmsman	**Rudder (steering) command**	N/A	**UCA 2a-1:** Helmsman provides wrong angle or wrong direction of steering command when it is needed to avoid contact from any ship or obstruction ahead. [H1, H2] **UCA 2a-2:** Helmsman provides rudder command to the steering system but the command is not implemented properly. [H1, H2, H3]	**UCA 2a-3:** Helmsman provides rudder command to the steering system too late when it is needed to avoid contact from any ship or obstruction ahead. [H1, H2]	N/A

Conning officer (Master)	**Command to change the course of the ship**	**UCA 2a-4:** The conning officer (Master) does not provide the command for changing course of the ship when it is needed to avoid contact from any ship ahead. [H1]	**UCA 2a-5:** The conning officer (Master) provides the command for changing the course of the ship when it is needed to avoid contact from any ship along the bearing of the new track. [H1]	**UCA 2a-6:** The conning officer (Master) provides the command to change the course of the ship too late when it is needed to avoid contact from any ship ahead. [H1] **UCA 2a-7:** The conning officer (Master) provides the command to change the course of the ship too late when it is needed to avoid contact from any stationary object, underwater obstruction or shoal ahead. [H2]	N/A

Conning officer (Master)	**Monitor the steering operation of helmsman**	**UCA 2a-8:** The conning officer (Master) does not monitor the steering operation of helmsman when the steering command is being implemented by the helmsman. [H1, H2]	N/A	N/A	**UCA 2a-9:** The conning officer (Master) stops monitoring the steering operation of helmsman too soon when the steering command is being implemented by the helmsman. [H1, H2]
Conning officer (Master)	**Command to increase propeller rpm**	N/A	**UCA 2a-10:** The conning officer (Master) commands to increase propeller rpm for increasing ship speed when the route is unsafe for moving the ship at high speed. [H1, H2]	N/A	N/A

Conning officer (Master)	**Command to increase propeller rpm**		**UCA 2a-11:** The conning officer (Master) commands to increase propeller rpm for increasing ship speed during rough weather condition. [H4]		
Conning officer (Master)	**Command to decrease propeller rpm**	**UCA 2a-12:** The conning officer (Master) does not command to decrease propeller rpm when the water depth has been reduced. [H2, H4] **UCA 2a-13:** The conning officer (Master) does not provide the command to decrease propeller rpm when it is needed to avoid contact with from any ship ahead. [H1]	N/A	N/A	N/A

Conning officer (Master)	**Command to stop propulsion system**	**UCA 2a-14:** The conning officer (Master) does not command to stop the propulsion system when it is needed to avoid contact with any ship or obstruction ahead. [H1, H2]	N/A	**UCA 2a-15:** The conning officer (Master) commands to stop propulsion system too late when it is needed to avoid contact with any ship or obstruction ahead. [H1, H2]	N/A
Conning officer (Master)	**Propulsion command (controlled from the bridge)**	N/A	N/A	**UCA 2a-16:** The conning officer (Master) provides propulsion command to the propulsion system (when controlled from bridge) too late during passing through a narrow or a traffic congested channel or maneuvering before berthing. [H1, H2]	N/A

OOW	**Visual fixing of position of the ship**	N/A	**UCA 2a-17:** Visual fixing of position of the ship is done inaccurately by OOW during the restricted visibility condition.[H1, H2]	**UCA 2a-18:** Visual fixing of position of the ship is done too late by OOW when the navigational area becomes busier. [H1, H2]	N/A
OOW	**Operate radar**	N/A	**UCA 2a-19:** OOW operates the radar with an incorrect parameter set when it is needed to avoid contact from any ship or obstruction ahead. [H1, H2]	N/A	**UCA 2a-20:** Operating radar is stopped too soon by OOW when it is needed to avoid contact from any ship or obstruction ahead. [H1, H2]
OOW	**Monitor or check status of echo sounder**	N/A	**UCA 2a-21:** OOW monitors or checks status of echo sounder inadequately when the water depth is reduced. [H2]	N/A	N/A

OOW	**Inform the conning officer (Master) about the presence of any nearby ship or other form of obstruction**	N/A	N/A	**UCA 2a-22:** OOW informs the conning officer (Master) too late when there is a nearby ship or other forms of obstructions ahead. [H1, H2]	N/A
OOW	**Challenge the conning officer (Master) for seeking clarification of any command**	**UCA 2a-23:** OOW does not challenge the conning officer (Master) for seeking clarification when the conning officer (Master) has given an unsafe command. [H1, H2, H4]	N/A	**UCA 2a-24:** OOW challenges the conning officer (Master) too late for seeking clarification when the conning officer (Master) has given an unsafe command. [H1, H2, H4]	N/A

Engine room crew	**Measurement of tank levels and check temperature and pressure at specified locations**	N/A	**UCA 2a-25:** Measurement of tank levels and checking of temperature and pressure at specified locations of the machinery spaces is performed without following standard procedure by the engine room crew during the routine inspection. [H3, H5]	N/A	**UCA 2a-26:** Measurement of tank levels and checking of temperature and pressure at specified locations of the machinery spaces is stopped too soon by the engine room crew during the routine inspection. [H3, H5]
Engine room crew	**Cleaning operation to keep machinery space free from accumulation of spilt oil**	N/A	N/A	**UCA 2a-27:** Cleaning operation to keep machinery space free from accumulation of spilt oil is started too late by the engine room crew during the routine operation. [H5]	**UCA 2a-28:** Cleaning operation to keep machinery space free from accumulation of spilt oil is stopped too soon by the engine room crew during the routine operation. [H5]

Engine room crew	**Sharing of information detected by five senses**	**UCA 2a-29:** The engine room crew does not share important information detected by five senses during the round in the machinery spaces. [H3, H5]	N/A	**UCA 2a-30:** The engine room crew shares important information too late detected by five senses during the round in the machinery spaces. [H3, H5]	N/A

The Controller constraints of this sub-phase are given below:

SC 2a-1: Helmsman must provide the right angle of the steering command to the right direction when it is needed to avoid contact from any ship or obstruction ahead. [UCA 2a-1, UCA 2a-3]

SC 2a-2: The command to the steering system applied by helmsman must be implemented properly without any discontinuity until the command is implemented properly. [UCA 2a-2]

SC 2a-3: The conning officer (Master) must provide the command for changing course of the ship when it is needed to avoid contact from any ship or obstruction ahead. [UCA 2a-4, UCA 2a-6, UCA 2a-7]

SC 2a-4: The conning officer (Master) must not provide the command for changing course of the ship when it is needed to avoid contact from any ship along the bearing of the new track. [UCA 2a-5]

SC 2a-5: The conning officer (Master) must properly monitor the steering operation of the helmsman for the complete period of time during the implementation of steering command by the helmsman. [UCA 2a-8, UCA 2a-9]

SC 2a-6: The conning officer (Master) must not command to increase propeller rpm for increasing ship speed when the route is unsafe for moving the ship at high speed. [UCA 2a-10]

SC 2a-7: The conning officer (Master) must not command to increase propeller rpm for increasing ship speed during rough weather condition. [UCA 2a-11]

SC 2a-8: The conning officer (Master) must command to decrease propeller rpm when the water depth has been reduced. [UCA 2a-12]

SC 2a-9: The conning officer (Master) must provide the command to decrease propeller rpm when it is needed to avoid contact with from any ship ahead. [UCA 2a-13]

SC 2a-10: The conning officer (Master) must command to stop the propulsion system when it is needed to avoid contact with any ship or obstruction ahead. [UCA 2a-14, UCA 2a-15]

SC 2a-11: The conning officer (Master) must provide propulsion command to the propulsion system (when controlled from bridge) at the right time during passing through a narrow or a traffic congested channel or maneuvering before berthing. [UCA 2a-16]

SC 2a-12: Visual fixing of position of the ship must always be done properly by OOW in due time. [UCA 2a-17, UCA 2a-18]

SC 2a-13: OOW must always operate the radar properly with the correct parameter set when it is required to identify any ship or obstruction ahead to avoid any contact. [UCA 2a-19, UCA 2a-20]

SC 2a-14: OOW must always monitor or check the status of echo sounder properly when it is required to identify the reduction of water depth. [UCA 2a-21]

SC 2a-15: OOW must always keep the master informed about the nearby traffic situation and other information properly. [UCA 2a-22]

SC 2a-16: OOW must always challenge the conning officer (Master) to seek clarification instantly whenever the conning officer (Master) has given an unsafe command. [UCA 2a-23, UCA 2a-24]

SC 2a-17: Measurement of tank levels and checking of temperature and pressure at specified locations of the machinery spaces must always be performed by following proper procedure and in due time by the engine room crew during the routine inspection. [UCA 2a-25, UCA 2a-26]

SC 2a-18: Cleaning operation to keep machinery space free from accumulation of spilt oil must always be performed at the right time by the engine room crew during routine operation. [UCA 2a-27, UCA 2a-28]

SC 2a-19: The engine room crew must always share important information instantly when detected by five senses during the round in the machinery spaces. [UCA 2a-29, UCA 2a-30]

The analysis of the Causal Scenarios is presented below:

Unsafe Control Action-UCA 2a-1: Helmsman provides wrong angle or wrong direction of steering command when it is needed to avoid contact from any ship or obstruction ahead. [H1, H2]

Scenario 2a-1:

The ship's steering control is operated by the helmsman at the helm. He follows the command of the conning officer (Master) to provide the rudder command (specific angle of rudder in a particular direction). When there is a ship, underwater obstruction or shoal ahead in the bearing of the track being followed, the execution of rudder command is a must to avoid the collision. At first, the conning officer (Master) commands helmsman to execute a particular rudder angle. Then, helmsman repeats the same command so that a final confirmation is given by the conning officer (Master). After that final confirmation from the conning officer (Master) helmsman executes the rudder angle and repeats the executed command again. But this practice of repeating command is not performed due to the fact that the conning officer (Master) and OOW works for a long time together and does not practice the repetition of the command before execution. A scenario occurs in a way that the helmsman does not clearly hear the command of the conning officer (Master). Then, the helmsman does not seek clarification and provides a wrong command to the steering system based on his own judgment.

Possible Requirements for scenario 2a-1:

1. Inadequate communication in the bridge must be avoided. Before executing a rudder command, helmsman should confirm the conning officer (Master) about the rudder command very clearly so that he gets proper confirmation from the conning officer (Master). In case of any doubt or confusion, he must consult with the conning officer (Master).
2. Regular training should be arranged to improve communication between the helmsman and master (also among all bridge team members).

Scenario 2a-1u:

Helmsman repeats the correct command asked by the conning officer (Master) but provides a wrong angle or wrong direction of steering command for being fatigued.

Possible Requirements for scenario 2a-1u:

The workload inside the ship should be evenly distributed among all crews so that no one gets fatigued. In this regard, the fatigue management plan should be developed and followed strictly to avoid fatigue of bridge deck crews.

Unsafe Control Action-UCA 2a-2: Helmsman provides rudder command to the steering system, but the command is not implemented properly. [H1, H2]

Scenario 2a-2:

The conning officer (Master) orders helmsman to execute rudder command to a particular direction at a particular angle. The helmsman executes the rudder command at the helm, but the rudder fails to execute the command properly at that moment. This could be caused by:

1. Steering system malfunctions due to component failure.
2. Power supply failure occurs inside the bridge deck.

Possible Requirements for scenario 2a-2:

1. A visual and audible alarm shall annunciate on wheelhouse if the steering system fails to deliver or maintain the ordered rudder angle.
2. Means must be available to recognize the fault of the steering system and fixing it in a very short period of time.
3. When the main power supply fails and the backup power supply is turned on, the transition period must not affect the steering command that was being implemented when the power supply was disrupted.

Unsafe Control Action-UCA 2a-3: Helmsman provides rudder command to the steering system too late when it is needed to avoid contact from any ship or obstruction ahead. [H1, H2, H3]

Scenario 2a-3:

The passenger ship enters a zone where traffic density is comparatively higher. In this situation, the responsibility of the conning officer (Master) is to call an additional crew in this situation for visual lookout or watch-keeping. However, the conning officer (Master) has an incorrect mental model that it is not necessary to call any additional crew. Rather, he thinks the helmsman has lots of experience and can continue visual lookout operation along with the steering operation. Therefore, the helmsman is given the responsibility of lookout. But the helmsman having excess pressure of work, loses situational awareness. Ultimately, he provides a rudder command to the steering system too late.

Possible Requirements for scenario 2a-3:

The watch-keeping and other relevant duties should not be assigned to the helmsman (or any other single crew). The conning officer (Master) must call an additional crew whenever there is a need for lookout operation.

Unsafe Control Action-UCA 2a-4: The conning officer (Master) does not provide the command for changing course of the ship when it is needed to avoid contact from any ship ahead. [H1]

Scenario 2a-4:

In a restricted visibility condition, OOW informs the conning officer (Master) about the presence or movement of a ship detected on radar. The conning officer (Master) has identified it as a small ship and thinks that it is not necessary to change the course of the ship. Rather, he assumes that that small ship will move away from the track of the ship to avoid the collision as the horn or siren is sounded (incorrect mental model). Therefore, he does not command for changing the course of the ship.

Possible Requirements for scenario 2a-4:

1. The conning officer (Master) should not rely on the fact that other ships will move away from the bearing of the track of the ship. Rather, he should be careful of external situation and try by any means to avoid hazardous state related to the collision.
2. The conning officer (Master) must always communicate with the nearby moving ship and be informed about its course via the VHF Telecommunication system.
3. Bridge team must give siren whenever a ship (that is on the track of the ship or may come on the track after sometime causing a collision) comes into their sight. But, they should not get stick with the belief that giving horn/siren is a perfect solution to avoid a hazard.

Scenario 2a-4u:

In restricted visibility Condition, OOW informs the conning officer (Master) about a ship (detected on radar) which is located ahead, but not along the bearing of the track of the passenger ship. The ship is actually a slow-moving ship that may come along the track of the ship after some time. Despite being informed by OOW, the conning officer (Master) does not provide the command for changing the course of the ship. This is because he considers it as an anchored ship due to the following factors:

1. The conning officer (Master) spends inadequate time (after being informed by OOW) to assess the characteristics of motion of the ship for being overloaded with lots of tasks.

2. Misjudgment about the motion characteristics due to inadequate skill (lack of adequate training)

Possible Requirements for scenario 2a-4u:

1. The conning officer (Master) must always communicate with the nearby moving ship and be informed about its course via the VHF Telecommunication system.
2. Bridge team must give siren whenever a ship comes into their sight. But, they should not get stick with the belief that giving horn/siren is a perfect solution to avoid a hazard.
3. Adequate training should be arranged for the bridge team members to assess a particular situation properly to ensure the safety of the passenger ship.

Unsafe Control Action-UCA 2a-5: The conning officer (Master) provides the command for changing the course of the ship when it is needed to avoid contact from any ship along the bearing of the new track. [H1]

Scenario 2a-5:

The ship is moving during restricted visibility condition. The OOW reports to the conning officer (Master) about the presence of a small ship along the bearing of the new track detected on the radar. But, the conning officer (Master) does not consider it as a ship; rather a false echo. Therefore, he commanded to change the course of the ship where the small ship is present.

Possible Requirements for scenario 2a-5:

1. The conning officer (Master) should not command to change the course of the ship without being confirmed of any danger ahead. He must not ignore the false echo considering the ship safety during the restricted visibility condition.

2. In restricted visibility condition, the ship should move at a safe speed. In case of extreme restricted visibility condition, the conning officer (Master) should not hesitate to command for stop the ship in a safe zone to ensure the safety of the ship.

3. Regular training and safety drills are needed to improve the expertise and skill of the bridge team members regarding the use of the navigational instruments to identify properly the location of safety hazards.

Scenario 2a-5u:

While monitoring the radar the conning officer (Master) is focused about only the situation ahead of the passenger ship and does not monitor that a ship at the back is moving forward at a considerable speed. Before giving the command to the helmsman, the conning officer (Master) also does not check visually about the presence of any ship astern (for being focused only on the conditions ahead). Lack of proper management and planning (Bridge Team Management) in the bridge regarding vessel navigation is the main cause of this unsafe control action.

Possible Requirements for scenario 2a-5u:

1. The communication between the conning officer (Master) and OOW should be improved by the implementation of proper bridge team management. In this regard the arrangement of the regular training program is important.

2. Checking astern (both visually and in radar) prior to altering the course of the ship should be a routine task of a particular bridge team members (either master or OOW as decided previously).

3. The helmsman should remind the conning officer (Master) whether astern is checked or not for being confirmed finally.

4. At present in many large passenger launches of Bangladesh, the rear part of the bridge deck contains space for passenger accommodation. It hinders the proper visual

checking of astern condition from the bridge deck by the crews. Therefore removal of such accommodation space is a recommendation from this perspective.

5. If it is not possible to eliminate the accommodation area behind the bridge within a short period, then a low-cost solution may be considered on a temporary basis. It could be the installation of a powerful camera at the stern zone of the ship.

Unsafe Control Action-UCA 2a-6: The conning officer (Master) provides the command to change the course of the ship too late when it is needed to avoid contact from any ship ahead. [H1]

Scenario 2a-6:

The passenger ship moves at considerable speed through a particular zone of the waterway route. Meanwhile, the conning officer (Master) is informed by OOW that a ship is approaching from the opposite direction. The conning officer (Master) does not command for reducing the speed of the ship. He makes a VHF contact with that ship and has decided to change the course of the ship by giving the command to the helmsman. However, the command is given too late due to the following causal factors:

1. Misjudgment about the timing of execution of rudder command for having inadequate knowledge on speed and handling characteristics of the ship.
2. Misjudgment that the ship approaching from the opposite direction has the same handling characteristics as that of this passenger ship.

Possible Requirements for scenario 2a-6:

1. Regular training is important for the conning officer as well as other bridge team members to reduce reaction time during emergency situations. It is also important for improving skill regarding maneuvering characteristics of the ship.
2. The conning officer (Master) and other bridge team members must accept that the handling characteristics of the other ships may differ from that of this ship. Adequate training is important to improve the skill and expertise of the conning officer (Master) to evade such misjudgment.
3. The ship should move at safe speed considering the condition of the surrounding environment e.g. traffic density, visibility condition, wind speed etc.

Unsafe Control Action-UCA 2a-7: The conning officer (Master) provides the command to change the course of the ship too late when it is needed to avoid contact from any stationary object, underwater obstruction or shoal ahead. [H2]

Scenario 2a-7:

The conning officer (Master) has seen or been reported by OOW about the presence of a permanent obstruction ahead. So, he decided to change the course of the ship by giving command to the helmsman. But, due to the presence of high amount of traffic, the conning officer (Master) felt that it is not necessary to change track so early to avoid any VHF communication with other ship. Rather, he assumed that he will command after covering some distance ahead when the route will be clearer from traffic. Consequently to avoid contact with the permanent obstruction he commands too late. This was done by him due to misjudgment about the timing of execution of rudder command for having inadequate knowledge on the handling characteristics of the ship with respect to the speed of the ship.

Possible Requirements for scenario 2a-7:

1. The conning officer (Master) should always keep the ship on a safe track. While he is notified of the presence of any obstruction ahead he should not be late to avoid the danger later. Rather he should decide to avoid it before a suitable range so that the ship can be handled safely in an effective way.

2. The ship should move at a safe speed considering the condition of the surrounding environment, e.g. traffic density, visibility condition, wind speed etc. Adequate training is essential to develop such skill of bridge team members.

Scenario 2a-7u:

The ship enters into a narrow channel and it is needed to navigate the ship more carefully. However, the conning officer (Master) provides the command to change the course of the ship too late when it is needed to avoid contact from any stationary object, underwater obstruction or shoal ahead. This may occur due to the fact that the conning officer (Master) does not discuss with OOW regarding the presence of no-go areas or any form of obstruction before entering into the narrow channel (lack of proper bridge team management).

Possible Requirements for scenario 2a-7u:

1. The conning officer (Master) should get confirmed from OOW about the location of any permanent obstruction or no-go areas early. He must order OOW to inform him early so that any critical situation (as stated above) can be evaded.
2. Effective bridge team management should be developed by the arrangement of the regular training program.

<u>Unsafe Control Action-UCA 2a-8:</u> The conning officer (Master) does not monitor the steering operation of helmsman when the steering command is being implemented by the helmsman. [H1, H2]

Scenario 2a-8:

The conning officer (Master) has been operating closely with the helmsman for a long time. Therefore, the conning officer (Master) has reliability over the helmsman and doesn't feel the importance to check the steering operation of helmsman after giving the verbal command.

Possible Requirements for scenario 2a-8:

The conning officer (Master) must check the execution of steering command by helmsman very carefully. In this regard, he should check the angle and direction (i.e. Port side or starboard side) of the execution of the rudder command being executed by helmsman each time.

<u>Unsafe Control Action-UCA 2a-9:</u> The conning officer (Master) stops monitoring the steering operation of helmsman too soon when the steering command is being implemented by the helmsman. [H1, H2]

Scenario 2a-9:

At any particular moment during the voyage VHF rings on as any nearby ship called to get confirmation of the intention of the motion of the passenger ship. The conning officer (Master) then commands for changing course of the ship. However, before the execution of that command, the conning officer (Master) receives the call and continues the conversation. During that moment the helmsman provides an incorrect command to the steering system. Lack of proper Bridge Team Management is responsible for the occurrence of such an unsafe scenario.

Possible Requirements for scenario 2a-9:

The conning officer (Master) should not receive the VHF call from any ship without checking the steering command of helmsman being implemented. Proper implementation of Bridge Team Management should is important to evade such errors.

Unsafe Control Action-UCA 2a-10: The conning officer (Master) commands to increase propeller rpm for increasing ship speed when the route is unsafe for moving the ship at high speed.[H1, H2]
Scenario 2a-10:

The conning officer (Master) needs to maintain a safe speed of the ship based on the surrounding circumstances e.g. state of visibility, traffic density and water depth. However, the conning officer (Master) feels rushed to complete the voyage in a short time. In this regard he has an incorrect mental model that operating the ship at high (unsafe considering the circumstances) speed may not cause any significant hazard when all the crew members are aware of their duties by using modern electronic navigational instruments.

Possible Requirements for scenario 2a-10:

1. The safe speed of the ship should be decided after using long range to detect approaching ships and any other form of obstruction.

2. Adequate training should be arranged to enhance the quality of bridge team members for safe navigation and maneuvering of the ship.

Scenario 2a-10u:

Bridge team should use radar in such a way that the range scale should be changed frequently to determine safe speed of the ship. But, the conning officer (Master) has ordered OOW to follow radar on small range scale to avoid any obstruction that is too close to the ship. The conning officer (Master) has ordered so for having inadequate knowledge on the determination of safe speed using radar operation.

Possible Requirements for scenario 2a-10u:

Same requirements as listed for scenario 2a-10

Unsafe Control Action-UCA 2a-11: The conning officer (Master) commands to increase propeller rpm for increasing ship speed during rough weather condition. [H4]

Scenario 2a-11:

The ship is moving and suddenly the weather becomes rough in nature. However, in that situation, the conning officer (Master) has ordered to increase the speed of the ship. He does so for having an incorrect mental model that during stormy weather it is required to increase the speed for safe navigation of the ship; otherwise, the ship may lose the stability and will capsize. This incorrect mental model is developed within him due to the following causal factors:

1. Operating the ship several times safely during stormy or rough weather in previous.

2. Inadequate knowledge or lack of training on ship maneuvering in rough weather conditions.

Possible Requirements for scenario 2a-11:

1. Specific guidelines should be updated and followed for navigation of the ship during rough weather. For instance, the ship should enter into the nearby specified shelter zone during the stormy weather condition.

2. Proper training should be arranged regularly to enhance the quality of bridge team members to navigate the ship safely during rough weather.

3. Updated information of weather forecasting should be informed to all ships in due time (e.g. after every 2 hours).

Unsafe Control Action-UCA 2a-12: The conning officer (Master) does not command to decrease propeller rpm when the water depth has been reduced. [H2, H4]

Scenario 2a-12:

While passing through a waterway route suddenly it is indicated that the water depth is reduced considerably. But, the conning officer (Master) does not command to reduce the speed of the ship when the water depth has been reduced. He thinks that such a reduction of the depth is acceptable for having inadequate knowledge on the squat effect on the ship.

Possible Requirements for scenario 2a-12:

1. Proper training should be arranged regularly to enhance the quality of bridge team members regarding the squat effect and safe navigation of the ship at limited water depth.

2. The echo sounder should be set to alarm when unsafe water depth is detected.

3. During the appraisal and planning for the voyage, the speed of the ship should be selected in different routes based on water depth and other important factors.

Unsafe Control Action-UCA 2a-13: The conning officer (Master) does not provide the command to decrease propeller rpm when it is needed to avoid contact with from any ship ahead. [H1]

Scenario 2a-13:

A small ship (usually the fishing ship or trawler) is crossing the river and moves in the lateral direction, i.e. perpendicular to the motion of the passenger ship. In this situation the conning officer (Master) has an incorrect mental model thinking that it is not necessary to decrease the speed of the ship. Rather, he assumes that the other ship is well aware of the situation and will be able to move away from the track of the passenger ship.

Possible Requirements for scenario 2a-13:

The conning officer (Master) should accept that the other ships have different maneuvering and handling characteristics. Therefore, he should judge the situation very carefully and should not hesitate to reduce the speed of the ship when there is any probability of contact or collision with other ships. Adequate training is needed to remove such confusion or misjudgment during emergency situations.

Scenario 2a-13u:

The passenger ship has entered in a narrow channel and there is a moving ship ahead approaching from the opposite direction. The conning officer (Master) made communication by VHF and the direction of movement of both the ships is decided after the conversation. The conning officer (Master) ordered to change the course of the ship to the helmsman. But, he does not reduce the speed of the ship for having a complacent behavior that the ship can be handled safely without speed reduction. This misjudgment is developed within him due to poor knowledge of ship handling characteristics.

Possible Requirements for scenario 2a-13u:

1. Adequate training should be arranged to enhance the quality of bridge team members for safe navigation and maneuvering of the ship (proper and effective utilization of steering and propulsion command to avoid any hazard).
2. The speed of the ship should be reduced from the normal speed limit when passing through a narrow channel.

Unsafe Control Action-UCA 2a-14: The conning officer (Master) does not command to stop the propulsion system when it is needed to avoid contact with any ship or obstruction ahead. [H1, H2]

Scenario 2a-14:

In case of any ship or obstruction ahead, the conning officer (Master) needs to change the course of the ship. In an extreme case when it is evident that a collision may occur if the ship is in usual motion; stopping the propulsion system or giving the command of full astern is a must. However, the conning officer (Master) does not give the command to stop the propulsion system due to incorrect judgment by the conning officer (Master) that executing the rudder command is enough to avoid the collision; stopping propulsion system is not necessary. He does so due to having improper knowledge regarding maneuvering characteristics of the ship.

Possible Requirements for scenario 2a-14:

1. Adequate training should be ensured to enhance the skill of the conning officer (Master) about ship maneuvering.
2. When there is any ship ahead, VHF communication should be made early to remove the confusion regarding maneuvering.
3. In foggy weather, the ship should move at a safe speed (less than the normal speed limit).

Scenario 2a-14u:

During the navigation, there is a small ship ahead approaching from the opposite direction. The conning officer (Master) does not make communication with that ship and depends solely on giving the horn to the draw attention of the ship. The conning officer (Master) has an incorrect mental model that since the other ship is small in size, so it will be able to move away from the track after hearing the sound of a horn. Therefore, he does not command to stop the propulsion system. He does so for being complacent about his decision.

Possible Requirements for scenario 2a-14u:
Adequate training should be ensured to enhance the skill of the conning officer (Master) about ship maneuvering.

Unsafe Control Action-UCA 2a-15: The conning officer (Master) commands to stop the propulsion system too late when it is needed to avoid contact with any ship or obstruction ahead. [H1, H2]
Scenario 2a-15:

In case of any obstruction ahead, the conning officer (Master) needs to change the course of the ship. In an extreme case when it is evident that a collision is imminent if the ship has motion; it is a must to stop the ship by stopping the propulsion system. However, the conning officer (Master) commands to stop the propulsion system too late for having inadequate knowledge of the stopping distance of the ship.

Possible Requirements for scenario 2a-15:
Adequate training should be ensured to reduce the reaction time during emergency situations for the conning officer (Master) and other bridge team members.

Unsafe Control Action-UCA 2a-16: The conning officer (Master) provides propulsion command to the propulsion system (when controlled from bridge) too late during passing through a narrow or a traffic congested channel or maneuvering before birthing. [H1, H2]

Scenario 2a-16:

The propulsion command is usually given by the engine room team. Besides, when it is necessary to change the propeller rpm very frequently (passing through a narrow or the traffic congested channel or maneuvering before berthing at the jetty) the control of propulsion command from the bridge is required. So, at that time he has to direct helmsman and control propeller rpm simultaneously. This is a critical situation that needs to be handled very carefully. However, the conning officer (Master) provides the command to the propulsion system too late (responded lately) for being task saturated.

Possible Requirements for scenario 2a-16:

1. In any situation when the conning officer (Master) has lots of tasks to be handled; he should assign an additional crew in the bridge. This should be planned before the voyage. Because the instantaneous distribution of task may lead to fatigue of crews.
2. In narrow or traffic congested channel the ship should run at a safe speed. Before berthing the conning officer (Master) should handle the ship in an effective way so that it does not hit the pontoon severely. Adequate training and regular safety drills are helpful to improve the quality of bridge team members.

<u>Unsafe Control Action-UCA 2a-17:</u> Visual fixing of position of the ship is done inaccurately by OOW during the restricted visibility condition. [H1, H2]

Scenario 2a-17:

The OOW is responsible to follow the track on GPS and fix the position of the ship after a particular time interval. He also needs to check gyrocompass to get proper direction. The passenger ship is moving in a busy navigational area and the visibility is also restricted to some extent. Therefore, OOW becomes busier than the previous times. Meanwhile, he misjudged a light of a slowly moving ship as a light of an anchored ship or shore light and fixes the position of the ship inaccurately or incorrectly. He does so due to the following causal factors:

1. Lack of situational awareness for being overloaded with lots of tasks in the bridge.

2. Spending inadequate time to come to a decision (self-complacency).

3. Inaccurate reading from the gyrocompass.

Possible Requirements for scenario 2a-17:

1. OOW must fix the position of the ship very carefully by taking adequate time. He must not rush to come to a decision quickly while visual fixing of the ship's position.

2. If OOW is perplexed to take any decision, he should call the conning officer (Master) immediately without being late. The conning officer (Master) should ensure that his standing order includes such guidelines for OOW.

3. The gyrocompass should be checked for error at an interval of one hour.

4. Regular training and safety drills are essential to improve the skills of the bridge team members regarding the fixing of a vessel's position properly.

Unsafe Control Action-UCA 2a-18: Visual fixing of position of the ship is done too late by OOW when the navigational area becomes busier. [H1, H2]
Scenario 2a-18:

OOW has selected a particular time interval for following track and visual fixing of ship position for a particular waterway segment. However, that interval may not be appropriate for other segments of the waterway where the navigational area is busier than previous times. In that case, it is needed to reduce the interval of time for fixing the position of the ship. OOW is too late to fix the position of the ship (does not reduce the interval of time for fixing the position of the ship) due to lack of situational awareness for being overloaded with lots of tasks to do on the bridge deck.

Possible Requirements for scenario 2a-18:

1. OOW should reduce the time interval for following track and visual fixing of the ship's position when the navigational area is busy that needs careful handling of the ship. This sense of decision-making should be developed by proper training.

2. When the ship enters into a busy navigational area OOW should not hesitate to seek assistance if he feels he needs the support to handle the ship safely.

Unsafe Control Action-UCA 2a-19: OOW operates the radar with an incorrect parameter set when it is needed to avoid contact from any ship or obstruction ahead. [H1, H2]

Scenario 2a-19:

The movement of any nearby ship or location of any obstruction above water is detected by radar. The radar needs to be operated in an efficient manner for safe maneuvering of the ship. Based on any prevailing circumstances, the OOW operates the radar in an inappropriate way. For instance, he is only using the long range scale of radar for monitoring the track or, he is using only short range scale when the ship is moving at high speed. He does so for having a lack of experience to monitor radar in unusual condition, e.g. high traffic density and high speed of ship, low visibility conditions.

Possible Requirements for scenario 2a-19:

OOW should be trained properly for using the radar appropriately. It should not only include the operation of radar, but also the techniques that incorporate checking surrounding circumstances by changing the range scale of radar in different conditions of the ship (e.g. high speed of the ship, low visibility conditions, the presence of high-density traffic etc.)

Unsafe Control Action-UCA 2a-20: Operating radar is stopped too soon by OOW when it is needed to avoid contact from any ship or obstruction ahead. [H1, H2]

Scenario 2a-20:

OOW had to change the range scale of radar frequently to identify the nearby objects as well as the distant objects (either stationary or moving). This is important for safe and smooth maneuvering of the ship in any particular area of the waterway route. However, the OOW stops checking radar when there is any ship or obstruction ahead due to the following causal factors:

1. OOW is task saturated due to passing through a busy navigational area.

2. OOW is fatigued.

Possible Requirements for scenario 2a-20:

1. The radar watch alarm should be set to an appropriate time limit so that OOW along with all the bridge team members remain aware of their activities and responsibilities on the bridge. There should be specific guidelines not to switch off the radar watch alarm.

2. OOW must accept that anyone in the bridge can be task saturated at any moment. So, he should not hesitate to call for assistance whenever he feels unable to maneuver the ship safely.

3. The fatigue management plan should be developed for the bridge team members.

4. Adequate training should be arranged to enhance the skill and expertise of bridge team members.

Unsafe Control Action-UCA 2a-21: OOW monitors or checks status of echo sounder inadequately when the water depth is reduced. [H2]

Scenario 2a-21:

In a certain area where the water depth is reduced it is necessary to reduce the speed of the ship to avoid the squat effect. OOW reports to the conning officer (Master) too late about this reduction of depth. This may occur due to the following causal factors:

1. The OOW is fatigued

2. OOW is overloaded with lots of tasks.

Possible Requirements for scenario 2a-21:

1. The conning officer (Master) should ensure that no member of the bridge team is fatigued or is task saturated. The fatigue management plan should be developed and followed to avoid fatigue of crews.
2. The echo sounder should be set to alarm when unsafe water depth is detected.
3. During the appraisal and planning for the voyage, the speed of the ship should be selected in different routes based on water depth and other important factors.
4. Proper training should be arranged regularly to enhance the quality of bridge team members to navigate the ship safely at low water depth.

Unsafe Control Action-UCA 2a-22: OOW informs the conning officer (Master) too late when there is a nearby ship or other forms of obstructions ahead. [H1, H2]

Scenario 2a-22:
In a particular navigation area, the weather is foggy and the traffic density is high. So, the OOW becomes overloaded with lots of tasks. Meanwhile, there is a nearby ship or obstruction ahead identified by radar. However, OOW is too late to inform the conning officer (Master) for losing situational awareness as he is overloaded with lots of tasks.

Possible Requirements for scenario 2a-22:

The conning officer (Master) should always keep mutual contact with the OOW and take care whether he is able to perform the duty properly or not. Moreover, the conning officer (Master) should also judge the situation based on his experience to determine the need for additional crew on the bridge for assisting the OOW.

Unsafe Control Action-UCA 2a-23: OOW does not challenge the conning officer (Master) for seeking clarification when the conning officer (Master) has given an unsafe command. [H1, H2, H4]

Scenario 2a-23:

When the conning officer (Master) has the Conn of the ship, OOW is mainly responsible to monitor the navigational instruments for safe navigation of the ship. Besides, the conning officer (Master) checks the navigational instruments and discusses with OOW before taking any decision. At any moment, the conning officer (Master) has ordered a command that seems unsafe to the OOW. For instance, the conning officer (Master) orders to change the course of the ship to any particular direction where it can collide with a shoal. But, OOW does not challenge the conning officer (Master) to seek clarification regarding the command. This may be done by OOW due to the following causal factors:

1. He does not have the confidence to seek clarification for being rebuked by the conning officer (Master). Perhaps he had challenged the conning officer (Master) for several times in previous and every time it was seen that the decision of the conning officer (Master) was correct.

2. OOW thinks that the conning officer (Master) is aware of the danger ahead. He believes that the conning officer (Master) is experienced and has the expertise to handle the ship safely in his own planning or judgment. So, it is not necessary to disrupt his intention.

Possible Requirements for scenario 2a-23:

1. OOW should keep in mind that most of the maritime accidents occur due to human faults and every human can make mistakes. So, he must accept that the conning officer (Master) can make a mistake. So, OOW must challenge the conning officer (Master) to seek clarification regarding any action that seems unsafe considering that particular situation.

2. Inadequate communication in the bridge should be avoided to remove any confusion regarding taking any action by the bridge team members. In this regard, proper and regular training for the bridge team members should be arranged.

3. The conning officer (Master) should not command helmsman to execute the steering command without proper consultation with OOW regarding the external situation or environment.

4. The conning officer (Master) should not rebuke any challenge from the bridge teammates. Rather, he should appreciate and welcome those challenges to ensure the safety of the ship. This appreciation is helpful to ensure the effective practice of safety culture in ship operation. Regular training is important for effective implementation of proper bridge team management.

<u>Unsafe Control Action-UCA 2a-24:</u> OOW challenges the conning officer (Master) too late for seeking clarification when the conning officer (Master) has given an unsafe command. [H1, H2, H4]

Scenario 2a-24:

During the voyage, the conning officer (Master) gives a command to helmsman that is unsafe considering the context of the external situation at that moment. However, OOW is late to challenge the conning officer (Master) for seeking clarification. This occurs due to the fact that the navigational area is busy and OOW keeps himself concentrated on working with navigational instruments. So, OOW recognizes the unsafe command from the conning officer (Master) too late when it is not possible to avoid a hazardous situation.

Possible Requirements for scenario 2a-24:

1. OOW should accept that although the conning officer (Master) gives all necessary commands, all important information of ship maneuvering is supported by him. He should not only keep him concentrated within the navigational instruments. Rather, he should keep himself dynamic to check the commands of the conning officer (Master) and other activities on the bridge.

2. The conning officer (Master) should not command helmsman to execute steering commands without proper consultation with OOW regarding the external situation or environment. Regular training is important for effective implementation of proper bridge team management.

Scenario 2a-24u:

The conning officer (Master) gives a command to helmsman that is unsafe considering the context of the external situation at that moment. However, OOW has been thinking for some time to understand the probable reasons for such command from the conning officer (Master). Later, he challenged the conning officer (Master) when it is too late to avoid any hazard.

Possible Requirements for scenario 2a-24u:

OOW should never be late to think of any reason behind the unsafe command from the conning officer (Master). Rather, he should challenge the conning officer (Master) immediately after the conning officer (Master) has commanded so.

Unsafe Control Action-UCA 2a-25: Measurement of tank levels and checking of temperature and pressure at specified locations of the machinery spaces is performed without following standard procedure by the engine room crew during the routine inspection. [H3, H5]

Scenario 2a-25:

Apart from the main engine and propeller, there are lots of machinery like the generator, air compressor, pump, cooler, etc. inside the engine room. These machineries contain several valves, sensors, indicators etc. Proper monitoring and checking of these items in due time is important to avoid any hazardous situation inside the engine room. But, the engine room crew may not perform monitoring action properly due to:

1. The excessive noisy environment inside the engine room may be a cause of fatigue of the crew (excessive vibration due poor design of the engine room).
2. The crew is task saturated.

Possible Requirements for scenario 2a-25:

1. The engine room must be designed in such a way that minimizes noise and vibration generated from the machinery. Special attention must be given to determine and solve the problem of vibration and sounding workplace in the engineering way. This is important to avoid fatigue of the engine room crews.
2. The engine room team must distribute the tasks so that no one gets fatigued for being task saturated. The fatigue management plan should be developed and followed strictly to avoid fatigue of the engine room crews.

Scenario 2a-25u:
The engine room crew has an incorrect mental model that checking minor locations is not so important. Therefore, he omits to check at some locations of the machinery spaces for having this complacent behavior. This behavior develops within him due to past experience during which he had not found any hazardous situation later.

Possible Requirements for scenario 2a-25u:

1. The engine room team must check all important machinery locations properly and timely. Inland marine engineer must not overlook the process of taking an update on the status of all machinery timely.
2. Regular training is essential to improve skill, situational awareness, assertiveness and remove complacent behavior among the engine room crews.

<u>Unsafe Control Action-UCA 2a-26:</u> Measurement of tank levels and checking of temperature and pressure at specified locations of the machinery spaces is stopped too soon by the engine room crew during the routine inspection. [H3, H5]

Scenario 2a-26:

Proper monitoring and checking of machinery is important to avoid any hazardous situation inside the engine room. However, the engine room crew stops too soon measuring tank levels and checking of temperature and pressure at specified locations of the machinery spaces. This is due to the fact that a problem is detected in the engine room and all the engine room crews are busy in solving the problem. Eventually, they forget or are distracted to check the points those were not checked in due time (lack of proper practice of the Engine Room Management).

Possible Requirements for scenario 2a-26:

1. If any unwanted situation arises inside the engine room, the task is required to be distributed among the engine room crews in a way so that monitoring action is not hampered at any time by working as a team. This task distribution plan should be developed before the voyage and maintained properly.
2. The engine room team should have to make prioritization of tasks in case of multiple problems have arisen. This should be done taking into account the safeness and urgency. Moreover, specific guidelines should be developed and followed to inform and keep communication with the bridge team in that situation.
3. Training should be updated with an assumption that a problem is detected in the engine room.
4. If any problem of machinery is severe then the complete propulsion and machinery system should be shut down to avoid any hazardous situation.

<u>Unsafe Control Action-UCA 2a-27:</u> Cleaning operation to keep machinery space free from accumulation of spilt oil is started too late by the engine room crew during routine operation. [H5]

Scenario 2a-27:

In the engine room, there are many types of machinery that need oil (e.g. Fuel oil, lubrication oil, etc.). In some zones, there occurs an accumulation of the spilt oil from the machinery. If this accumulated oil gets contact with a heated surface, then it may cause a fire. Moreover, any crew may be injured severely when slipped over the oily surface. Therefore, it is necessary to clean the accumulated oil inside the machinery space. However, the engine room crew is task saturated, so that he cannot start the cleaning operation in due time.

Possible Requirements for scenario 2a-27:

1. The inland marine engineer should ensure that the cleaning operation is maintained in due time. He should also ensure that no crew is overloaded with tasks.
2. The engine room crew should not hesitate to ask for assistance if it seems to him that he is unable to handle the situation properly for being overloaded with work or tasks.
3. Fire safety drills should be performed regularly to raise awareness and develop the skill of the crews regarding fire safety.

<u>Unsafe Control Action-UCA 2a-28</u>: Cleaning operation to keep machinery space free from accumulation of spilt oil is stopped too soon by the engine room crew during routine operation. [H5]

Scenario 2a-28:

It is important for cleaning the accumulated oil inside the machinery space to avoid contact with a heated surface and stay safe from the danger of fire. However, the engine room crew stops too soon cleaning the accumulated oil inside machinery spaces. This is due to a problem is detected in the engine room and all the engine room crews are busy in solving the problem. Meanwhile, they forget or are distracted to clean the accumulated oil inside the machinery spaces in due time (lack of proper engine room Management).

Possible Requirements for scenario 2a-28:

Same requirements as listed for scenario 2a-26

<u>Unsafe Control Action-UCA 2a-29:</u> The engine room crew does not share important information detected by five senses during the round in the machinery spaces. [H3, H5]

Scenario 2a-29:

During the round inside machinery spaces, the engine room crew has identified a small deviation of a parameter from standard value but decides not to share the information (e.g. Rapid rising of exhaust gas temperature of any cylinder of the engine). This is due to the fact that he has an incorrect mental model that such difference is acceptable. Moreover, he thinks that if it becomes a serious issue, then the alarm will be sounded. Therefore, such a situation can be handled just after hearing the alarm. This behavior is the indication of lack of situational awareness of the engine room crew.

Possible Requirements for scenario 2a-29:

1. The engine room crew must not accept any small difference of a parameter from standard or acceptable value and inform other members immediately.
2. If any the engine room crew has any confusion regarding safeness of any action being done by his senior officer, he (regardless of the rank) should not hesitate to ask for an explanation of that action. This assertive behavior is helpful to avoid most of the hazardous scenarios in the machinery spaces. In this regard, regular training and safety drills are to be arranged properly.

Unsafe Control Action-UCA 2a-30: The engine room crew shares important information too late detected by five senses during the round in the machinery spaces. [H3, H5]

Scenario 2a-30:

During the round inside machinery spaces, the engine room crew has found a small difference of any parameter and decided to inform it to other members after some time as he is involved in the monitoring activities of some other important equipment. Therefore, being complacent, he decides to share the information later (incorrect mental model).

Possible Requirements for scenario 2a-30:

1. The engine room crew should be trained properly so that they can understand the importance of reporting any problem immediately just after identification.
2. The inland marine engineer should specify clearly the activities and reporting schemes during machinery rounds to every the engine room crews.

4.4.2.2 Sub-phase 2b- OOW acting as the conning officer

Master may handover the responsibility of conning to the OOW at anytime during the voyage. Usually, OOW is given the responsibility as the conning officer of the ship when the navigational area is less busy and the river width is higher that is the route is comparatively easier to navigate the ship. In this case, the safety related responsibilities, control action, feedback and communication of all crews inside the ship are presented in Table 4.13.

Table 4.13: Safety related responsibilities of the crews during the sub-phase of OOW acting as the conning officer of the ship.

Designation of Crew	**Safety Related Responsibilities**
Conning officer (OOW)	• To follow the standing order of Master i.e. to inform Master about any problem • Request for posting visual lookout on bridge. • Ensure safe motion, navigation and maneuvering of the ship by giving the proper navigational command to the helmsman. • To monitor the steering operation of helmsman after the verbal command. • Operate radar for proper maneuvering of the ship (to identify any ship or obstruction ahead). • Follow track and visual fixing of the position of the ship by checking paper charts, GPS and gyroscope. • Monitor or check the status of echo sounder to check the water depth. • Control engine rpm (either manually or by giving command to the engine room team). • Keep communication and provide command to the engine room crews. • Take decisions regarding maneuvering from the communication made to the conning officer (Master) of the nearby moving ship via VHF (engaged in traffic negotiations with other ships).

The responsibilities of the helmsman, Inland marine engineer, driver and greaser remain the same as previous.

The Control Actions of this sub-phase are presented in Table 4.14.

Table 4.14: Control Actions of the sub-phase of OOW acting as the conning officer.

ID	Control Action path	Description of Control Action
13´	Conning Officer (OOW) → Navigational instruments	• Request for posting visual lookout on bridge • Follow the track and visual fixing of position of the ship • Operate radar

Control action number **13´** indicates the operation of navigational instruments when OOW acts as the conning officer of the passenger ship. Besides, Control action numbers **9**, **10**, **11**, **12, 13** and **15** remain the same as previous.

In this sub-phase the Feedback numbers **a**, **b**, **c**, **d**, **e**, **g**, **i** and **j** remain the same as previous.

The Communication numbers **xx** and **yy** remain the same as previous.

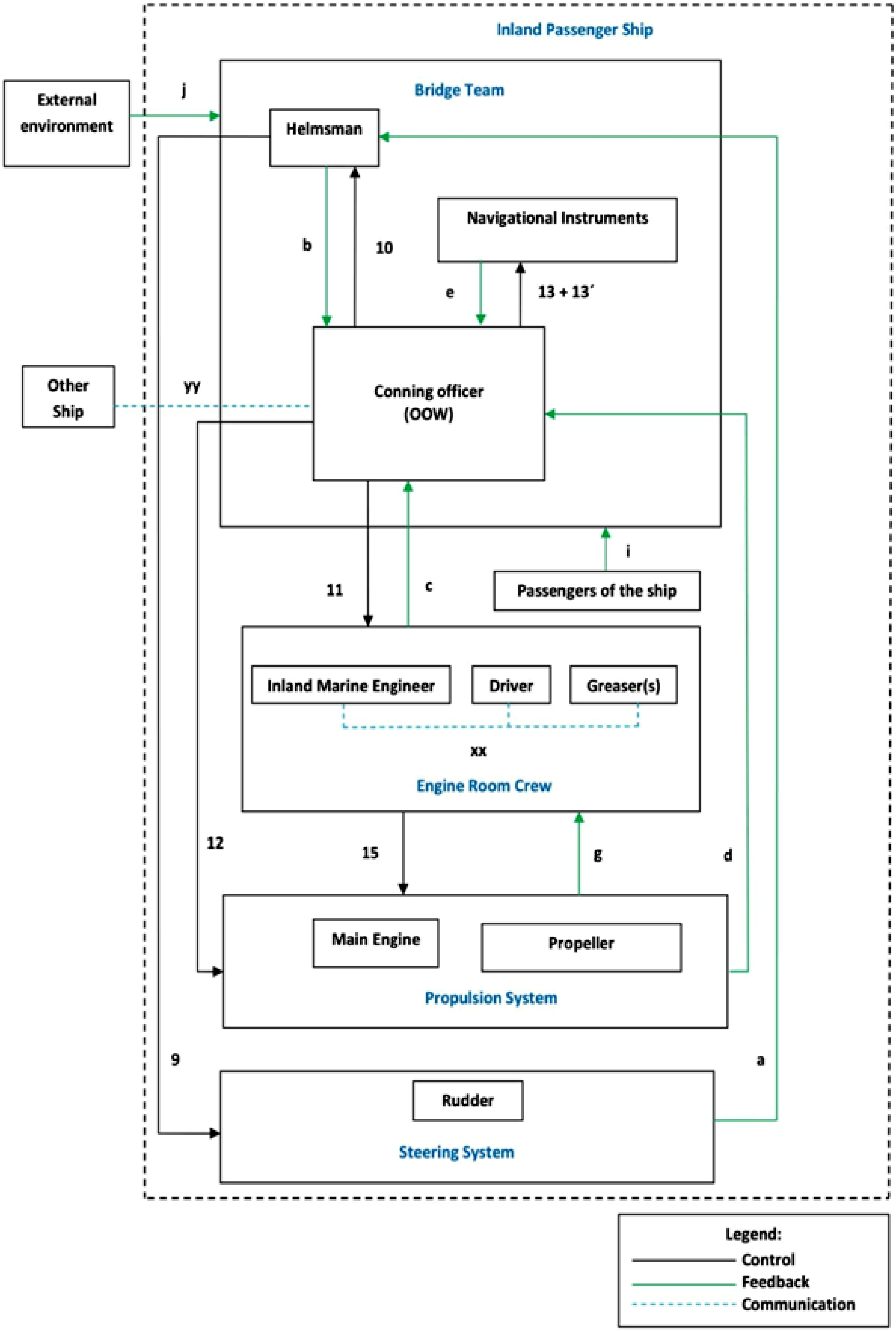


Fig. 4.20: Functional control structure of an inland passenger ship during the sub-phase of OOW acting as the conning officer.

The Unsafe Control Actions of this sub-phase are presented in Table 4.15.

Table 4.15: Unsafe Control Actions of the sub-phase of OOW acting as the conning officer.

Controller	Control Actions (CA)	Not providing CA causes hazard	Providing CA causes hazard	Wrong timing/Order of CA causes hazard (applied too early or too late)	CA stopped too soon/applied too long
OOW	**Request for posting visual lookout on bridge**	**UCA 2b-1:** OOW does not request for posting visual lookout on bridge when the navigational area becomes busier. [H1, H2]	N/A	**UCA 2b-2:** OOW requests too late for posting visual lookout on bridge when the navigational area becomes busier. [H1, H2]	N/A
OOW	**Follow the track and visual fixing of position of the ship**	**UCA 2b-3:** Following the track and visual fixing of position of the ship is not done by OOW when it is needed to fix the position of the ship. [H1, H2]	**UCA 2b-4:** Following the track and visual fixing of position of the ship is done without following proper procedure by OOW when it is needed to fix the position of the ship. [H1, H2]	N/A	N/A

OOW	**Operate radar**	N/A	**UCA 2b-5:** The radar is operated insufficiently by OOW when it is needed to identify any ship or obstruction ahead to avoid any contact. [H1, H2]	N/A	N/A

The Controller constraints of this sub-phase are given below:

SC 2b-1: OOW must request for posting visual lookout on bridge whenever the navigational area becomes busier. [UCA 2b-1, UCA 2b-2]
SC 2b-2: Following the track and visual fixing of ship's position must be done properly following the correct procedure by OOW when it is needed to fix the position of the ship. [UCA 2b-3, UCA 2b-4]
SC 2b-3: For identification of any ship or obstruction ahead, the radar must be operated properly by OOW when it is needed to identify any ship or obstruction ahead to avoid any contact. [UCA 2b-5]

In addition to the Unsafe Control Actions (UCA) and associated safety constraints listed above, the Unsafe Control Actions (UCA) listed in Table 4.16 are also included in this sub-phase. These are not described yet again for the repetition of similar Unsafe Control Actions (UCA) and associated causal scenarios. However, in this case, the control actions of the conning officer are performed by OOW instead of the Master.

Table 4.16: Additional Unsafe Control Actions (UCA) to be considered in the sub-phase of OOW acting as the conning officer.

Controller	Unsafe Control Actions (UCA)
Helmsman	UCA 2a-1, UCA 2a-2, UCA 2a-3
Conning officer (OOW)	UCA 2a-4, UCA 2a-5, UCA 2a-6, UCA 2a-7, UCA 2a-8, UCA 2a-9, UCA 2a-10, UCA 2a-11, UCA 2a-12, UCA 2a-13, UCA 2a-14, UCA 2a-15, UCA 2a-16, UCA 2a-17, UCA 2a-18, UCA 2a-19, UCA 2a-20, UCA 2a-21
Engine room crew	UCA 2a-25, UCA 2a-26, UCA 2a-27, UCA 2a-28, UCA 2a-29, UCA 2a-30

The analysis of the Causal Scenarios is presented below:

<u>Unsafe Control Action-UCA 2b-1:</u> OOW does not request for posting visual lookout on the bridge when the navigational area becomes busier. [H1, H2]

Scenario 2b-1:

During the voyage, the inland passenger ship enters into a busy navigational area. However, OOW has a self-complacent behavior that having highly technical navigational aids or instruments (e.g. Radar, GPS, etc.) it is possible to evade any hazardous situation. So, in spite of the situation being deteriorated, he does not request for posting an additional crew for visual lookout action on the bridge for being self-complacent.

Possible Requirements for scenario 2b-1:

1. OOW must seek for assistance for posting an additional lookout on bridge whenever needed. He must accept that accidents can occur despite having highly technical navigational aids or instruments (e.g. Radar, GPS, etc.).

2. Adequate training (including some real case studies) is helpful to remove the complacent behavior of the OOW and other bridge team members.

Scenario 2b-1u:

The inland passenger ship enters a busy navigational area during the voyage. The OOW becomes overwhelmed by the huge responsibilities he had to handle. Thus he lost his situational awareness and was not confident enough to call Master or request to post additional crew for lookout operation.

Possible Requirements for scenario 2b-1u:

1. Master should ensure that OOW is supported properly in a busy navigational area. He should carry out a proper assessment of the capability of OOW before he leaves the bridge. In this regard, Master should provide standing order to OOW for calling Master if the situation becomes tough to handle safely by OOW alone.

2. Regular training is helpful to improve the expertise of the OOW and other bridge team members.

Unsafe Control Action-UCA 2b-2: OOW requests too late for posting visual lookout on Bridge when the navigational area becomes busier. [H1, H2]

Scenario 2b-2:

OOW observes that the waterway route becomes traffic congested in a particular area. Before calling the Master he has been thinking for a while that the situation may improve after some time (incorrect mental model). Thus, he waits to call and keeps himself busy in bridge responsibilities to be performed by him. After some moment, he observes that the situation has worsened than previous. Therefore, he comes to a decision to call Master for assistance or request to post visual lookout on the bridge. However, it becomes too late to avoid the hazardous situation.

Possible Requirements for scenario 2b-2:

1. Master should provide standing order to OOW for calling Master if the situation becomes tough to handle safely by OOW alone.OOW should never hesitate to call for assistance when he feels task saturated. He must not be late to do so. He must keep it in mind that '*If I am thinking to seek assistance, then surely the time has come to do so right now*'.
2. Regular training is essential to develop the skills and responsibilities of the bridge deck crews.

Unsafe Control Action-UCA 2b-3: Following the track and visual fixing of position of the ship is not done by OOW when it is needed to fix the position of the ship. [H1, H2]

Scenario 2b-3:

An inland passenger ship usually makes voyage in a particular route. Thus an OOW has long experience of voyaging in a particular route. When the ship moves at a particular segment of waterway he thinks that the route is familiar to him. Moreover, the visibility condition is good at that moment. Therefore, a self-complacent behavior develops within him to depend only on the normal visual lookout to operate the ship and thus he ignores the procedure of following track and visual fixing of the ship's position.

Possible Requirements for scenario 2b-3:

OOW should perform the action of visual fixing of the ship's position and follow the track after a particular interval of time (e.g. checking after an interval of 10 minutes). The interval should be reduced based on weather and visibility conditions, traffic density and presence of bends along the waterway route etc.

Unsafe Control Action-UCA 2b-4: Following the track and visual fixing of position of the ship is done without following proper procedure by OOW when it is needed to fix the position of the ship. [H1, H2]

Scenario 2b-4:

OOW directs helmsman and also checks the navigational instruments for proper maneuvering of the passenger ship. OOW has a mental model flaw to depend solely on navigational instruments to follow the track. Therefore, he ignores the procedure of visual fixing of ship's position (verification procedure). This is because he is confident enough that highly automated navigational instruments are error-free. This complacent behavior develops within him as he had seen that navigational instruments operate acceptably for long periods. Therefore, he overlooks the verification of information provided by navigational instruments.

Possible Requirements for scenario 2b-4:

1. OOW should never solely rely on the navigational instruments for following the track and fixing ships' position. He should look out of the bridge windows to observe what is ahead, astern or either side of the ship by taking bearings of fixed navigation marks or any readily identifiable shore objects.
2. Adequate training should be arranged and some case studies should be discussed to remove the complacent behavior of the bridge team members.

Unsafe Control Action-UCA 2b-5: The radar is operated insufficiently by OOW when it is needed to identify any ship or obstruction ahead to avoid any contact. [H1, H2]

Scenario 2b-5:

An inland passenger ship usually makes voyage in a specific route. Thus, an OOW has a long experience of navigating a ship in that particular route. When the ship moves at a particular segment of waterway he thinks that this particular segment of the route is very familiar to him and the visibility condition is also good. So, a self-complacent behavior develops within him to depend mainly on the normal visual lookout to operate the ship. Therefore, he operates the radar insufficiently or inadequately for navigating the ship.

Possible Requirements for scenario 2b-5:

1. Specific guidelines should be developed to properly operate the navigational instruments (including radar) on the bridge and followed strictly.

2. Adequate training (including some real case studies) is helpful to remove the complacent behavior of the OOW and other bridge team members.

4.4.2.3 Sub-phase 2c- anchoring operation of the ship

A ship needs to be anchored for different purposes like machinery failure, unfavorable environment etc. During anchor drop or heave up operation, master becomes the conning officer. In this case, the safety related responsibilities, control action, feedback and communication of all crews inside the ship are presented in Table 4.17.

Table 4.17: Safety related responsibilities of the crews during the sub-phase of anchoring operation of the ship.

Designation of Crew	Safety Related Responsibilities
Conning officer (Master)	• Choose a suitable and safe anchoring area. • Command the anchor team to drop or heave up anchor. • Check the navigational instruments (GPS, echo sounder, Gyrocompass etc.) for proper maneuvering of the ship. • Check the movement or presence of nearby moving ships on radar. • Take decisions regarding maneuvering from the communication made with the conning officer (Master) of nearby moving ship via VHF (engaged in traffic negotiations with other ships).
OOW (at anchor station)	• Conduct visual lookout during anchor drop or heave up operation. • Inform the conning officer (Master) about the presence of any nearby moving ship. • Inform the conning officer (Master) about the marked number of anchor shackles while dropping or heaving up the anchor. • Follow instructions of the conning officer (Master). • Supervise and monitor the actions of the crew operating the anchor windlass for safe anchoring operation
Crew (at anchor station)	• Inspect the all anchoring equipment before anchoring operation • Follow the instructions of OOW • Operate anchor windlass for anchor drop and anchor heave up operation as directed by OOW.

The responsibilities of the helmsman, Inland marine engineer, driver and greaser remain the same as previous.

The Control Actions of this sub-phase are presented in Table 4.18.

Table 4.18: Control Actions of the sub-phase of anchoring operation of the ship.

ID	Control Action path	Description of Control Action
16	Conning officer (Master) → Navigational instruments	• Selection of anchoring area • Check the movement or presence of nearby ships on radar
17	Conning officer (Master) → Anchor team	• Command to drop or heave up anchor
18	OOW → Conning officer (Master)	• Inform the conning officer (Master) about presence of any nearby moving ship
19	OOW → External environment	• Conduct visual lookout
20	OOW → Crew	• Supervise the action of the crew
21	Crew → Anchor system	• Visual inspection of the anchor system • Anchor drop or heave up operation

Control action numbers **9**, **10**, **11**, **12** and **15** remain the same as previous.

The Feedbacks of this sub-phase are presented in Table 4.19.

Table 4.19: Feedbacks of the sub-phase of anchoring operation of the ship.

ID	Feedback path	Description of Feedback
k	Navigational instruments → Conning officer (Master)	• Visual sensory feedback • Auditory sensory feedback • Proprioceptive feedback
l	Anchor team → Conning officer (Master)	• Verbal feedback • Anchor status/ information
m	Conning officer (Master) → OOW	• Verbal feedback
n	External environment → OOW	• Visual sensory feedback • Auditory sensory feedback

		• Proprioceptive feedback
o	Crew → OOW	• Verbal feedback • Visual sensory feedback
p	Anchor system → Crew	• Visual sensory feedback • Auditory sensory feedback • Proprioceptive feedback

Feedback numbers **a**, **b**, **c**, **d**, **g**, **i** and **j** remain the same as previous.

The Communication numbers **xx** and **yy** remain the same as previous.

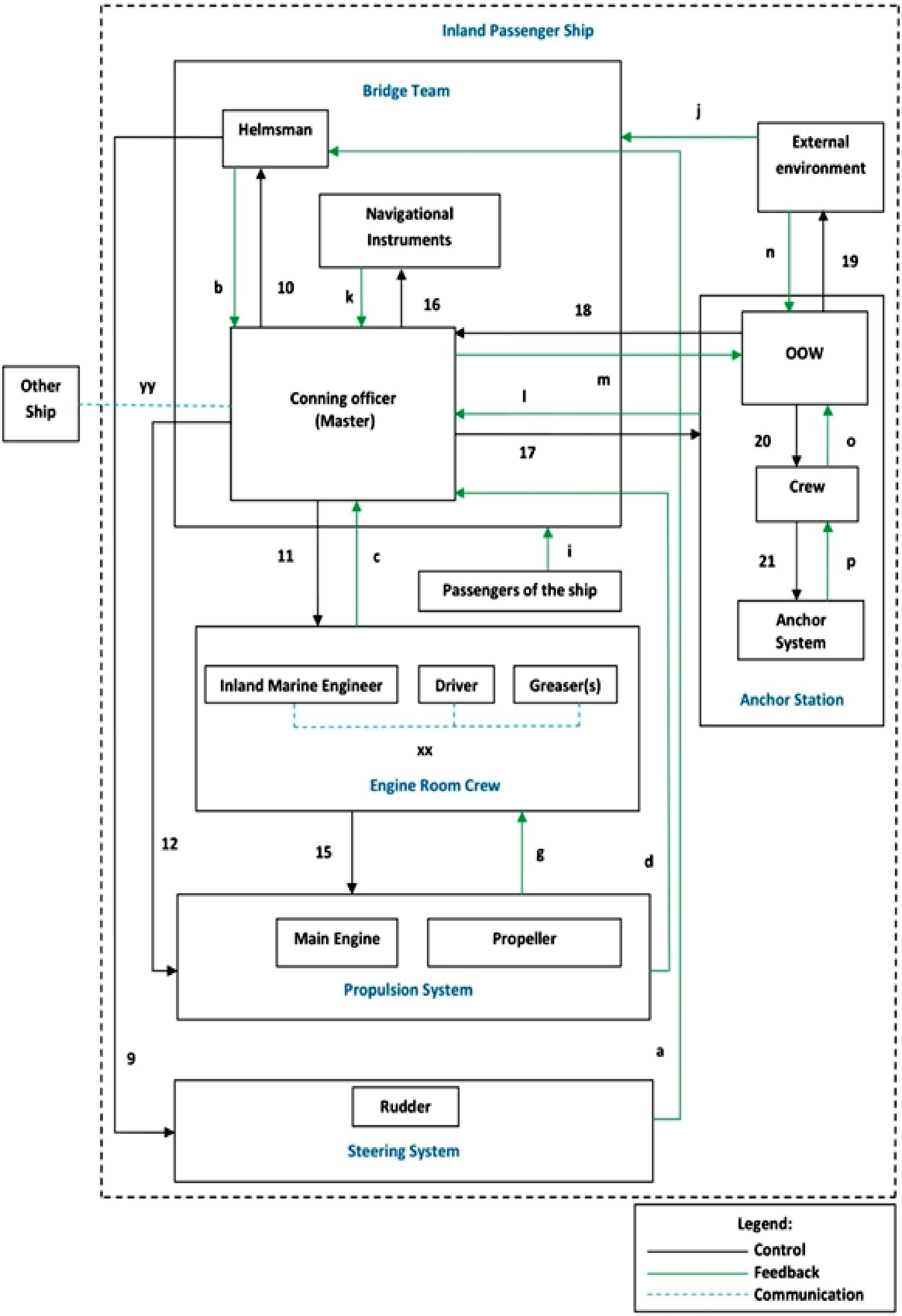


Fig. 4.21: Functional control structure of an inland passenger ship during the sub-phase of anchoring operation.

The Unsafe Control Actions of this sub-phase are presented in Table 4.20.

Table 4.20: Unsafe Control Actions of the sub-phase of anchoring operation of the ship.

Controller	Control Actions (CA)	Not providing CA causes hazard	Providing CA causes hazard	Wrong timing/Order of CA causes hazard (applied too early or too late)	CA stopped too soon/applied too long
Conning officer (Master)	**Selection of anchoring area**	N/A	**UCA 2c-1:** The conning officer (Master) selects an area that is not appropriate for safe anchoring before beginning the anchoring operation. [H4]	N/A	N/A
Conning officer (Master)	**Check the movement or presence of nearby ships on radar**	**UCA 2c-2:** The conning officer (Master) does not check the movement or presence of nearby ships on the radar during the anchoring procedure. [H1]	N/A	**UCA 2c-3:** The conning officer (Master) checked the movement or presence of nearby ships on the radar too late during the anchoring procedure. [H1]	N/A

Conning officer (Master)	**Command to drop or heave up anchor**	N/A	**UCA 2c-4:** The conning officer (Master) commands to drop or heave up the anchor when there is a nearby ship that may have contact with the anchor or anchor chain. [H1]	N/A	N/A
OOW	**Inform the conning officer (Master) about the presence of any nearby moving ship**	N/A	**UCA 2c-5:** OOW reports The conning officer (Master) with inadequate information regarding ship characteristics after identification of a nearby moving ship by the visual lookout. [H1]	N/A	N/A
OOW	**Conduct visual lookout**	**UCA 2c-6:** OOW does not conduct the visual lookout during the anchoring process. [H1]	N/A	**UCA 2c-7:** OOW started the visual lookout too late during the anchoring process. [H1]	N/A

OOW	**Supervise the action of the crew**	**UCA 2c-8:** The OOW does not supervise the action of the crew during anchoring operation. [H3, H5]	N/A	N/A	N/A
Crew	**Visual inspection of the anchor system**	**UCA 2c-9:** The crew does not inspect the anchor system before beginning the anchoring operation. [H3, H5]	N/A	N/A	N/A
Crew	**Anchor drop or heave up operation**	N/A	**UCA 2c-10:** Anchor drop or heave up procedure is performed by the crew without following the exact procedure during the anchoring process. [H3, H5]	N/A	N/A

The Controller constraints of this sub-phase are given below:

SC 2c-1: Conning officer (Master) must select a safe area for anchorage before beginning the anchoring operation. [UCA 2c-1]

SC 2c-2: The conning officer (Master) must properly check the movement or presence of nearby ships on radar during the anchoring procedure. [UCA 2c-2, UCA 2c-3]

SC 2c-3: The conning officer (Master) must not command to drop or heave up the anchor when there is a nearby ship that may have contact with anchor or anchor chain. [UCA 2c-4]

SC 2c-4: OOW must report the conning officer (Master) with complete description regarding ship characteristics after identification of a nearby moving ship by the visual lookout. [UCA 2c-5]

SC 2c-5: OOW must conduct visual lookout properly during the anchoring process. [UCA 2c-6, UCA 2c-7]

SC 2c-6: The OOW must properly supervise the action of crew during the anchoring operation. [UCA 2c-8]

SC 2c-7: The crew must inspect the anchor system before beginning the anchoring operation. [UCA 2c-9]

SC 2c-8: Anchor drop or heave up procedure must be performed by crew by following the exact procedure during the anchoring process. [UCA 2c-10]

In addition to the Unsafe Control Actions (UCA) and associated safety constraints listed above, the Unsafe Control Actions (UCA) listed in Table 4.21 are also included in this sub-phase. These are not described yet again for the repetition of similar unsafe control actions (UCA) and associated causal scenarios. However, in this case, some control actions of OOW are performed by the conning officer (Master) as OOW moves to the anchor station.

Table 4.21: Additional Unsafe Control Actions (UCA) to be considered in the sub-phase of anchoring operation of the ship.

Controller	Unsafe Control Actions (UCA)
Helmsman	UCA 2a-1, UCA 2a-2, UCA 2a-3
Conning officer (OOW)	UCA 2a-4, UCA 2a-5, UCA 2a-6, UCA 2a-7, UCA 2a-8, UCA 2a-9, UCA 2a-12, UCA 2a-13, UCA 2a-14, UCA 2a-15, UCA 2a-16, UCA 2a-17, UCA 2a-18, UCA 2a-21
Engine room crew	UCA 2a-25, UCA 2a-26, UCA 2a-27, UCA 2a-28, UCA 2a-29, UCA 2a-30

The analysis of the Causal Scenarios is presented below:

Unsafe Control Action-UCA 2c-1: The conning officer (Master) selects an area that is not appropriate for safe anchoring before beginning the anchoring operation. [H4]

Scenario 2c-1:

Selection of a safe area for anchoring is one of the most important aspects of safe anchoring. The area chosen by the conning officer (Master) may be unsafe for anchoring due to the presence of high-density traffic on the route or high water turbulence that may lead to anchor dragging etc. The conning officer (Master) has selected the area for anchoring without proper assessment of the anchorage area for the following causal factors:

1. He does not spend sufficient time for selecting a safe area for anchoring due to having inadequate knowledge or skill.
2. The conning officer (Master) does not communicate properly with the OOW regarding the no-go zones of the area where he intends to anchor the ship.

Possible Requirements for scenario 2c-1:

1. The conning officer (Master) should spend adequate time for selecting a safe area for anchoring. Adequate training should be arranged regularly to enhance the skill of the conning officer (Master) and other bridge team members to select a safe anchoring area for the passenger ship.

2. The conning officer (Master) should discuss with OOW before selection of a safe anchoring area for the passenger ship.

Unsafe Control Action-UCA 2c-2: The conning officer (Master) does not check the movement or presence of nearby ships on the radar during the anchoring procedure. [H1]

Scenario 2c-2:

During the anchoring process, The conning officer (Master) ceases to monitor the movement of any nearby ships as he depends solely on showing appropriate signals (specific horn and light signal that indicates the anchoring process or anchored condition of a ship). He has an incorrect mental model that when the signals are shown or given; it is not necessary to monitor the motion of other ships. This incorrect mental model is developed within him for being complacent.

Possible Requirements for scenario 2c-2:

Monitoring action on navigational instruments should be given high priority during the anchoring operation. Proper training, including some case studies, is helpful to avoid the complacent behavior during the anchoring process.

<u>Unsafe Control Action-UCA 2c-3:</u> The conning officer (Master) checked the movement or presence of nearby ships on the radar too late during the anchoring procedure. [H1]

Scenario 2c-3:

The conning officer (Master) is involved in giving direction and guidance for safe anchoring operation to the OOW. During that time the conning officer (Master) is distracted for some moment and was late to detect the presence or monitor the movement of a nearby moving ship within the anchoring zone.

Possible Requirements for scenario 2c-3:

The radar watch alarm should be set into small interval so that it can make the conning officer (Master) aware of monitoring action.

<u>Unsafe Control Action-UCA 2c-4:</u> The conning officer (Master) commands to drop or heave up the anchor when there is a nearby ship that may have contact with the anchor or anchor chain. [H1]

Scenario 2c-4:

During the anchoring procedure, the conning officer (Master) has to observe the presence and movement of nearby ships on radar and keep contact with OOW at anchor station, so that safety is ensured during the anchoring process. However, the conning officer (Master) does not identify the presence of a nearby moving ship on radar due to the following causal factors:

1. The conning officer (Master) uses radar in inappropriate (very small) range scale and thus misses the presence of a nearby ship.

2. The conning officer (Master) is involved in a lengthy conversation with the OOW (who present at the anchor station) regarding the anchoring process being conducted. Therefore, he is distracted from following the radar for some moment.

Possible Requirements for scenario 2c-4:

1. During anchoring the ship, the appropriate radar range scale should be selected to identify any nearby ship. The conning officer should be trained up regularly to achieve such expertise and skill.
2. The conning officer (Master) must spend adequate time on navigational instruments before giving the order for dropping anchor by observing the presence of other nearby ships.

Scenario 2c-4u:

Before commanding to drop or heave up anchor the conning officer (Master) identifies a nearby ship on radar, but does not follow up its motion or does not contact via VHF. This may be due to the fact that the conning officer (Master) has a mental model flaw that the ship is aware of the anchoring process after being observed the appropriate light and signal indicating anchoring process. This incorrect mental model is developed within him for being complacent.

Possible Requirements for scenario 2c-4u:

1. In case any ship is identified within the anchoring zone, the conning officer (Master) should not solely rely on giving the sound signal or showing appropriate light. Rather, he should contact with the ship via VHF to discuss the ongoing situation and the intent of movement of that ship.
2. In any case, if the conning officer (Master) feels that he may be in a situation to become unable to handle the situation safely and effectively; he should call an additional crew on the bridge to assist him. Regular training of bridge team members is needed to ensure safety during the anchoring process.

<u>Unsafe Control Action-UCA 2c-5:</u> OOW reports the conning officer (Master) with inadequate information regarding ship characteristics after identification of a nearby moving ship by the visual lookout. [H1]

Scenario 2c-5:

In restricted visibility condition, OOW has identified a small watercraft or ship and informed the conning officer (Master) without complete description like *'there is a small watercraft ahead'*. Or, OOW does not specify the location of the ship that is located on the port side of the ship. The conning officer (Master) has acknowledged it in that way. In fact, there were two ships in the nearby location; one on the port side and another in the starboard side. However, the conning officer (Master) has not identified the ship informed by OOW as being missed on the radar (inappropriate range scale). Rather, he thinks it as another ship he detects on the radar; that is on the starboard side of the ship. Inadequate communication (containing insufficient information) is the main factor behind this scenario.

Possible Requirements for scenario 2c-5:

1. OOW must specify clearly the location and direction of motion of the nearby moving ship so that the conning officer (Master) can clearly identify the ship that is indicated by the OOW.
2. The conning officer (Master) should not acknowledge any information quickly and ambiguously i.e. without being confirmed properly.
3. Regular training is needed to be arranged to remove such ambiguous communication among the bridge team members.

<u>Unsafe Control Action-UCA 2c-6:</u> OOW does not conduct visual lookout during the anchoring process. [H1]

Scenario 2c-6:

During the anchoring process, the conning officer (Master) is in the bridge to detect the presence and monitor the movement of any nearby ship by using radar. Therefore, OOW has an incorrect mental model that as the conning officer (Master) is monitoring the nearby traffic conditions with the aid of highly technical navigational instruments, so, it is unnecessary to have a visual lookout at the anchoring station. This incorrect mental model is developed within him for being self-complacent.

Possible Requirements for scenario 2c-6:

1. OOW should never leave the visual lookout operation. The conning officer (Master) should ensure it by keeping continuous contact with him.
2. The arrangement of regular training, including some case studies regarding some anchoring incidents; is helpful to remove the complacent behavior of the bridge team members regarding the anchoring process.

<u>Unsafe Control Action-UCA 2c-7:</u> OOW started the visual lookout too late during the anchoring process. [H1]

Scenario 2c-7:

OOW is busy in instructing the crew about anchoring operation and thus he is distracted for some moment from performing the visual lookout. Therefore, he was too late to identify a moving ship in the vicinity for losing situational awareness.

Possible Requirements for scenario 2c-7:

Same requirements as listed for scenario 2c-6

<u>Unsafe Control Action-UCA 2c-8:</u> The OOW does not supervise the action of the crew during anchoring operation. [H3, H5]

Scenario 2c-8:

The OOW is responsible for safe operation at the anchor station. He has to supervise and guide the crew properly so that, there occurs no hazardous scenario during anchoring operation. However, OOW does not guide the crew during the operation due to having an incorrect mental model that the crew does not need such guidance for having lots of experience.

Possible Requirements for scenario 2c-8:

1. The OOW should operate closely with the crew and communicate with him adequately to be guided properly regarding safe anchoring operation.

2. The crew should seek proper supervision by keeping continuous contact during anchoring operation (e.g. informing the number of shackles, safe speed of windlass etc.).

3. Regular training programs should be conducted to develop communication between OOW and the crew regarding the anchoring operation at the anchor station.

Unsafe Control Action-UCA 2c-9: The crew does not inspect the anchor system before beginning the anchoring operation. [H3, H5]

Scenario 2c-9:

Before beginning the anchoring operation, it is important to inspect the anchor system properly. During the anchoring process, any mechanical failure may hamper the operation and can lead to a hazard. It may be caused due to not conducting a visual inspection of the anchor system before anchoring operation. The crew has a mental model flaw that it is not necessary to conduct visual inspection of the anchor system before beginning the anchoring operation. This is due to the fact that he had performed the visual inspection before some days or in the last voyage and there is no probability of occurrence of any problem in anchor system within this small period of time (self-complacent behavior).

Possible Requirements for scenario 2c-9:

1. The conning officer (Master) must ensure that before clearing anchor, visual inspection of the anchor system has been conducted by the crew. The anchor windlass should be tested before anchoring and the moving parts should be well greased.
2. Regular training along with some case studies of some incidents is essential to eliminate the complacent behavior among the crews regarding the importance of visual inspection of the anchor system.
3. A regular check of all equipment and machinery of the anchor system should be conducted.

Scenario 2c-9u:

The crew does not get sufficient time for proper inspection of the anchor system before the anchoring operation. This may occur due to the fact that he has been involved in some other task assigned by the conning officer (master) just before beginning the anchoring operation (lack of proper management & planning).

Possible Requirements for scenario 2c-9u:

Specific guideline must be in place so that the crew gets sufficient time to inspect the anchor system before beginning the anchoring operation.

Unsafe Control Action-UCA 2c-10: Anchor drop or heave up procedure is performed by the crew without following the exact procedure during the anchoring process. [H3, H5]

Scenario 2c-10:

Anchor drop and heave up operation needs a specific amount of time based on external conditions viz. weather, tide and riverbed conditions. So, careful handling of the anchor by operating anchor windlass is needed to be done for safe anchoring process. Anchoring of a seagoing ship is a common and regular phenomenon. However, the anchoring of a passenger ship in the inland river route may be a novel phenomenon, as it is usually not needed unless an emergency situation occurs. During anchoring operation, the crew operates the windlass in sudden and repeated alteration of speed. Moreover, he is not alert to any changing circumstances e.g. excessive vibration or unusual noise of machinery which may be a sign of machinery failure related problems of the anchor system. It may cause anchor failure and even lead to a fire in the anchor station. The crew operates the anchor windlass in such improper way due to the fact that he is mesmerized to operate the anchor windlass to drop or heave up anchor after a long period of time (facing a novel situation)

Possible Requirements for scenario 2c-10:
1. Adequate training and regular safety drills are needed to enhance the skill of the crew regarding safe anchoring operation.

2. While dropping/heaving the anchor, it should be done in gradual speed by the operating crew. Sudden and repeated alteration of the windlass should be avoided.

Scenario 2c-10u:

During the anchoring operation, the conning officer (Master) has ordered the anchor team to give a pause to the anchor drop (or anchor heave up) procedure for a short period (for any important issue that needs to be solved for safe anchorage e.g. safe movement of a nearby ship). The crew keeps the weight of the cable solely on the windlass instead of using the chain stopper or guillotine bar. The crew does so due to having an incorrect mental model that using guillotine bar is not necessary to keep the weight of the cable as it will resume within a short period of time. This may lead to catastrophic damage to anchor cable and human injury in any worst case.

Possible Requirements for scenario 2c-10u:
The weight of anchor cable must not be on the windlass brake alone. Rather, the chain stopper/guillotine bar should be kept in a locked position which is designed to take the weight of the anchor cable.

Scenario 2c-10v:

During Anchor drop or heave up operation, the crew has to keep a safe distance from the anchor windlass to ensure safety. Otherwise, the anchor chain (if it is ruptured any time) may hit their body and severe injury can occur. However, the crew remains close to the windlass while dropping or heaving the anchor due to the following causal factors:

1. The crew loses awareness about personal safety for focusing on anchor cable movement or anchoring operation only.

2. The crew has inadequate knowledge and training on safe anchoring operation.

Possible Requirements for scenario 2c-10v:

1. A marked zone should be designed in front of the windlass so that the crew can stand in that zone safely.
2. The crew should stay well clear from the anchor windlass during the anchor drop and heave up operation. The OOW should warn the crew if he mistakenly gets near to the windlass.
3. Adequate training on safe anchoring operation, including personal and machinery safety issues is needed to be arranged regularly.

Scenario 2c-10w:

During Anchor drop or heave up operation, the crew does not wear proper Personal Protective Equipment (PPE). This may happen due to:

1. The crew has inadequate knowledge on the safety of anchoring operation.

2. Inadequate guidance from OOW and The conning officer (Master).

Possible Requirements for scenario 2c-10w:

1. The conning officer (Master) must ensure that OOW and crew are attended at the anchor station wearing proper personal protective equipment (PPE). He should guide so during briefing the anchor team and make it confirm before beginning of the anchoring process.

2. Following a safety checklist at the anchor station before starting anchoring operation is helpful to follow the personal safety issues at the anchor station.

4.4.2.4 Sub-phase 2d- anchored condition of the ship

After successfully anchoring a ship, it is needed to keep watch-keeping of the external situation, anchor dragging movement of nearby traffic during anchored condition. In this case, the safety related responsibilities, control action, feedback and communication of all crews inside the ship are presented in Table 4.22.

Table 4.22: Safety related responsibilities of the crews during the sub-phase of anchored condition of the ship.

Designation of Crew	Safety Related Responsibilities
Conning officer (OOW)	• Fixing the position of the ship and to check for the occurrence of anchor dragging. • Check the radar for checking the presence of any ship moving near to the ship. • To communicate with the conning officer (Master) of nearby moving ship via VHF (whenever seems necessary). • Check echo sounder for checking the water depth in the anchorage area. • To follow the standing orders of master.
Crew	• Conduct visual lookout to inform OOW about the presence of a nearby moving ship. • To sound horn after a particular time interval for warning nearby ships about the anchored condition of the passenger ship.

The responsibilities of the helmsman, Inland marine engineer, driver and greaser remain the same as previous.

The Control Actions of this sub-phase are presented in Table 4.23.

Table 4.23: Control Actions of the sub-phase of anchored condition of the ship.

ID	Control Action path	Description of Control Action
22	Conning officer (OOW) → Navigational instruments	• Position fixing of the ship • Communicate with a nearby moving ship by VHF • Monitor the movement of nearby moving ships in radar
23	Crew → Conning officer (OOW)	• Inform OOW about a nearby moving ship (identified by visual lookout)
24	Crew → Horn operating system	• Sound horn

Control action numbers **11** and **15** remain the same as previous.

The Feedbacks of this sub-phase are presented in Table 4.24.

Table 4.24: Feedbacks of the sub-phase of anchored condition of the ship.

ID	Feedback path	Description of Feedback
q	Navigational instruments → Conning officer (OOW)	• Visual sensory feedback • Auditory sensory feedback
r	Conning officer (OOW) → Crew	• Verbal feedback
s	Horn system → Crew	• Auditory sensory feedback

Feedback numbers **c**, **g**, **i** and **j** remain the same as previous.

The Communication numbers **xx** and **yy** remain the same as previous.

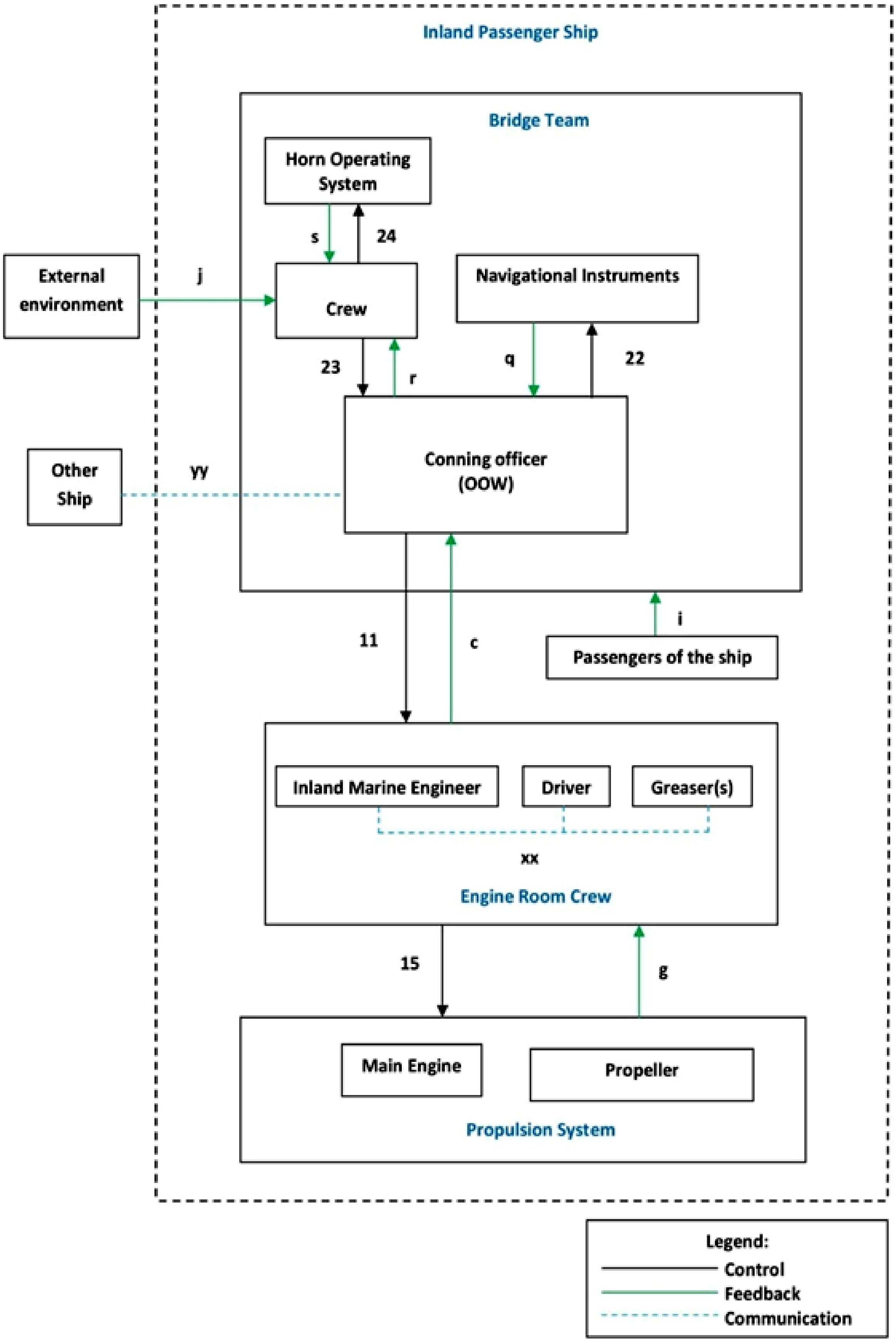


Fig. 4.22: Functional control structure of an inland passenger ship during the sub-phase of anchored condition.

The Unsafe Control Actions of this sub-phase are presented in Table 4.25.

Table 4.25: Unsafe Control Actions of the sub-phase of anchored condition of the ship.

Controller	Control Actions (CA)	Not providing CA causes hazard	Providing CA causes hazard	Wrong timing/Order of CA causes hazard (applied too early or too late)	CA stopped too soon/applied too long
Conning officer (OOW)	**Position fixing of the ship**	N/A	**UCA 2d-1:** Position fixing of the ship is done inaccurately by OOW when it is needed to check anchor dragging of the ship in anchored condition. [H1, H2]	N/A	N/A
Conning officer (OOW)	**Communicate with a nearby ship by VHF**	**UCA 2d-2:** OOW does not communicate by VHF with the nearby ship when it is needed to communicate to avoid any contact with the ship. [H1]	N/A	**UCA 2d-3:** OOW communicates with a nearby ship too late by VHF when it is needed to communicate to avoid any contact with the ship. [H1]	N/A

Conning officer (OOW)	**Monitor the movement of nearby ships in radar**	**UCA 2d-4:** OOW does not monitor the traffic movement on the radar when there is a moving ship in the vicinity. [H1]	N/A	**UCA 2d-5:** OOW monitors the traffic movement on the radar too late when there is a moving ship in the vicinity. [H1]	N/A
Crew	**Inform OOW about a nearby moving ship (identified by visual lookout)**	N/A	**UCA 2d-6:** Crew reports OOW with inadequate information regarding ship characteristics after identification of a nearby moving ship by the visual lookout. [H1]	N/A	N/A
Crew	**Sound horn**	N/A	**UCA 2d-7:** Crew sounds horn inadequately when it is needed to sound the horn to warn the nearby moving vessels about the anchored condition of the passenger ship. [H1]	N/A	N/A

The Controller constraints of this sub-phase are given below:

SC 2d-1: Position fixing of the ship must be done accurately by OOW when the ship is in anchored condition. [UCA 2d-1]
SC 2d-2: OOW must communicate by VHF with a nearby ship when it is needed to communicate to avoid any contact with the ship. [UCA 2d-2, UCA 2d-3]
SC 2d-3: OOW must properly monitor the traffic movement on the radar to check any moving ship in the vicinity. [UCA 2d-4, UCA 2d-5]
SC 2d-4: Crew must properly conduct the visual lookout to report OOW with complete information regarding ship characteristics after identification of a nearby moving ship. [UCA 2d-6]
SC 2d-5: Crew must sound horn properly to warn any nearby moving ship when the passenger ship remains in the anchored condition. [UCA 2d-7]

In addition to the Unsafe Control Actions (UCA) and associated safety constraints listed above, the Unsafe Control Actions (UCA) listed in Table 4.26 are also included in this sub-phase. These are not described yet again for the repetition of similar unsafe control actions (UCA) and associated causal scenarios.

Table 4.26: Additional Unsafe Control Actions (UCA) to be considered in the sub-phase of anchored condition of the ship.

Controller	Unsafe Control Actions (UCA)
Engine room crew	UCA 2a-25, UCA 2a-26, UCA 2a-27, UCA 2a-28, UCA 2a-29, UCA 2a-30

The analysis of the Causal Scenarios is presented below:

<u>Unsafe Control Action-UCA 2d-1:</u> Position fixing of the ship is done inaccurately by OOW when it is needed to check anchor dragging of the ship in anchored condition. [H1, H2]

Scenario 2d-1:

When the ship is in anchored condition, it is necessary to draw the swinging circle of the ship to determine the probable direction of motion of the ship. The position of the ship should be fixed by drawing the swinging circle. If the ship moves out of the swinging circle then it is confirmed that the anchor is being dragged. Therefore, it is very important to check whether anchor dragging occurs or not. Besides, the echo sounder should also be used to check the underkeel clearance of the ship in the anchorage area. If these are not calculated properly the ship may experience collision or grounding. However, OOW fixes the position of the ship inaccurately for having improper knowledge or lack of training regarding fixing the position of the passenger ship.

Possible Requirements for scenario 2d-1:

1. To fix the position of the ship accurately, the OOW should not rely only on a single technique; rather he should apply a number of techniques viz. set anchor watch alarm to the GPS (set to alarm when the ship moves out of swinging circle and negative speed over ground), watching on radar and taking visual bearing of two objects located at shore.
2. Specific guidelines should be developed to use the navigational instruments by following a checklist procedure.
3. Adequate training is essential to avoid any mistake regarding position fixing of the ship

Unsafe Control Action-UCA 2d-2: OOW does not communicate by VHF with the nearby ship when it is needed to communicate to avoid any contact with the ship. [H1]

Scenario 2d-2:

When the ship is in the anchored condition it remains almost stationary in the anchorage area. So it is very important to observe the movement of nearby traffic and contact by VHF whenever necessary. However, the OOW does not communicate with the nearby ship for having an incorrect mental model that, since the anchor light is shown in a good weather condition and the horn is sounded after a particular interval, hence it is not needed to communicate with a nearby moving vessel.

Possible Requirements for scenario 2d-2:

1. For ease of deciding to make contact by VHF, an approximate safe range of distance should be selected. If any ship comes within that specific range and does not change the track that may lead to a collision, then communication

should be made immediately. As for instance, a distance of 2 km from the swinging circle can be fixed on the radar.

2. Adequate training and learning some case studies regarding accidents of the ship in anchored condition are helpful to avoid any confusion and consequent hazardous situation during the stay at the anchorage area.

Scenario 2d-2u:

OOW had made contact with a number of ships for several times and each time he was informed by the bridge personnel of those ships that they are aware of the anchored condition of the inland passenger ship. So, OOW being complacent decides that it is not necessary to further communicate with the nearby moving ships.

Possible Requirements for scenario 2d-2u:

When the ship is in anchored condition, the OOW should closely monitor the movement of a nearby moving ship. He should never leave the attempt to communicate by VHF communication for being complacent at any time.

Unsafe Control Action-UCA 2d-3: OOW communicates with a nearby ship too late by VHF when it is needed to communicate to avoid any contact with the ship. [H1]

Scenario 2d-3:

Anchoring and stay of the ship in anchored condition may not be needed frequently by a passenger ship in the inland river routes. Hence OOW may face a novel situation when he has to handle a ship in the anchored condition after a long time. While the ship is in anchored condition, OOW continues monitoring the movement of a nearby ship and waits for a while thinking that it will move away from its current course. However, due to misjudgment about speed and handling characteristics of the ship he made VHF contact with the ship that is too late to avoid the collision.

Possible Requirements for scenario 2d-3:

1. The radar watch alarm must not be kept off and should be set to alarm at a short interval so that OOW remains aware of the surrounding traffic movement by monitoring in radar without being distracted.

2. The training of bridge team members should be conducted on a regular basis so that no crew experiences a novel situation (regarding anchoring of a ship after a long time).
3. OOW should report Master whenever he feels that he is task saturated and is unable to handle the ship safely at the anchored condition. He should seek assistance from an additional crew on the bridge.

Scenario 2d-3u:

In a busy navigational area, OOW keeps monitoring in radar and identifies a nearby moving ship. He attempts to make VHF contact with the ship and communicated accordingly to inform about the anchored condition of the passenger ship. However, the location of the VHF system within the passenger ship is located at a distance from where keeping simultaneous observation in radar is not possible. Therefore, during the conversation, he could not detect the location and movement of another ship that is coming closer to the ship. OOW made contact with the ship, but that is too late to avoid the collision.

Possible Requirements for scenario 2d-3u:

1. The bridge deck should be designed properly so that all the navigational instruments are installed at a close distance and monitoring action in radar is not hampered during any conversation by VHF.
2. If the OOW feels task saturated (e.g. he has to make frequent conversation by VHF due to the presence of high-density traffic) then he should seek assistance immediately by informing Master.

<u>Unsafe Control Action-UCA 2d-4:</u> OOW does not monitor the traffic movement on radar when there is a moving ship in the vicinity. [H1]

Scenario 2d-4:

During the stay of the vessel in the anchored condition, the visibility condition is good and the crew performs visual lookout action. Therefore, OOW keeps himself concentrated in other activities like position fixing and anchor dragging calculation etc. He does not keep monitoring traffic movement in radar having an incorrect mental model that the crew (on duty of visual lookout) will inform him regarding the presence of any vessel in the vicinity. The causal factors behind this incorrect mental model are:

1. Self-complacency of OOW.
2. Inadequate knowledge and skill of OOW regarding the safe operation of the ship during anchored condition.

Possible Requirements for scenario 2d-4:

1. When the ship is in anchored condition, OOW should never leave monitoring the movement of a nearby moving ship. He should closely monitor the nearby traffic movement by observing radar.
2. The arrangement of regular training, including analysis of some case studies regarding the safety of passenger ship during the anchored condition and the importance and techniques of monitoring procedure on the radar should be conducted.

<u>Unsafe Control Action-UCA 2d-5</u>: OOW monitors the traffic movement on the radar too late when there is a moving ship in the vicinity. [H1]

Scenario 2d-5:

OOW is task saturated with position fixing, anchor dragging calculation, etc. in a busy navigational area and is distracted to perform the monitoring action properly. Consequently, he detects a ship coming closer to the passenger ship. However, the situation might become such that it is too late to avoid contact.

Possible Requirements for scenario 2d-5:

1. For ease of deciding to make contact by VHF, an approximate safe range of distance should be selected. If any ship comes within that specific range and does not change the track that may lead to a collision, then communication should be made immediately. As for instance, a distance of 2 km from the swinging circle can be fixed on the radar.

2. Regular training should be arranged to enhance the skill of bridge team members during the anchored condition of the ship.

Unsafe Control Action-UCA 2d-6: Crew reports OOW with inadequate information regarding ship characteristics after identification of a nearby moving ship by the visual lookout. [H1]

Scenario 2d-6:

In restricted visibility condition, the crew has identified a moving ship ahead and informed OOW without complete description like *'there is a moving ship ahead, can you detect it on the radar?'* Or, the crew does not specify the location of the ship that is located on the port side of the ship. OOW checking on radar replies to the crew *'I have marked it on radar and monitoring its motion'*. In fact, there were two ships in the nearby location; one on the port side and another on the starboard side. OOW has not identified the ship informed by crew as being missed on the radar (using inappropriate range scale). Rather, he thinks it as another ship he detects on the radar; that is, on the starboard side of the ship. Inadequate communication (containing insufficient information) is the main factor behind this scenario.

Possible Requirements for scenario 2d-6:

1. The crew on lookout operation should not inform OOW in an ambiguous way. Rather, he should specify clearly the location or direction of motion of the ship and ensure that it is detected on radar.
2. The crew should look all around (e.g. astern, ahead and lateral) for the presence of any moving ship. He should move both sides of the bridge deck to perform the visual lookout action effectively.
3. The OOW must seek a clear explanation from the crew regarding approximate location and movement of the nearby ship.
4. Training should be arranged on a regular basis to improve communication among bridge team members. It is also helpful to remove any confusion during communication by studying some real case studies of some incidents.

Unsafe Control Action-UCA 2d-7: Crew sounds horn inadequately when it is needed to sound the horn to warn the nearby moving vessels about the anchored condition of the passenger ship. [H1]

Scenario 2d-7:

The crew has to give the horns along with performing visual lookout operation in the bridge when the ship is in anchored condition. The crew has an incorrect mental model that sounding horn (after a particular time interval) is basically effective during foggy weather. Since during the stay of the ship in anchored condition specific light (during the night) or visual signal (during the daytime) is shown, so he thinks that in clear weather it is not necessary to continue sounding the horn at a particular interval. Rather, he decides to sound the horn whenever any ship comes to his sight.

Possible Requirements for scenario 2d-7:

1. The crew should never stop giving horn in any situation. Because this is a form of the first non-verbal communication with the other ships. OOW should ensure it by proper guidance to the crew when the ship is in anchored condition.
2. Proper training is essential to enrich adequate knowledge of the crew regarding the safety of passenger ship in anchored condition.

4.4.2.5 Sub-phase 2e- Pilot acting as the conning officer

The pilot has the expertise of maneuvering a ship in a particular waterway zone where special skill is needed. After embarkation on the ship, he is assisted by the bridge team to maneuver the ship. It is recommended that he should become the conning officer of the ship. However, the Master can change it depending on the prevailing circumstances. In this case, the pilot is considered as the conning officer of the ship. The safety related responsibilities, control action, feedback and communication of all crews during this sub-phase are presented in Table 4.27.

Table 4.27: Safety related responsibilities of the crews during the sub-phase of Pilot acting as the conning officer.

Designation of Crew	Safety Related Responsibilities
Conning officer (Pilot)	• To check the pilot card to get acquainted about the characteristics of the ship. • Directs the ship on the correct course and speed the ship has to follow to safely execute the voyage plan based on his specialized knowledge on local winds, tides and currents, weather, water depths and underwater obstruction etc. • To keep communication with the conning officer (Master) and OOW for safe maneuvering of the ship. • Ensure safe motion, navigation and maneuvering of the ship by giving the proper navigational command to the helmsman. • To monitor the steering operation of helmsman after the verbal command. • Operate radar for proper maneuvering of the ship (to identify any ship or obstruction ahead). • Follow track and visual fixing of the position of the ship by checking paper charts, GPS and gyroscope. • Monitor or check the status of echo sounder to check the water depth. • Control engine rpm (either manually or by giving command to the engine room team).

	• Keep communication and provide command to the engine room crews. • Take decisions regarding maneuvering from the communication made to the conning officer (Master) of the nearby moving ship via VHF (engaged in traffic negotiations with other ships).
Master	• Responsible for ensuring the overall safety of the ship • Supervise and monitor actions of the pilot by cross-checking with navigational instruments • Seek explanation or clarification regarding any decision of pilot whenever it seems unsafe considering the external situation
OOW	• Monitor the actions of the pilot by cross-checking with navigational instruments • Seek explanation or clarification regarding any decision of pilot whenever it seems unsafe considering the external situation • Visual lookout of the external situation

The responsibilities of the helmsman, inland marine engineer, driver and greaser remain the same as previous.

The Control Actions of this sub-phase are presented in Table 4.28.

Table 4.28: Control Actions of the sub-phase of Pilot acting as the conning officer.

ID	Control Action path	Description of Control Action
25	Conning officer (Pilot) → Navigational instruments	• Check the pilot card of the ship.
26	Master → Conning officer (Pilot)	• Monitor the actions of the pilot by cross-checking with navigational instruments.
27	OOW → Conning officer (Pilot)	• Monitor the actions of the pilot by cross-checking with navigational instruments. • Speak up to seek clarification.
19	OOW → External environment	• Visual lookout of external situation

Control action numbers **9**, **10**, **11**, **12, 13** and **15** remain the same as previous.

The Feedbacks of this sub-phase are presented in Table 4.29.

Table 4.29: Feedbacks of the sub-phase of Pilot acting as the conning officer.

ID	Feedback path	Description of Feedback
t	Navigational instruments → Conning officer (pilot)	• Visual sensory feedback • Auditory sensory feedback
u	Conning officer (Pilot) → Master	• Verbal feedback (explanation of the action being commanded when asked by the Master)
v	Conning officer (Pilot) → OOW	• Verbal feedback (explanation of the action being commanded when asked by OOW)
w	Navigational instruments → OOW	• Visual sensory feedback • Auditory sensory feedback
n	External environment → OOW	• Visual sensory feedback • Auditory sensory feedback • Proprioceptive feedback

Feedback numbers **a**, **b**, **c**, **d, g, h, i**, and **j** remain the same as previous.

The Communication numbers **xx** and **yy** remain the same as previous.

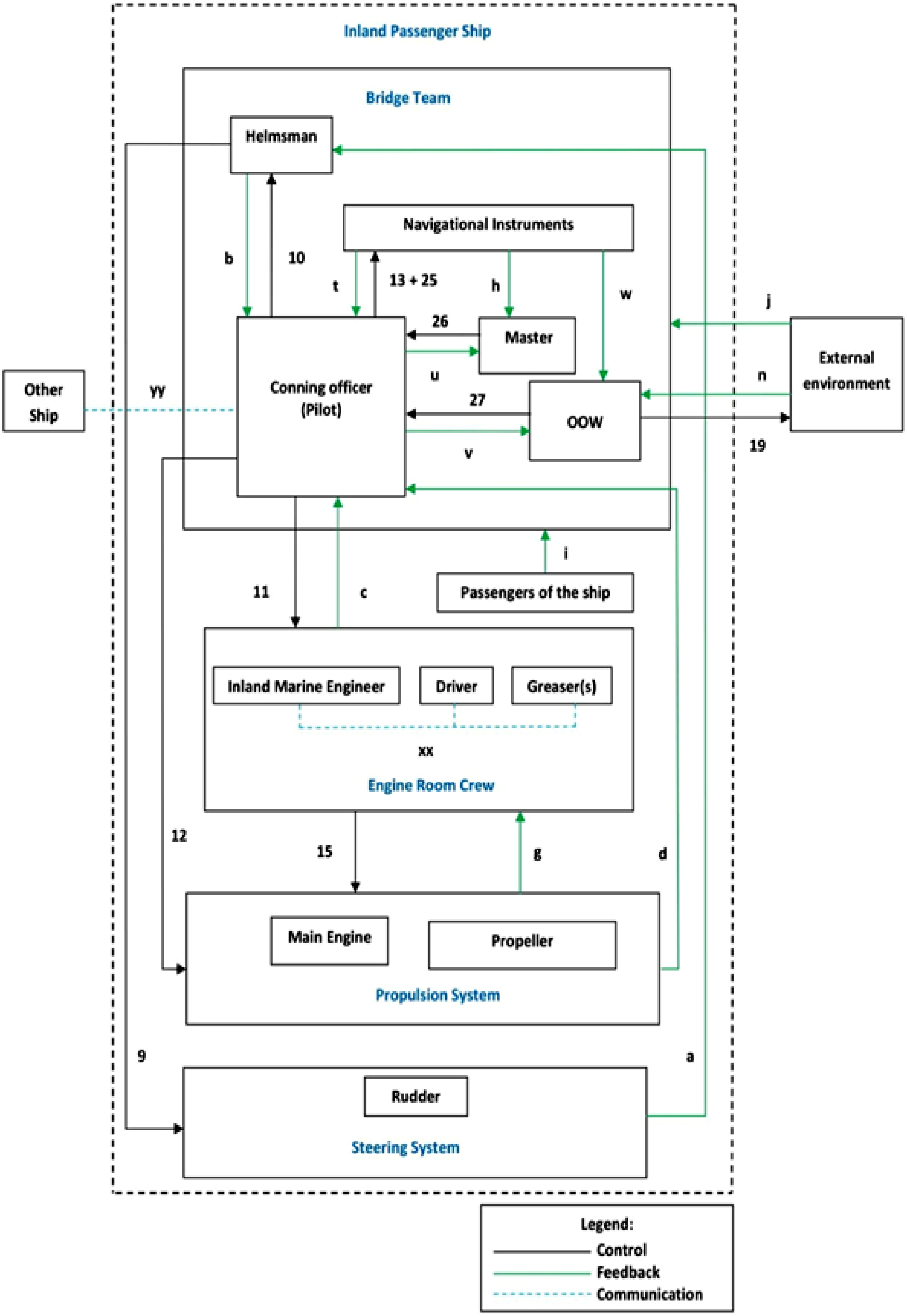


Fig. 4.23: Functional control structure of an inland passenger ship during the sub-phase of Pilot acting as the conning officer.

The Unsafe Control Actions of this sub-phase are presented in Table 4.30.

Table 4.30: Unsafe Control Actions of the sub-phase of Pilot acting as the conning officer.

Controller	**Control Actions (CA)**	**Not providing CA causes hazard**	**Providing CA causes hazard**	**Wrong timing/Order of CA causes hazard (applied too early or too late)**	**CA stopped too soon/applied too long**
Conning officer (Pilot)	**Check the pilot card of the ship**	**UCA 2e-1**: The Pilot does not check the pilot card before taking the responsibility of conning the ship. [H1, H2]	N/A	N/A	N/A
Master	**Monitor actions of the pilot by cross-checking with navigational instruments**	**UCA 2e-2**: Master does not monitor the actions of pilot by cross-checking with navigational instruments after the pilot has taken the conning responsibility. [H1, H2]	**UCA 2e-3**: Master inadequately monitors the actions of pilot by cross-checking with navigational instruments after the pilot has taken the conning responsibility. [H1, H2]	N/A	N/A

OOW	**Monitor actions of pilot by cross-checking with navigational instruments**	N/A	**UCA 2e-4**: OOW inadequately monitors actions of the pilot by cross-checking with navigational instruments after the pilot has taken the conning responsibility. [H1, H2]	N/A	N/A
OOW	**Speak up to Seek clarification**	**UCA 2e-5**: OOW does not speak up to seek clarification from the pilot whenever OOW is in doubt of any decision or action for being safe. [H1, H2]	N/A	N/A	N/A
OOW	**Visual lookout of external situation**	N/A	**UCA 2e-6**: OOW inadequately performs the visual lookout of the external situation after the pilot has taken the conning responsibility. [H1, H2]	N/A	N/A

The Controller constraints of this sub-phase are given below:

SC 2e-1: Pilot must check the pilot card before taking the responsibility of conning the ship. [UCA 2e-1]
SC 2e-2: Master must properly monitor the actions of the pilot by cross-checking with navigational instruments after the pilot has taken the conning responsibility. [UCA 2e-2, UCA 2e-3]
SC 2e-3: OOW must properly monitor the actions of the pilot by cross-checking with navigational instruments after the pilot has taken the conning responsibility. [UCA 2e-4]
SC 2e-4: OOW must speak up to seek clarification from the pilot whenever OOW is in doubt of any decision or action for being safe. [UCA 2e-5]
SC 2e-5: OOW must perform the visual lookout of external situation properly after the pilot has taken the conning responsibility. [UCA 2e-6]

In addition to the Unsafe Control Actions (UCA) and associated safety constraints listed above, the Unsafe Control Actions (UCA) listed in Table 4.31 are also included in this sub-phase. These are not described yet again for the repetition of similar Unsafe Control Actions (UCA) and associated causal scenarios. However, in this case, the control actions of the conning officer are performed by the pilot instead of Master and responsibilities of OOW to operate navigational instruments are also performed by the pilot.

Table 4.31: Additional Unsafe Control Actions (UCA) to be considered in the sub-phase of Pilot acting as the conning officer.

Controller	**Unsafe Control Actions (UCA)**
Helmsman	UCA 2a-1, UCA 2a-2, UCA 2a-3
Conning officer (Pilot)	UCA 2a-4, UCA 2a-5, UCA 2a-6, UCA 2a-7, UCA 2a-8, UCA 2a-9, UCA 2a-10, UCA 2a-11, UCA 2a-12, UCA 2a-13, UCA 2a-14, UCA 2a-15, UCA 2a-16, UCA 2a-17, UCA 2a-18, UCA 2a-19, UCA 2a-20, UCA 2a-21
Engine room crew	UCA 2a-25, UCA 2a-26, UCA 2a-27, UCA 2a-28, UCA 2a-29, UCA 2a-30

The analysis of the Causal Scenarios is presented below:

Unsafe Control Action-UCA 2e-1: Pilot does not check the pilot card before taking the responsibility of conning the ship. [H1, H2]

Scenario 2e-1:

Before receiving the responsibility of conning from the Master, it is necessary for the pilot to check the pilot card. The general information regarding characteristics of the ship like stopping distance, steering characteristics, engine power etc. are known from the pilot card. These characteristics vary from ship to ship. Thus, it is very important for the pilot to check the pilot card before taking the responsibility of conning for safe maneuvering of the ship. However, the pilot has an incorrect mental model that he has lots of experience of maneuvering a ship in this particular route. Therefore, he does not check the pilot card for being complacent.

Possible Requirements for scenario 2e-1:

1. The Pilot should accept that human can make mistakes. He should also recognize that many accidents have occurred in previous due to misjudgment of the pilots. Therefore, he must check the pilot card before receiving the conning responsibility. Adequate training of the pilot should be conducted to remove the complacent behaviors.
2. Master should ensure that pilot has checked the pilot card properly before taking the responsibility of the conning the ship.

Scenario 2e-1u:

The Pilot had the intention to check the pilot card, but he had to leave that intention later. This may occur due to the fact that Master insists on the pilot to take the conning of the ship as soon as possible to reach the destination in time (existing unsuitable procedure to reduce voyage time).

Possible Requirements for scenario 2e-1u:

1. Master and the other bridge team members should appreciate the importance of the presence of the pilot on the bridge for safe maneuvering. So, pilot should be given enough time to check the pilot card and briefed by the Master. Meanwhile, the pilot

should also discuss the voyage plan and other important aspects with the bridge team members so that there remains no confusion.

2. Bridge team must be trained on a regular basis regarding the responsibility and safety issues when the pilot is on board.

Unsafe Control Action-UCA 2e-2: Master does not monitor the actions of pilot by cross-checking with navigational instruments after the pilot has taken the conning responsibility. [H1, H2]

Scenario 2e-2:

The master should crosscheck the actions and order of pilot after transferring the conning responsibility to the pilot. This is because; the master is ultimately responsible for the overall safety of the ship. However, master has an incorrect mental model regarding cross-checking the actions of the pilot. The reasons could include:

1. When the pilot has been given the responsibility of the Conn of the ship, Master could think that it is not necessary to continue monitoring the actions of the pilot who is basically a local expert.

2. Master believes that he can relax as OOW can perform the monitoring action properly. This is because; it seems to him as repetition of similar task (inadequate knowledge of the master).

Possible Requirements for scenario 2e-2:

1. Pilots are the local expert, having better knowledge to maneuver the ship in a particular zone of waterway route. However, it must be taken into consideration that they are human and may commit any mistake at any time. Therefore, the Master must not cease the monitoring action and work closely with the pilot to ensure the safety of the passenger ship.

2. Bridge team must be trained on a regular basis regarding the responsibility and safety issues when the pilot is on board.

Unsafe Control Action-UCA 2e-3: Master inadequately monitors the actions of the pilot by cross-checking with navigational instruments after the pilot has taken the conning responsibility. [H1, H2]

Scenario 2e-3:

Master has an incorrect mental model that whenever the pilot has taken the conning responsibility it is not so important to continuously monitor the actions of the pilot and crosscheck with navigational instruments. Therefore, he decides to check it inadequately after a particular time interval (e.g.10 minutes). This incorrect mental model is developed within him due to the following causal factors:

1. Successful completion of the voyage without properly monitoring the actions of the pilot in the previous voyages.

2. Inadequate knowledge on the importance of monitoring the actions of the pilot for lack of training.

Possible Requirements for scenario 2e-3:

1. The master should monitor the actions of the pilot without any discontinuity for safe maneuvering of the ship. Pilot and OOW should ensure that they are being assisted by the Master to work as a team.

2. Bridge team must receive adequate training regarding the responsibility and safety issues when the pilot is on board.

<u>Unsafe Control Action-UCA 2e-4:</u> OOW inadequately monitors actions of the pilot by cross-checking with navigational instruments after the pilot has taken the conning responsibility. [H1, H2]

Scenario 2e-4:

OOW has an incorrect mental model that, in the presence of the pilot on the bridge as conning officer having lots of experience, it is not necessary to continuously monitor the actions of pilot by cross-checking with navigational instruments. He thinks it as overlapping of the same work as the pilot is also checking navigational instruments to follow the track. OOW thus has a complacent behavior that no accident will happen in this route when the pilot is present on the bridge. So the OOW performs monitoring action inadequately after a particular time interval (e.g.10 minutes). This incorrect mental model is developed within him for having inadequate knowledge of the importance of monitoring the actions of the pilot due to the lack of sufficient training.

Possible Requirements for scenario 2e-4:

1. OOW should monitor the actions of pilot continuously and help pilot by cross-checking with navigational instruments. There should not be any lack of communication among them. Regular training is helpful to develop such responsibility among the OOW and other bridge team members.
2. Pilot and Master should ensure that they are being assisted by OOW to work as a team.

<u>Unsafe Control Action-UCA 2e-5:</u> OOW does not speak up to seek clarification from the pilot whenever OOW is in doubt of any decision or action for being safe. [H1, H2]

Scenario 2e-5:

The master remains busy with an important task inside the bridge, e.g. contact with other ship via VHF. Meanwhile, the pilot has ordered the helmsman to steer the ship in a track that is not safe or slightly deviated from the planned track. As a result, the ship may enter near to the no-go areas. However, OOW does not seek an explanation or clarification from the pilot about the decision he has taken. Rather, he thinks that as the pilot is an expert on this route, he will handle the situation safely in spite of the ship being deviated from the planned track.

Possible Requirements for scenario 2e-5:

OOW should always speak up to seek clarification from the pilot when any doubt arises regarding actions or intentions of the pilot to ensure the safety of the ship. OOW and other bridge team members must recognize that a number of marine accidents took place due to inadequate communication between pilot and bridge team members. Learning some case studies through training will develop such assertive behavior among the bridge team.

<u>Unsafe Control Action-UCA 2e-6:</u> OOW inadequately performs the visual lookout of the external situation after the pilot has taken the conning responsibility. [H1, H2]

Scenario 2e-6:

In some situation, it may be needed to perform visual lookout by OOW as requested by the pilot. However, the OOW performs the visual lookout inadequately thinking that the route is familiar to the pilot.

Possible Requirements for scenario 2e-6:

1. OOW should leave the attitude that he can relax when there is a pilot at the bridge. He must keep it in mind that the pilot should not be considered as a replacement for bridge team members; rather an integration to the bridge team.

2. Bridge team must receive adequate training regarding the responsibility and safety issues when the pilot is on board.

4.4.2.6 Sub-phase 2f- mooring or unmooring operation of the ship

After berthing a ship into jetty it is needed to moor the ship. Similarly, just before beginning the voyage it is needed to unrig mooring rope from the jetty. The whole mooring process needs considerable safety precautions. The safety related responsibilities, control action, feedback and communication of all crews during this sub-phase are presented in Table 4.32.

Table 4.32: Safety related responsibilities of the crews during the sub-phase of Mooring or unmooring operation of the ship.

Designation of Crew	Safety Related Responsibilities
Conning officer (Master)	• Brief mooring team before mooring operation • Provide Command to OOW for mooring or unmooring operation.
OOW	• Follow instructions of the conning officer (Master) and guide the crew (operating mooring system) accordingly. • Supervise the actions of the crew operating mooring system for safe mooring or unmooring operation.
Crew (operating mooring system)	• Operate mooring windlass for mooring operation as directed by OOW. • Inspect the mooring rope after mooring or unmooring operation • Follow the instructions of OOW

The responsibilities of the helmsman, Inland marine engineer, driver and greaser remain the same as previous.

The Control Actions of this sub-phase are presented in Table 4.33.

Table 4.33: Control Actions of the sub-phase of mooring or unmooring operation of the ship.

ID	Control Action path	Description of Control Action
28	Conning officer (Master) → OOW	• Brief OOW about the safe procedure of mooring or unmooring • Command to unrig mooring rope from jetty
29	OOW → Crew	• Give guidance or direction for safe mooring or unmooring operation
30	Crew → Mooring system	• Mooring or unmooring operation by operating mooring windlass • Visual inspection of mooring rope

Control action numbers **9**, **10**, **11**, **12** and **15** remain the same as previous.

The Feedbacks of this sub-phase are presented in Table 4.34.

Table 4.34: Feedbacks of the sub-phase of mooring or unmooring operation of the ship.

ID	Feedback path	Description of Feedback
x	OOW → Conning officer (Master)	• Verbal feedback about mooring conditions
y	Crew → OOW	• Verbal feedback • Visual sensory feedback
z	Mooring system → Crew	• Visual sensory feedback • Auditory sensory feedback

Feedback numbers **a**, **b**, **c**, **d**, **g**, **i** and **j** remain the same as previous.

The Communication numbers **xx** and **yy** remain the same as previous.

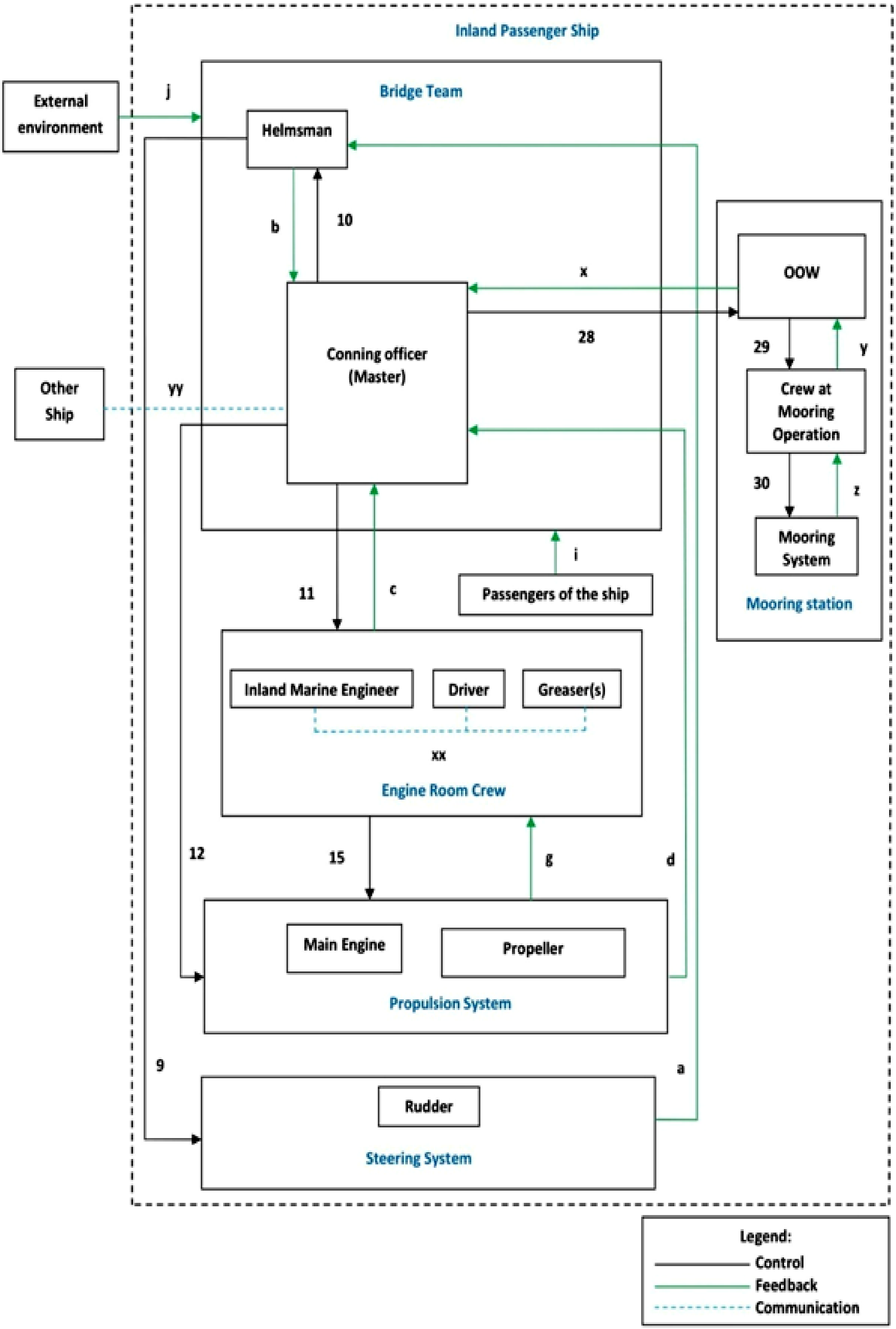


Fig. 4.24: Functional control structure of an inland passenger ship during the sub-phase of mooring or unmooring operation.

The Unsafe Control Actions of this sub-phase are presented in Table 4.35.

Table 4.35: Unsafe Control Actions of the sub-phase of mooring or unmooring operation of the ship.

Controller	Control Actions (CA)	Not providing CA causes hazard	Providing CA causes hazard	Wrong timing/Order of CA causes hazard (applied too early or too late)	CA stopped too soon/applied too long
Conning officer (Master)	**Brief OOW about the safe procedure of mooring/ unmooring**	**UCA 2f-1:** The conning officer (Master) does not brief OOW about the safe procedure of mooring or unmooring before beginning the mooring or unmooring operation. [H3]	N/A	N/A	N/A
Conning officer (Master)	**Command to unrig mooring rope from jetty**	**UCA 2f-2:** The conning officer (Master) does not command OOW to unrig mooring rope from jetty when the ship is about to begin the voyage. [H3]	N/A	N/A	N/A

OOW	**Give guidance or direction for safe mooring or unmooring operation**	**UCA 2f-3:** OOW does not give guidance or direction to the crew during mooring or unmooring operation. [H3]	N/A	N/A	N/A
Crew	**Mooring or unmooring operation by operating mooring windlass**	N/A	**UCA 2f-4:** Mooring or unmooring operation is performed without following the correct procedure by the crew when the ship is being moored at or unmoored from jetty. [H3]	N/A	N/A
Crew	**Visual inspection of mooring rope**	**UCA 2f-5:** Visual inspection of mooring rope is not done by the crew after completing the mooring or unmooring operation. [H3]	N/A	N/A	N/A

The Controller constraints of this sub-phase are given below:

SC 2f-1: The conning officer (Master) must brief OOW about the safe procedure of mooring or unmooring before beginning the mooring or unmooring operation. [UCA 2f-1]

SC 2f-2: The conning officer (Master) must command OOW to unrig mooring rope from jetty when the ship is about to begin the voyage. [UCA 2f-2]

SC 2f-3: OOW does must give guidance or direction to the crew during mooring or unmooring operation. [UCA 2f-3]

SC 2f-4: The crew should perform the mooring or unmooring operation by following the specified procedure during mooring or unmooring process of the ship. [UCA 2f-4]

SC 2f-5: Visual inspection of mooring rope must be done by the crew after completing the mooring or unmooring operation. [UCA 2f-5]

In addition to the Unsafe Control Actions (UCA) and associated safety constraints listed above, the Unsafe Control Actions (UCA) listed in Table 4.36 are also included in this sub-phase. These are not described yet again for the repetition of similar unsafe control actions (UCA) and associated causal scenarios. However, in this case, some control actions of OOW are performed by the conning officer (Master) as OOW moves to the mooring station.

Table 4.36: Additional Unsafe Control Actions (UCA) to be considered in the sub-phase of mooring or unmooring operation of the ship.

Controller	Unsafe Control Actions (UCA)
Helmsman	UCA 2a-1, UCA 2a-2, UCA 2a-3
Conning officer (Master)	UCA 2a-8, UCA 2a-9, UCA 2a-16, UCA 2a-19, UCA 2a-20
Engine room crew	UCA 2a-25, UCA 2a-26, UCA 2a-27, UCA 2a-28, UCA 2a-29, UCA 2a-30

The analysis of the Causal Scenarios is presented below:

Unsafe Control Action-UCA 2f-1: The conning officer (Master) does not brief OOW about the safe procedure of mooring or unmooring before beginning the mooring or unmooring operation. [H3]

Scenario 2f-1:

Before the beginning of mooring or unmooring operation, it is necessary for the conning officer (Master) to give a briefing about a safe mooring operation to OOW. However, the conning officer (Master) does not perform so as he has a mental model flaw regarding briefing that giving guidance before every mooring or unmooring operation is not necessary. This reason is he has a complacent mentality that the crews are well experienced to do the operation safely without any instruction.

Possible Requirements for scenario 2f-1:

The conning officer (Master) should not ignore the importance of briefing about safe mooring or unmooring operation. He must accept that a human can make mistakes at any time, even being experienced in any particular job.

Unsafe Control Action-UCA 2f-2: The conning officer (Master) does not command OOW to unrig mooring rope from jetty when the ship is about to begin the voyage. [H3]

Scenario 2f-2:

There are lots of tasks to do when the voyage is about to begin. One of the main tasks is to unrig mooring rope from the jetty. But the conning officer (Master) orders the OOW to unmoor ship within a specified time e.g. 3 minutes. Therefore, after that time without taking feedback from the OOW at the mooring station, he assumes that the ship has been unmoored within this time (without taking any feedback).

Possible Requirements for scenario 2f-2:

1. The conning officer (Master) must take feedback from the OOW before starting the voyage.
2. In most of the passenger ship (especially the passenger launches) of Bangladesh, the mooring station is not visible from the bridge deck due to extended portion

of bridge deck and upper deck at the front side. Therefore, this limitation should be removed during the design stage of the ship.

Unsafe Control Action-UCA 2f-3: OOW does not give guidance or direction to the crew during mooring or unmooring operation. [H3]

Scenario 2f-3:

During mooring or unmooring operation, OOW should be responsible for the overall safety at mooring station. He should ensure the personal safety of himself and the crew. He has to guide the crew so that mooring or unmooring operation is performed safely. However, he has an incorrect mental model regarding giving guidance to the crew during mooring operation. The reasons may include:

1. OOW thinks that giving guidance during every mooring or unmooring operation is not necessary. Moreover, he has reliance over the crew that he is capable of handling the mooring or unmooring operation safely for having adequate experience.

2. OOW has an incorrect belief that there is no probability of occurrence of an accident as he has not seen or not even heard of any hazardous incident during mooring operation.

3. The conning officer (Master) does not communicate and guide properly OOW to instruct the crew during mooring or unmooring operation. So, OOW is reluctant to guide the crew.

Possible Requirements for scenario 2f-3:

1. OOW should never let the crew alone to perform the mooring operation. Rather he should work closely with the crew and keep contact with the conning officer (Master) to work as a team.
2. The conning officer (Master) should keep contact with OOW for safe mooring operation and take feedback continuously.
3. Proper training and safety drills are essential to improve responsibility, awareness and consciousness regarding the mooring operation.

Unsafe Control Action-UCA 2f-4: Mooring or unmooring operation is performed without following the correct procedure by the crew when the ship is being moored at or unmoored from jetty. [H3]

Scenario 2f-4:

During the mooring or unmooring process, the crew at mooring station stands in the 'snap-back zone' or in a bight of a coil as he is focused only on viewing the mooring or unmooring operation. The crew can do so due to:

1. Losing awareness of personal safety.

2. Inadequate knowledge of safe mooring or unmooring operation.

Possible Requirements for scenario 2f-4:

1. Well painted, marked and highlighted '*snap-back zone'* must be designed on mooring station.
2. The OOW must monitor the actions of the crew properly. He should warn the crew if he observes any unsafe action being done by the crew.
3. Adequate training should be arranged regarding safe mooring operation, including personal and machinery safety issues.

Scenario 2f-4u:

Keeping the lead of rope in the middle of windlass is essential to avoid any incident related to parting the rope. However, the crew can perform the mooring operation improperly or in an unsafe way as he does not keep the lead of the rope in the middle of the windlass. This may be done by him for having a lack of proper knowledge of mooring operation.

Possible Requirements for scenario 2f-4u:

1. The angular or directional lead of rope should be avoided. Rather the lead of rope should be kept in the middle when released from the windlass.
2. Visual inspection of mooring ropes should be made after every mooring operation and during windlass operation.

3. Proper and regular training should be arranged for safe mooring operation.

4. OOW should observe the overall safety issues at the mooring station and warn the crew whenever any important issue arises.

Scenario 2f-4v:

During mooring or unmooring operation, the crew does not wear proper Personal Protective Equipment (PPE). This may happen due to:

1. The crew has inadequate knowledge on the safety of mooring operation.

2. Inadequate guidance from OOW and The conning officer (Master).

Possible Requirements for scenario 2f-4v:

1. The conning officer (Master) should ensure that OOW and crew are attended at the mooring station wearing proper personal protective equipment (PPE). He should guide so during the briefing and confirm it before the beginning of mooring or unmooring process.

2. Specific guidelines should be in place to follow a safety checklist at the mooring station before beginning the mooring operation.

<u>Unsafe Control Action-UCA 2f-5:</u> Visual inspection of mooring rope is not done by the crew after completing the mooring or unmooring operation. [H3]

Scenario 2f-5:

The mooring rope is subjected to a huge tensile force during the stay in port in berthed condition and during the mooring or unmooring operation. Therefore, it is necessary to monitor visually the existing condition of mooring ropes so that it may be replaced before any damage to mooring rope and subsequent human injury occurs. But, the crew is not able to check the condition of mooring rope after completing the mooring or unmooring operation due to fact that he has been given the responsibility of some other tasks just after finishing the mooring or unmooring operation (lack of proper management & planning).

Possible Requirements for scenario 2f-5:

1. The conning officer (Master) and OOW should ensure that the mooring rope is checked after every mooring and unmooring operation. A specific guideline should be in place to follow the inspection schedule properly.

2. Proper maintenance of mooring equipment should be done on a regular basis.

Scenario 2f-5u:

The crew had inspected it before some days or in the previous voyage. He has an incorrect mental model that the standard condition of the mooring rope does not deteriorate quickly. Therefore, a complacent behavior develops within him not to check the condition of the mooring rope after mooring or unmooring operation.

Possible Requirements for scenario 2f-5u:

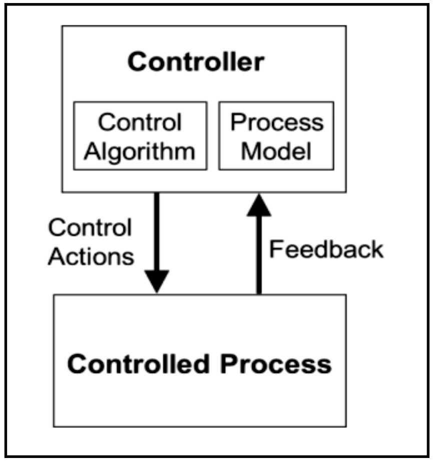
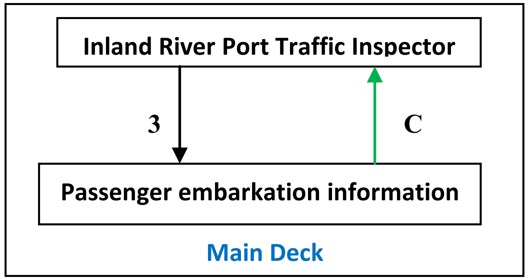
Proper training and learning some case studies regarding mooring incidents are essential to develop the practice of safety during the mooring operation.

4.5 Overview of the Steps of STPA Method Including an Example

Table 4.37 presents the steps of the STPA method along with an application of STPA for the operation of an inland passenger ship. The phase considered here is the stay of the passenger ship in an inland river terminal (sub-phase 1a) and the controller is Inland River Port Traffic Inspector. The Unsafe Control Action considered here is UCA 1a-5.

Table 4.37: Steps of STPA method including an example.

<table>
<tr><th>Step No.</th><th>Steps of STPA Method</th><th>Application of STPA for an inland passenger ship</th></tr>
<tr><td>Step 1</td><td><u>Identify loss:</u>
Losses may include a loss of human life or human injury, damage of property, environmental pollution, loss of mission, or any other loss that is unacceptable to the stakeholders (Leveson and Thomas, 2018).
<u>Identify system-level hazards:</u>
A hazard is a system state or set of conditions that, together with a particular set of worst-case environmental conditions, will lead to a loss (Leveson and Thomas, 2018).
<table>
<tr><th>Hazard specification =</th><th>System</th><th>Unsafe Condition</th><th>Link to Losses</th></tr>
<tr><td>H-1 =</td><td>Ship</td><td>violates minimum separation from another ship.</td><td>[L-1,L-2, L-3]</td></tr>
</table>
<u>Identify system-level constraints:</u>
A system-level constraint specifies system conditions or behaviors that need to be satisfied to prevent hazards and ultimately to prevent the losses (Leveson and Thomas, 2018).
<table>
<tr><th>Safety Constraint =</th><th>System</th><th>Condition to Enforce</th><th>Link to Hazards</th></tr>
<tr><td>SC-1 =</td><td>Ship</td><td>must not violate minimum separation standards from other ships.</td><td>[H-1]</td></tr>
</table>
</td><td>Phase 1-ships' stay at inland river terminal
<u>Loss:</u>
A1: Loss of life or serious injury to people.
A3: Ship is capsized (due to losing stability during the stay at the terminal or after leaving terminal).
<u>Hazard:</u>
h3: Ship is overloaded. [A1, A3]
<u>Safety Constraint:</u>
sc 3: Ship must not exceed the maximum acceptable (designed) limit of loading condition. [h3]</td></tr>
</table>

Step 2	<u>Model the control structure:</u> A hierarchical control structure is a system model that is composed of feedback control loops (Leveson and Thomas, 2018). A hierarchical control structure usually contains at least five types of elements. These are stated below: -Controllers -Control Actions - Feedback - Controlled processes - Other inputs to and outputs from components (neither control nor feedback) 	<u>Controller:</u> Inland River port traffic inspector <u>Safety related responsibilities of Inland River port traffic inspector:</u> • Count and examine the number of passengers onboard to check loading condition of the ship so that it is ensured that the ship is not overloaded. • To give permission to leave the ship from terminal for the voyage after checking that the ship is not overloaded. Control Action ID: **3** Control action path: Inland river port traffic inspector → Passengers Description of control action: Check the loading condition of the ship Feedback ID: **C** Feedback path: Passengers → Inland river port traffic inspector Description of feedback: Visual sensory feedback 

<table>
<tr>
<td>Step 3</td>
<td>Identify the Unsafe Control Actions (UCA):
An Unsafe Control Action (UCA) is a control action that, in a particular context and worst-case environment, will lead to a hazard (Leveson and Thomas, 2018). A control action can be unsafe in four ways. These are:
1. Not providing the control action leads to a hazard.
2. Providing the control action leads to a hazard.
3. Providing a potentially safe control action but too late, too early, or in the wrong order.
4. The control action lasts too long or is stopped too soon (for continuous control actions, not discrete ones).

<table>
<tr><td>Unsafe Control Action=</td><td>Controller</td><td>Type</td><td>Control Action</td><td>Context</td><td>Link to Hazards</td></tr>
<tr><td>UCA-1=</td><td>Master</td><td>does not provide</td><td>the command for changing course of the ship</td><td>when it is needed to avoid contact from any ship ahead.</td><td>[H1]</td></tr>
</table>

Identify Controller constraints:
A controller constraint specifies the controller behaviors that are needed to be satisfied to prevent the occurrence of Unsafe Control Actions. In general, each UCA can be inverted to define constraints for each controller (Leveson and Thomas, 2018).</td>
<td>Controller: Inland River port traffic inspector

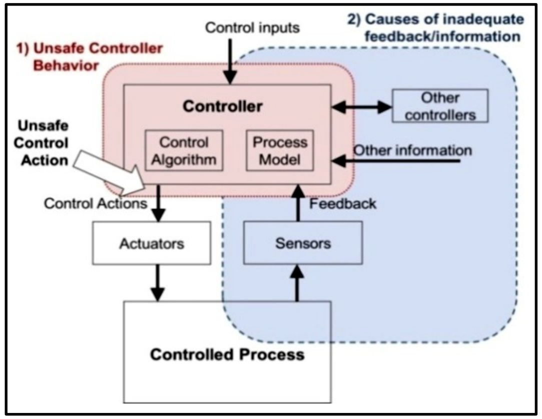
Control Action: Check the loading condition of the ship

Category of control action: Wrong timing/Order of CA causes hazard (applied too early or too late)

Unsafe Control Action-UCA 1a-5: Inland River Port Traffic Inspector starts to check the loading condition of the ship too late from the scheduled time before the voyage. [h3]

SC 1a-4: Inland River Port Traffic Inspector must begin to check the loading condition of the ship at the scheduled time and be performed properly using sufficient time before the voyage. [UCA 1a-5]</td>
</tr>
</table>

<table>
<tr>
<td>Step 4</td>
<td>
<u>Identify loss scenarios:</u>



A loss scenario describes the causal factors that can lead to the unsafe control actions and to hazards (Leveson and Thomas, 2018). To identify loss scenarios that lead to Unsafe Control Actions (UCA) needs the consideration of following two points:

1. Unsafe Controller Behaviors:

There are four general ways a control action can be unsafe (Leveson and Thomas, 2018). These are:

- Failures involving the controller (for physical controllers)
- Inadequate control algorithm
- Unsafe control inputs (from other controllers)
- Inadequate process model

2. Causes of inadequate feedback and information:

Scenarios related to inadequate feedback and information might involve:

- Feedback or information not received
- Inadequate feedback is received

(Note: for details Chapter 3 on Methodology can be seen)
</td>
<td>
<u>Scenario 1a-5:</u>

If the inland river port traffic inspector is given the responsibility of checking the loading condition of several ships within a very short period, then without completing the overload check procedure of one ship, he has to move to another ship (due to the shortage of manpower of regulatory bodies). Therefore, he has to start the procedure of checking the load condition (whether overloaded or not) of a particular ship too late for being burdened with excessive task. Lack of proper management and planning has led to this unsafe control action.

<u>Possible Requirements for scenario 1a-5:</u>

1. A sufficient number of inland river port traffic inspector should be recruited to ensure proper checking and examining of load condition (whether overloaded or not) of the passenger ship.
2. An inland river port traffic inspector should not be given responsibility to check a number of ships within a very short time. He should take sufficient time to check the loading condition of a ship.

<u>Observation from the field visit:</u> Inland river port traffic inspector was not present during the embarkation of the passengers into the passenger ship.

(Note: For detailed description about field observation the Case 2 of Chapter 5 can be seen)
</td>
</tr>
</table>

CHAPTER 5

FIELD OBSERVATION

5.1 General

The purpose of this chapter is to present some findings from the field observation that matches with the analysis of the STPA method. At first, a preliminary discussion is presented that is helpful to match the findings of field observation with the STPA method. After that, the findings from the field observation are presented.

5.2 Preliminary Discussion

At the outset, it is needed to present the definitions of hazard, Unsafe Control Action (UCA) again that were presented in chapter 3. A hazard is a system state or set of conditions that, together with a particular set of worst-case environmental conditions, will lead to a loss (Leveson and Thomas, 2018). In this regard, the study mentions that there are two significant aspects of this definition. The first one is that a hazard should be within the system boundaries over which the controllers have control. For example, a hazard for a ship is not the water current or weather condition; because the designer of the ship has no control over the water current or weather condition. Instead, the hazard may be the ship getting too close to the excessive water current or the ship is in an area of bad weather. In a different way, it can be said that the hazard must be in the design space of those designing and engineering the system or in the operational space of those operating it.

The second part of the definition is that there must be some worst-case set of conditions in the environment that will cause a loss or accident. If there is no set of worst-case conditions inside or outside the system boundary that will combine with the hazard to lead to a loss, then there is no need to consider it in hazard analysis. Even if two ships violate minimum separation, the masters may see each other and avoid a collision, but there are also worst-case conditions under which the accident may not be avoided such as low visibility and lack of attention by the crew etc. Therefore, this can be termed as a hazard (Leveson and Thomas, 2018).

Leveson and Thomas (2018) state that, STPA is a worst-case analysis method; not a best-case, average-case, or most-likely-case method. To explain this fact let us define the Unsafe Control Action (UCA) again. An Unsafe Control Action (UCA) is a control action that, in a particular context and worst-case environment, will lead to a hazard. In a best-case scenario, an UCA might occur early and the crews of a ship recognize that the UCA has happened. Therefore, they immediately take measures to prevent the UCA and there occurs no accident. However, in a worst-case scenario, the crews might not be able to react and recover in time; their attempts to prevent the UCA might be unsuccessful and ultimately an accident can occur. In a worst-case scenario the safeguards may not operate as intended, may not be sufficient, or they may not be effective for the situation at hand. The goal of STPA is not to argue whether the best-case or worst-case scenarios are more likely to occur or to make assumptions about the capabilities and response of the crew.

5.3 Description of Field Observation

To validate the results of STPA analysis it is needed to correlate the findings from the field observation. It will help the researchers and stakeholders to identify the drawbacks of the current operation of the inland passenger ships from the safety perspective. Besides, the advantages and strengths of STPA analysis are also revealed. A number of visits were made at the inland river terminal at Sadarghat of Dhaka District. Figure 5.1 shows some glimpses of the field visit at different locations inside the passenger ship.

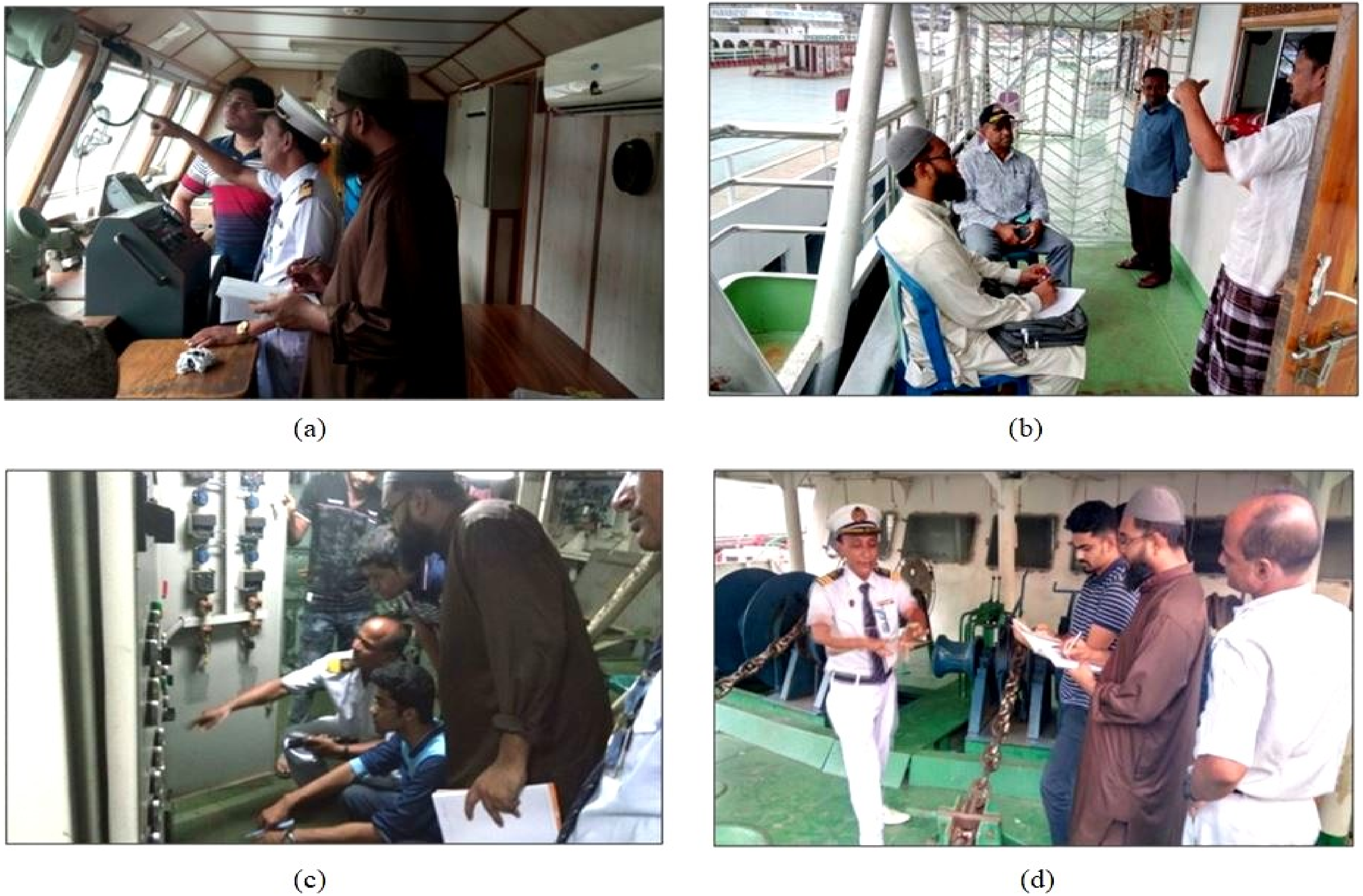


Fig. 5.1: (a) Visit inside the wheelhouse; (b) Conversation with a master during visit at the bridge deck; (c) Visit inside the engine room; (d) Visit at anchor and mooring station of the inland passenger ship.

Before beginning the discussion with the findings of the field visit, it is needed to understand why a UCA may not be found during the field study. This is because an UCA will only occur if the relevant causal factors do occur. It means that a system will move towards a hazardous state if the conditions to fulfill the criteria of UCA are satisfied i.e. if the causal factors are found. It is to be noted that a particular causal factor identified by the analysis may even not be found in thousands of voyages for a particular vessel. Again a number of causal factors may be found in just a single voyage. This is due to the fact that a causal factor is responsible for the occurrence of UCA and hazardous state which is ultimately responsible for the occurrence of an accident. If the hazardous state is not recovered properly then an accident can occur. Therefore, it may not be possible to identify all the causal factors by observing the operation of an inland passenger ship. However, there are some issues that are directly or indirectly related to those causal factors and the possible requirements. The observation by the field visit has identified those issues which are indicative of the current unsafe practice in the operation of an inland passenger ship in Bangladesh. These discrepancies or deviation from the safety standards can be taken into consideration from two viewpoints; relation with the causal factors and relation with the possible requirements. The following section presents these two aspects from the findings of the field observation.

5.4 Findings from Field Observations

The findings from the field observations are discussed below:

5.4.1 Case 1

Unsafe Control Action (UCA) 1a-2 states that OOW performs the appraisal and planning for the voyage inadequately before the voyage. The causal factor related to the UCA is that OOW thinks that any required correction or change of decision (as recommended by river notice) can be made during the voyage. Therefore, OOW does not perform appraisal and planning for the voyage properly and consequently accidents related to the collision, grounding, fire, mechanical failure and structural failure may occur during the voyage.

Observation from the field visit:

During the field visit, it was found that master and OOW are engaged in the preparation of the report of loading condition that is to be submitted to the inland river port traffic inspector. After starting the main engine, only the set-up of some navigational equipment are checked in the bridge deck. Therefore, the appraisal and planning for the voyage in bridge deck is found to be inadequate.

Remarks:

The scenario of STPA matches with the present condition of appraisal and planning for the voyage of the inland passenger vessels. As a result, the hazards related to this scenario can happen at any time during the voyage. Therefore, OOW must complete the steps of appraisal and planning for the voyage properly. Besides, the conning officer (Master) should take frequent feedback from OOW regarding the appraisal and planning for the voyage.

5.4.2 Case 2

Unsafe Control Action (UCA) 1a-4 and Unsafe Control Action (UCA) 1a-5 are concerned with the improper check of the loading condition of the passenger ship before the voyage by the inland river port traffic inspector. The causal factors related to these UCA are allocation of insufficient time for the lack of appropriate number of inland river port traffic inspectors. Therefore the ship may become overloaded and accident may happen during the voyage.

Fig. 5.2: Overloaded vessels due to absence of inland river port traffic inspectors, source: author.

Observation from the field visit:

During the embarkation of the passengers into the passenger launch, the presence of inland river port traffic inspector was not found during the field visit. The most probable causes of this fact may be an inadequate number of inspectors and overlooking behavior of safety issues by them. Therefore, the absence of inland river port traffic inspector often leads to an overloaded passenger ship.

Remarks:

The practical scenario regarding the overloading of the passenger ship is more risky than the hazard indicated by the scenario of STPA analysis. Therefore accidents related to overloading may happen at any time during the voyage. The automatic passenger counting system should therefore be installed at the entry point of the passenger ship to overcome this risk. To ensure proper counting, the specified zone of every passenger can be marked by drawing a rectangular box on the main deck (for passengers remaining on the main passenger deck). Besides, a sufficient number of inland river port traffic inspector should be recruited to ensure proper checking and examining of load condition (whether overloaded or not) of the passenger ship. As a final point an inland river port traffic inspector should not be given responsibility to check a number of ships within a very short time. He should take sufficient time to check the loading condition of a particular passenger ship.

5.4.3 Case 3

The Unsafe Control Action (UCA) 1a-6 is concerned with the improper supervision of embarkation or disembarkation of passengers by the crew. The causal factor responsible for this UCA is the involvement of crew in some other activities of the passenger ship. As a result, any passenger may be injured during the embarkation or disembarkation due to lack of proper supervision and assistance or guidance.

Observation from the field visit:

No crew was found to supervise the embarkation or disembarkation process of the passengers during the field visit. As a result, the passengers were found to embark into the passenger ship without any supervision and guidance.

Fig. 5.3: Embarkation of passengers inside the ship without the supervision of crew, source: author.

Remarks:

The practical scenario regarding the supervision of embarkation and disembarkation of the passengers is more risky than the hazard indicated by the scenario of STPA analysis. As a result, injury or death of any passenger may happen at any time during the embarkation or disembarkation of the passengers. The conning officer (Master) should give necessary instructions or guideline before sending the crew to the task of supervision. Moreover, he should take feedback from the crew instantaneously during the embarkation or disembarkation of passengers.

5.4.4 Case 4

One of the safety requirements regarding the Unsafe Control Action (UCA) 1a-6 is to fit a safe gangway for the passenger for safe embarkation inside the ship or disembarkation from the ship. This is a primary safety issue before the voyage.

Observation from the field visit:

During the field visit it was found that people were embarking and disembarking by using the wooden structure as shown in the figure 5.4 (a). Besides, there was no crew to supervise them, as mentioned earlier.

(a)

(b)

Fig. 5.4: (a) An unsafe gangway is used for passenger embarkation, source: author; (b) A standard gangway for safe embarkation inside a passenger ship, reproduced from Nauticexpo (2019).

Remarks:

The accident reports of the Department of Shipping of Bangladesh reveal that a number of accidents have taken place due to unsafe embarkation of the passengers into the ship. In those accidents many people died and severely injured after being slipped while embarking into the ship. Therefore deployment of a standard gangway for embarkation of the passengers is highly recommended. Figure 5.4 (b) shows a standard gangway for safe embarkation inside a passenger ship.

5.4.5 Case 5

One of the safety requirements regarding the Unsafe Control Action (UCA) 1a-6 is to avoid nose berthing of the passenger ship. The lateral berthing is preferable to ensure the safety of passengers during embarkation inside the ship and disembarkation from the ship.

Observation from the field visit:

It was found that the passenger launches were berthing in the pontoon perpendicularly (nose berthing). It creates the problem of passengers during embarkation and disembarkation. Besides the bow of most of the ships were found to be scratched and slightly deteriorated condition. The obvious reason for this is the high impact (due to not decreasing the speed limit) with pontoon during nose berthing. Moreover, the inadequate space for berthing often causes severe friction with the ships on both sides as shown in figure 5.5.

(a) (b)

Fig. 5.5: (a) Nose berthing of a passenger ship; (b) Inadequate space for berthing often causes lateral friction among the ships, source: author.

Remarks:

To ensure safe embarkation of the pasengers lateral berthing of a passenger ship is preferable. Therefore the capacity of berthing the ship should be increased so that lateral berthing is possible.

5.4.6 Case 6

Unsafe Control Action (UCA) 1a-8 (scenario 1a-8u) is related to the improper checking of the condition of the life-saving appliances by the crew before the voyage. The causal factors behind this UCA are complacent behavior (thinking that there is no deterioration of the condition) regarding the existing condition of the life-saving appliances and insufficient knowledge of crew due to lack of training. If the life-saving appliances are not checked properly then during an emergency these items may not be used effectively to save the lives of the passengers of the ship.

Observation from the field visit:

During field observation, it was found that before the voyage the condition the life-saving appliances are not checked. In addition, it was found that there is not a single life jacket in most of the passenger ships. This is a great deficiency in the context of safety of the huge passenger launches plying in the inland river routes. It is important to mention that there is still no rule for keeping life jackets inside the passenger ship.

Fig. 5.6: Unchecked condition of the lifebuoys before the voyage, source: author.

Remarks:

Passenger vessel is the most vulnerable type of vessel in comparison to other vessel types. This is because a single accident of a passenger vessel may cause the death of hundreds of people. In this regard new laws should be regulated and mandated to keep sufficient life-jackets inside all the passenger ships. Regular training and safety drills should be arranged for the crews to learn the techniques to check the operational readiness and stowage condition of the life-saving appliances effectively.

5.4.7 Case 7

The Unsafe Control Action (UCA) 1a-9 is related to not checking the conditions of mooring ropes by the crew during the change of the draft of the ship or due to any external influence. The causal factor behind this UCA is the involvement of the crew in some other activities in the passenger ship. As a result, the mooring rope may part under huge tension during the change of draft due to tidal effect or any other external influence and an accident can occur.

Observation from the field visit:

It was observed during the field visit that some mooring ropes were in huge tension that is not checked properly by the crews. Besides, some other mooring ropes were found in the worn out condition. If the mooring rope parts then it may cause death or severe injury to the people.

(a) (b)

Fig. 5.7: (a) Unchecked condition of a mooring rope that is under huge tension; (b) Worn out condition of mooring rope, source: author.

Remarks:

The crews of the ship should check the mooring rope after a particular time interval and report to the conning officer (Master) regarding the existing condition in due time. The crew should not involve him in any other task whenever there is a need to check the items.

5.4.8 Case 8

One of the possible requirements regarding the Unsafe Control Action-UCA 2a-5 (Scenario 2a-5u) is to remove the passenger accommodation space behind the wheelhouse on the bridge deck. This is a design issue that hinders the safe operation of the passenger ship.

Observation from the field visit:

It was found that most of the passenger launches have passenger cabin just behind the wheelhouse. Therefore it creates visual obstruction while checking astern for maneuvering purposes. This may lead to a rear-end collision with another ship.

Remarks:

The portion of the bridge deck behind the wheelhouse should be removed during the design stage of the ship. The removal of such extended portion (containing passenger cabin) of the bridge deck from the existing ship needs design consideration with consultation from the ship designers. If it is not possible to eliminate the accommodation area behind the bridge within a short period, then a low-cost solution may be considered on a temporary basis. It could be the installation of a powerful camera at the stern zone of the ship.

Fig. 5.8: Accommodation space behind the wheelhouse on the bridge deck, source: author.

5.4.9 Case 9

The Unsafe Control Action (UCA) 2a-11 is related to moving the passenger ship above the safe speed limit during the rough weather condition. The causal factors related to this UCA are operating the ship at high speed during stormy weather in previous times and inadequate knowledge of the master. The ship may capsize by losing stability in a worst-case due to this unsafe decision.

Observation from the field visit:

Currently there is no regular training program for the ship crews. A crew is promoted to a higher rank considering the length of service and passing an examination for promotion. This is a serious issue as the lack of training may lead to a lack of skill of the crews. During a conversation, a master was asked what he should do during stormy weather. He replied that the speed of the ship should be increased to win against the storm. This complacent behavior and lack of skill may be a significant reason for the accidents during the inclement weather condition in Bangladesh.

Remarks:

Although it may not be possible to record the behavior of a master during the stormy weather, a conversation has led to reveal what the master would actually do in such a situation. Therefore, to avoid such risky behavior of master, proper training should be arranged regularly to enhance the skill of bridge team members (including the master) and to navigate the ship safely during rough weather. Besides, the ship should enter into the nearby specified shelter zone during the stormy weather condition. Updated information regarding weather forecasting should be informed to all ships in due time.

5.4.10 Case 10

The Unsafe Control Action (UCA) 2a-25 is concerned with the improper check of machinery items inside the engine room during the routine inspection. One causal factor behind this UCA is the fatigue caused due to excessive noisy environment inside the engine room. As a result, some machinery items may remain in unchecked condition and this hazardous state can lead to an accident.

Fig. 5.9: Machinery items inside the engine room of an inland passenger ship, source: author.

Observation from the field visit:

During field observation, it was found that the engine room is excessively noisy. It can be a cause of fatigue of the engine room members. Moreover, it also creates problem regarding effective verbal communication among the engine room crews inside the engine room.

Remarks:

Noise and vibration inside the engine room is a design problem. Therefore, the engine room must be designed in such a way that minimizes noise and vibration generated from the machinery. This is important to avoid fatigue of the engine room crews. The engine room team must distribute the tasks so that no one gets fatigued for being task saturated. The fatigue management plan should be developed and followed strictly to avoid fatigue of the engine room crews.

5.4.11 Case 11

The Unsafe Control Action (UCA) 2a-27 is concerned with the delayed cleaning of the accumulated oil that is spilled from the machinery items. One causal factor behind this UCA is the task saturation of the crew. Consequently, an accident (viz. fire and internal damage due to burning) may occur inside the engine room.

Observation from the field visit

During field visit, it was found that there are some zones where spilled oil is found beside the machinery equipment.

Fig. 5.10: Accumulation of spilled oil under the machinery items inside the engine room, source: author.

Remarks:

Removal of spilled oil from the engine room space should be given high priority to avoid hazards related to fire. Therefore, the inland marine engineer should ensure that the cleaning operation is maintained in due time. He should also ensure that no crew is saturated with tasks. The engine room crew should inform other members if he feels fatigued. Fire safety drills should be performed regularly to raise situational awareness and develop the skill of the crews regarding fire safety.

5.4.12 Case 12

The Unsafe Control Action (UCA) 2c-9 is related to not conducting the visual inspection of the anchor system before beginning the anchoring operation. The assigned crew for this responsibility may have an incorrect mental model that regular checking of the anchor system is not needed. The causal factor is that he has self complacency in this regard for checking the anchor system in the last voyage or before few days. As a result, an accident can occur at anchor station during the anchoring operation.

Fig. 5.11: A broken anchor in an inland passenger ship, source: author.

Observation from the field visit

It was mentioned previously that anchoring operation is not a regular activity during the voyage in the inland river routes. However, it was found during the field visit that the overall condition of anchor station is not satisfactory from the safety perspective. Irregular and poor maintenance of anchor station is the major cause behind this fact.

Remarks:

Regular training, safety drills and proper maintenance of anchor station including visual inspection are recommended for ensuring safety in the anchor station. The conning officer (Master) must ensure that before clearing anchor, visual inspection of the anchor system has been conducted by the crew. The anchor windlass should be tested before anchoring and the moving parts should be well greased.

5.4.13 Case 13

The Unsafe Control Action (UCA) 2d-3 is associated with making late communication of OOW with a nearby ship by VHF. One safety requirement to avoid such UCA is to install the navigational equipment (especially the VHF) in bridge deck closely. This will be helpful to avoid unexpected errors of bridge deck crews regarding monitoring the navigational instruments during the conversation by VHF.

Observation from the Field visit:

During field observation, the location of all navigational instruments (including VHF) was found near to the radar which is satisfactory. However, if there is any existing ship where the location of VHF is fixed at a distant location from the radar, then those equipment should be fixed nearly.

Remarks:

During design stage of the ship, the ship designers should keep in mind that the locations of the navigational instruments should be placed as near as possible. This will allow the crews to avoid hazardous situation during operation of the ship.

5.4.14 Case 14

Unsafe Control Action (UCA) 2f-2 is related to the conning officer not commanding OOW to unrig mooring rope from the jetty when the ship starts the voyage. One of the safety requirements to control this UCA is to remove the extended portion of bridge deck and upper deck in the front side.

Observation from the Field visit:

It was found during field observation that most of the passenger launches are designed in such a way that the mooring station is not visible from the bridge deck as seen from the figure 5.12. This hinders the visual supervision by master during mooring operation as well as during anchoring operation.

Fig. 5.12: Extended portion of the bridge deck and upper deck that creates visual obstruction during mooring operation, source: author.

Remarks:

The extended portion of the deck in front of bridge deck and upper deck should be removed during the design stage of the ship. The removal of such extended portion of deck from the existing ship needs design consideration with consultation from the ship designers.

5.4.15 Case 15

One of the possible requirements regarding Unsafe Control Action (UCA) 2f-4 is to design well painted, marked and highlighted ‘snap-back zone’ on mooring station. This will guide the crew for standing at a safe zone during mooring operation.

Observation from the Field visit:

During the field visit, no painted snap-back zone was found in the mooring station of the inland passenger ships. This may lead to death or severe injury of crew if he stands in the snap-back zone during parting of mooring rope.

(a) (b)

Fig. 5.13: Unmarked snap-back zones in the mooring station of the passenger ship, source: author. (b) A well-marked snap-back zone in mooring station, reproduced from The Maritime Executive (2019).

Remarks:

Well marked and painted snap-back zone should be designed in the mooring station as recommended in the possible requirements for scenario 2f-4. Figure 5.13(b) illustrates a standard marked snap-back zone at the mooring station to ensure safe mooring and unmooring operation.

CHAPTER 6

RESULTS AND DISCUSSION

6.1 General

STPA is an extensive hazard analysis method. The major outputs and findings of this analysis will guide the stakeholder related to the passenger vessel operation for comprehending the major threats to the safety. Hence, this chapter will present the results and major findings of the STPA hazard analysis of inland passenger ship operation in Bangladesh.

6.2 Categorization of Losses, Related Accidents and Hazards

The grouping of ‘Loss’ defined at the beginning of the STPA analysis requires to be determined by following some specific rules as described by Leveson and Thomas (2018). Similarly, the hazard list is formed based on the losses. Table 6.1 shows the ‘Loss’ terms defined in the STPA analysis during the ship’s stay at inland river terminal.

Table 6.1: The ‘Loss’ terms defined in the STPA analysis during the ship’s stay at inland river terminal.

Loss ID	Loss
A1	Loss of life or serious injury to people.
A2	Damage to the ship or objects outside the ship occurs.
A3	Ship is capsized (due to losing stability during the stay at the terminal or after leaving terminal).

The term ‘Loss’ used in STPA is somewhat different from the general accident terms. As for example, a number of accident categories such as passenger injury during berthing, accidents due to lack of voyage preparation, capsizing of ship due to overloading, stability failure and collision with permanent obstruction at port are categorized under the same category of ‘Loss’ named as ‘Loss of life or serious injury to people (A1)'. Similarly, the other loss terms A2 and A3 are categorized. This categorization will be helpful to comprehend the results of the STPA analysis. Table 6.2 presents this categorization of losses, accidents and hazards during the stay of the passenger ship at the inland river terminal.

Table 6.2: Categorization of losses, accidents and hazards during the ship's stay at inland river terminal.

Loss ID	Related Accident	Related Hazard
A1	Passenger injury during berthing.	h1: Passengers of the ship are subjected to insufficient supervision and guidance regarding safety by the crews of the ship.
A1, A2	Accident due to insufficient voyage planning (related to collision, grounding, fire, mechanical failure and structural failure).	h2: Voyage preparation and planning is performed inadequately.
A1, A3	Capsizing of the ship for being overloaded.	h3: Ship is overloaded.
A1, A2, A3	Stability failure & collision with permanent obstruction at port.	h4: Ship exceeds the maximum acceptable (designed) limit of list/trim.

In the same way, table 6.3 presents the 'Loss' terms defined in the STPA analysis during the voyage condition of the passenger ship. Furthermore, table 6.4 presents the categorization of losses, accidents and hazards during the voyage condition.

Table 6.3: The 'Loss' terms defined in the STPA analysis during the voyage condition.

Loss ID	Loss
L1	Loss of life or serious injury to people.
L2	Damage to the ship or objects outside the ship.
L3	Ship is capsized.

Table 6.4: Categorization of losses, accidents and hazards during the voyage condition.

Loss ID	Related Accident	Related Hazard
L1, L2	Collision with other ship.	Ship violates minimum separation from other ship.
L1, L2	Grounding and collision with permanent obstruction.	Ship violates minimum separation from any stationary object or underwater object.
L1, L2	Mechanical failure (steering system and machinery failure).	Loss of ship control.
L1, L2	Fire and internal damage due to burning.	Fire occurs inside the ship.
L1, L3	Stormy weather, excessive current & stability failure.	Ship enters into dangerous area/ region.

6.3 Distribution of Unsafe Control Actions (UCA) and Causal Scenarios

Figure 6.1 shows the number of Unsafe Control Actions (UCA) and causal scenarios on the basis of hazard type during the ship's stay at the inland river terminal. It is observed that the numbers of UCA and causal scenarios are highest when the ship is inadequately prepared for the voyage (hazard no. h2). It indicates that there is a greater scope of erroneous or unsafe actions by the crews under this category of hazard. However, those numbers are comparatively lower for both of the cases when the passengers are subjected to insufficient guidance ((hazard no. h1) and when the ship is overloaded (hazard no. h3). The numbers of UCA and causal scenarios are lowest when the ship exceeds the maximum acceptable or designed limit of list/trim (hazard no. h4). That is to say, there is a minor scope of erroneous or unsafe actions by the crews under this category of hazard.

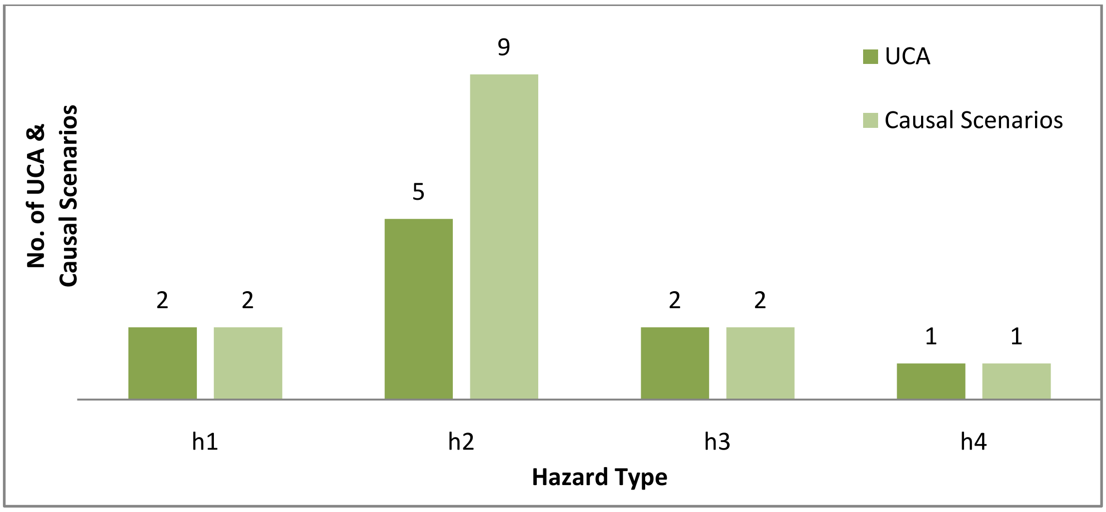


Fig. 6.1: Distribution of Unsafe Control Actions (UCA) and causal scenarios on the basis of hazard type during the ship's stay at the terminal.

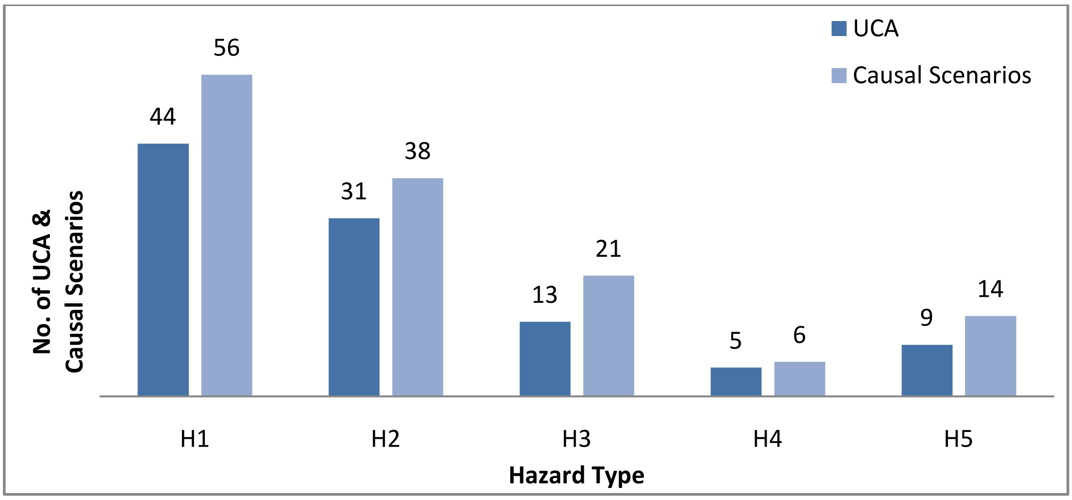


Fig. 6.2: Distribution of Unsafe Control Actions (UCA) and causal scenarios on the basis of hazard type during the voyage condition.

Figure 6.2 shows the number of Unsafe Control Actions (UCA) and causal scenarios on the basis of hazard type during the voyage of the passenger ship. It is observed that the numbers of UCA and causal scenarios are highest for the hazard of violation of minimum separation by the passenger ship from other ship (hazard no. H1). This indicates that there is a greater scope of incorrect or unsafe actions by the crews under this category of hazard. That is to say, there are so many ways a passenger ship may face a situation of colliding with other ship. The second most number of Unsafe Control Actions (UCA) and associated causal scenarios are likely to occur for the hazard category of ship violating minimum separation from any stationary object or underwater object (hazard no. H1). The other hazard types like loss of ship control (hazard no. H3), ship entering into a dangerous area (hazard no. H4) and occurrence of fire inside the ship (hazard no. H5) have comparatively less number of UCA and causal scenarios than the first two types of hazards. Therefore, the most vulnerable category of hazard is related to the collision of the passenger ship. As shown earlier in figure 4.9 that, at present collision is the most frequent type of accident by the passenger ship. Therefore, the analysis by STPA reflects that the wider scope of occurrence of hazards related to the collision is causing the higher number of collision to take place. Moreover, it also indicates the lack of safety constraints that are needed to mitigate those UCAs or hazards related to the collision at present.

6.4 Distribution of Causal Factors

Each causal factor that is identified from the causal scenario of the STPA hazard analysis can be assigned to any of the three causal factor categories i.e. human factor, operational factor and technical factor. The distributions of the factors that are considered under each category of causal factor are illustrated in table 6.5.

Table 6.5: Distribution of the factors considered under each category of causal factor.

Human factor	Operational/ management factor	Technical factor
• Poor decision making or misjudgment • Self-complacency • Inadequate knowledge or skill / lack of training • Fatigue • Task saturation • Failing to communicate effectively or sufficiently with others • Insufficient supervision or overlooking behavior	• Existing unsuitable procedure or legal acts • Lack of proper management or planning & allocation of inadequate time for any specific task • Poor maintenance schedule • Displace any crew from working place	• Poor engineering and design issues • Hardware malfunctions • Other technical issues

The distribution of causal factors on the basis of accident types during the stay of the passenger ship at inland river terminal is illustrated in figure 6.3. It is observed that there is no human factor or technical factor involved for the accidents involving passenger injury during berthing, capsizing of the ship for being overloaded and stability failure & collision accidents at the terminal. The only factor involved in these accidents is the operational or management factor. However, there are two types of factors involved in the occurrence of accident due to lack of voyage preparation; the human factor and operational or management factor. The number of causal factors is also highest under this category of accident.

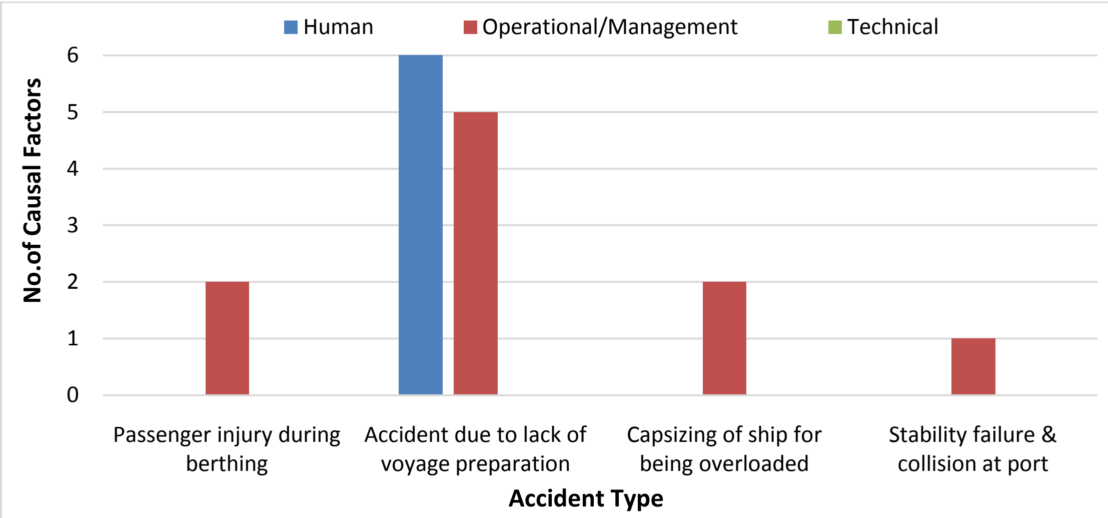


Fig. 6.3: Distribution of causal factors on the basis of accident types during the stay of the passenger ship at the inland river terminal.

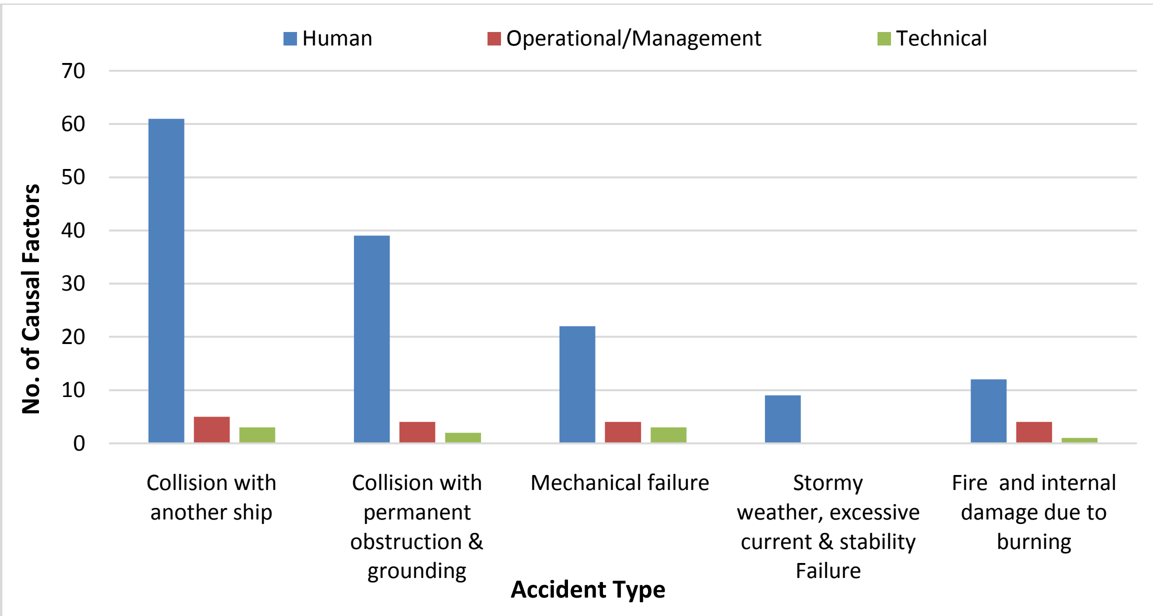


Fig. 6.4: Distribution of causal factors on the basis of accident types during the voyage condition.

The distribution of causal factors on the basis of accident types during the voyage condition is illustrated in figure 6.4. It is observed that, for all types of accidents, the human factor is the leading causal factor. For the accidents collision with another ship, and grounding and collision with permanent obstruction, the human factor has significant contribution than the other types of causal factors. Accidents due to mechanical failure, stormy weather, excessive current & stability failure, and fire have lesser number of causal factors. However, there is no operational or management and technical factor for the accident due to stormy weather, excessive current & stability failure. This implies that these accidents are only caused by the human factor.

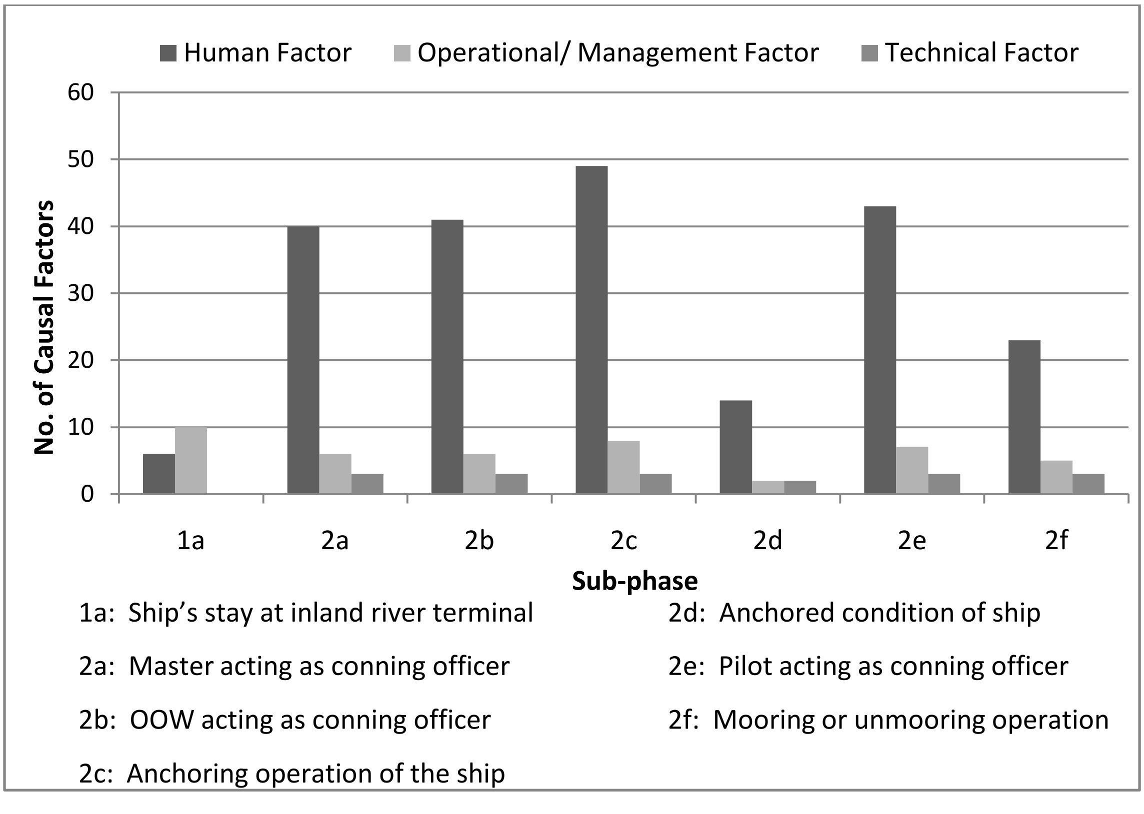


Fig. 6.5: Distribution of the causal factors on the basis of sub-phases of operation of the passenger ship.

The distribution of the causal factors on the basis of the sub-phases of the operation of the passenger ship is illustrated in figure 6.5. It is observed that during all the sub-phases of voyage condition human factor is the leading category of the causal factor, except for the sub-phase 1a. For the sub-phase 1a, the number of causal factors related to operational or management factor is higher than the human factor. During sub-phase 2c (anchoring operation of the ship), the contribution of the human factor is highest. Apart from this, the contribution of the human factor is also significant during the three sub-phases namely sub-phase 2a (Master acting as the conning officer), sub-phase 2b (OOW acting as the conning officer) and sub-phase 2e (Pilot acting as the conning officer).

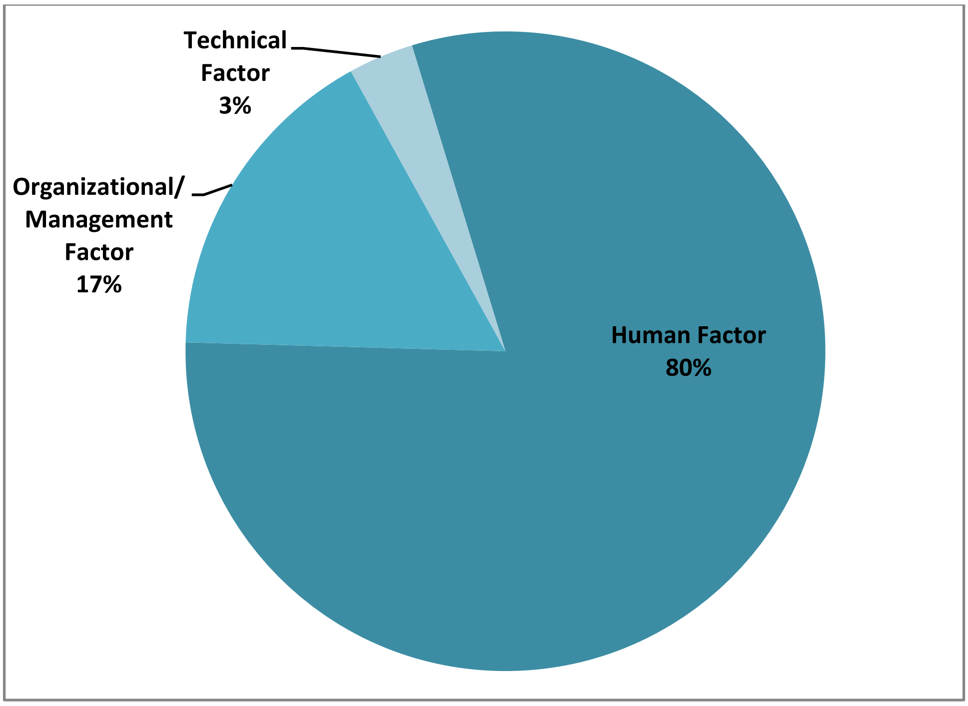


Fig. 6.6: Percentage of the causal factors.

The overall percentages of the causal factors are illustrated in figure 6.6. It is observed that the human factor shares the major proportion (80%) of the causal factors. Apart from this, the operational or management factors and technical factors constitute 17% and 3% of the causal factors respectively. As a final point, it can be stated that in all types of accidents, the contribution of human factor is drastically higher than other factors. Therefore, constraining the effect of human factors by implementing proper safety requirements will obviously reduce the number of accidents.

6.5 Distribution of Safety Requirements

The possible safety requirements that are identified to mitigate the effect of the causal factors by acting as constraints can be assigned to any of the four safety requirements categories i.e. training, team management, technical arrangement, and design modification. The distribution of the factors that are considered under each category of safety requirements are illustrated in table 6.6.

Table 6.6: Distribution of factors considered under each category of safety requirements.

Category of safety requirements	Factors considered under the category
Training	Training of crew to develop individual skill
Team Management	Issues related to Bridge Team Management (BTM) or Engine Room Resource Management (ERM)
Technical Arrangement	Engineering solutions, Recommendations regarding technical or equipment setup.
Design Modification	Modification of existing design of the passenger ship to improve safety.

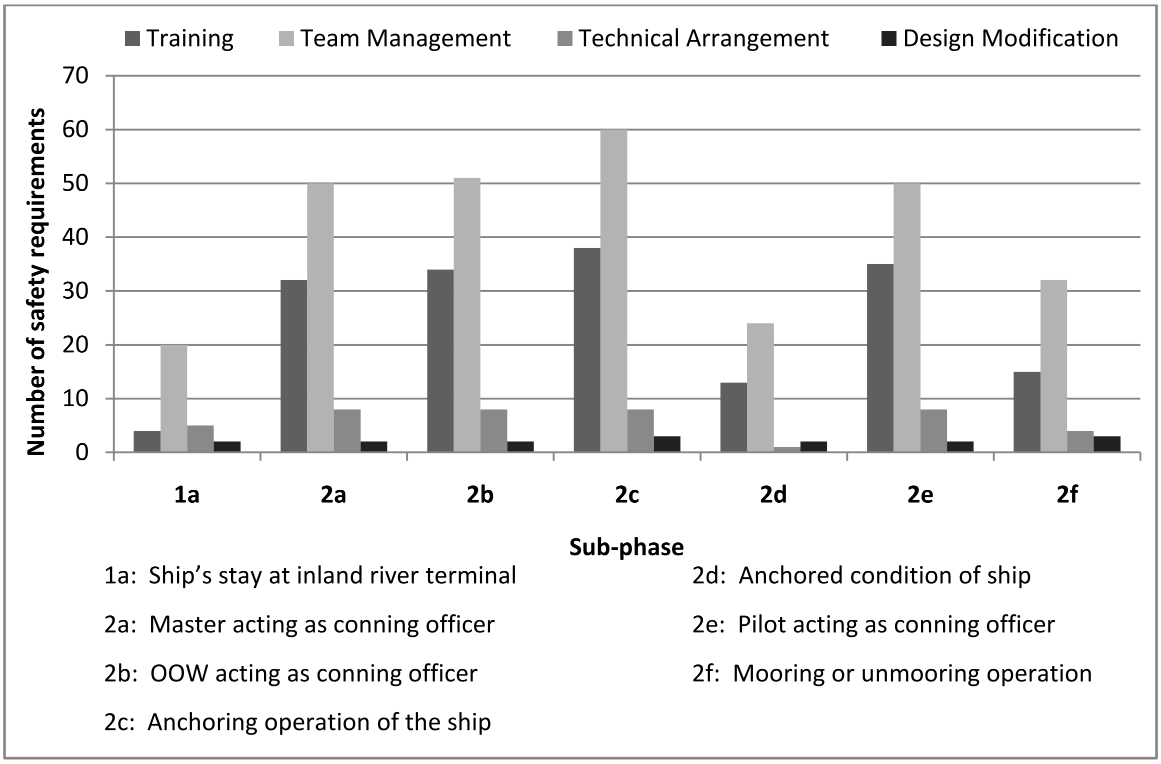


Fig. 6.7: Distribution of safety requirements based on the sub-phases of operation of the passenger ship.

The distribution of the possible safety requirements on the basis of the sub-phases of the operation of the passenger ship is illustrated in figure 6.7. It is seen that the team management is the leading category of safety requirements for all the sub-phases. During the sub-phases 2a (Master acting as the conning officer), 2b (OOW acting as the conning officer), 2c (anchoring operation of the ship) and 2e (Pilot acting as the conning officer) the percentage of the safety requirements related to team management is significantly higher. Except for the sub-phase 1a, the second most leading safety requirement for all sub-phases is the training. The requirements related to the technical arrangement and design modification are comparatively lower than the other types of safety requirements.

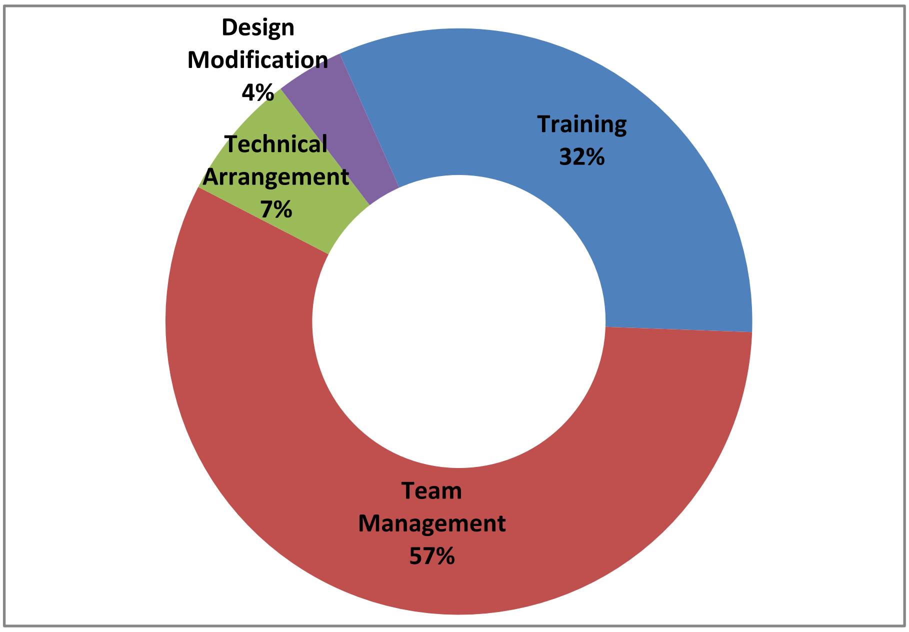


Fig. 6.8: Percentage of the safety requirements.

The percentage distribution of these requirements is illustrated in figure 6.8. It is observed that the team management (57%) and training (32%) share the major part of the safety requirements. In addition, technical arrangement and design modification constitute 7% and 3% of the total safety requirements respectively. The effective implementation of these safety requirements can ensure the safety of the operation of the passenger ships by mitigating the occurrence of Unsafe Control Actions (UCA).

6.6 Summary of Results

The statistical summary of the output of the STPA analysis is shown in figure 6.9. It illustrates the number of Unsafe Control Actions (UCA), causal scenarios, causal factors, and safety requirements during the two phases of vessel operation, namely ship's stay at inland river terminal and voyage condition of the passenger ship. It is observed that the number of Unsafe Control Actions (UCA) is comparatively higher during the voyage condition than the ships' stay at the terminal. Correspondingly the number of causal scenarios, causal factors, and safety requirements are also higher during the voyage condition.

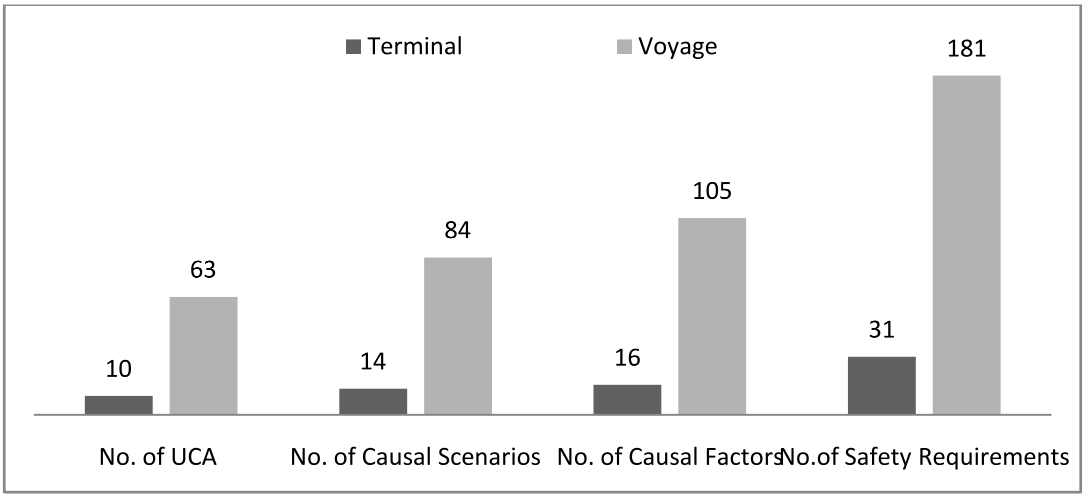
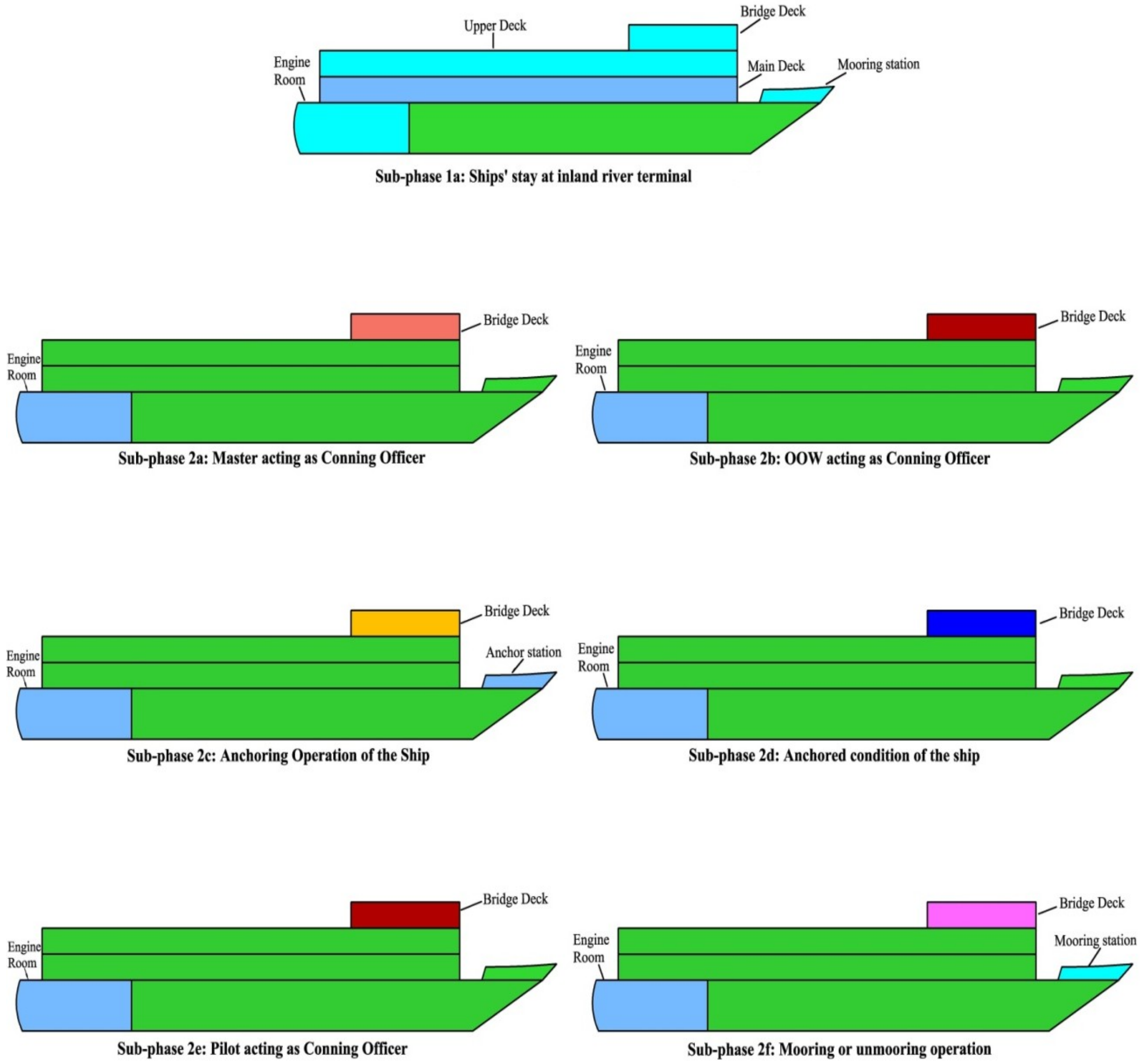


Fig. 6.9: Comparison of the number of UCA, causal scenarios, causal factors and safety requirements among two different phases of the vessel operation.

Table 6.7: Percentage of Unsafe Control Actions (UCA) in different sub-phases of inland passenger ship operation.

Phase	Sub-Phase	No. of Unsafe Control Actions (UCA)	Percentage of UCA
1- Ships' stay at inland river terminal	1a- Ships' stay at inland river terminal	10	5.88%
2- Voyage condition of the ship	2a- Master acting as the conning officer	30	17.65%
	2b- OOW acting as the conning officer	32	18.82%
	2c- Anchoring operation of the ship	33	19.41%
	2d- The anchored condition of the ship	13	7.65%
	2e- Pilot acting as the conning officer	33	19.41%
	2f- Mooring/unmooring operation of the ship	19	11.18%

Table 6.7 presents the percentage of Unsafe Control Actions (UCA) in different sub-phases of operation of the inland passenger ship. It is observed that during each of the sub-phases 2c and 2e the highest percentage (19.41%) of Unsafe Control Actions (UCA) exists in the passenger ship. Besides, the sub-phases 2b and 2a share 18.80% and 17.65% of Unsafe Control Actions (UCA) within the passenger ship respectively. The lowest number of UCA exists for the sub-phase of the ship's stay at inland river terminal.



Number of UCA	Color Code	Number of UCA	Color Code	Number of UCA	Color Code	Number of UCA	Color Code	Number of UCA	Color Code
0		4 - 6		10 - 12		16 - 18		22 - 24	
1 - 3		7 - 9		13 - 15		19 - 21		25 - 27	

Fig. 6.10: Zone-wise distribution of the number of Unsafe Control Actions (UCA) inside the passenger ship in different sub-phases.

The zone-wise distribution of the number of Unsafe Control Actions (UCA) inside the passenger ship during different sub-phases is illustrated in figure 6.10. Sub-phase 1a includes all the activities related to the appraisal and planning for the voyage of the passenger ship during the stay at inland river terminal. All the zones of the ship need to be checked properly in this sub-phase so that the ship is prepared safely for the voyage. Therefore, it is seen that different zones of the passenger ships, namely bridge deck, engine room, main deck, upper deck, and mooring station the generation of a number of Unsafe Control Actions (UCA) occur.

As mentioned earlier that the voyage condition phase is divided into six sub-phases. It is observed from figure 6.10 that, during all these sub-phases most of the Unsafe Control Actions (UCA) are generated from the bridge deck of the passenger ship. Besides, during the sub-phases 2b and 2e, the number of UCA is highest in comparison to the other sub-phases. In each sub-phase of the voyage condition, the second most number of UCA are generated from the engine room. Besides, during the sub-phase 2c, the number of UCA in the anchor station is equal to that of the engine room. During the sub-phase 2f, the number of UCA in the mooring station is almost half of that of the engine room.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 General

The main objectives of this research are to apply STPA hazard analysis to find out the unsafe activities that are responsible for the occurrence of accidents in the inland waterways of Bangladesh and to find possible safety requirements that can mitigate those unsafe acts. This chapter presents some key findings of the study, some recommendations based on those findings and some suggestions for future research works to be carried out in this field.

7.2 Conclusions

The main concern in the inland water transportation system of Bangladesh has been the disastrous accidents and fatalities involving the passenger ships. Although a number of studies analyzed the safety issues of inland passenger ship operations, the recommendations of those studies were unable to reveal and analyze the latent causal factors responsible for the accident. The studies were unable to perform the detailed causal analysis of the unsafe actions related to the operation of the ship. Some of the studies performed a general statistical analysis and put forward a number of general and common recommendations that are being suggested for a long time. Some other studies focused only on a specific area like collision of ships, mitigation of overloading problem, mitigation of stability failure related accident, improvement of ship design and stability etc. However, there was no study that considered the overall problems through extensive analysis. In this regard, the present study has extensively analyzed the unsafe actions involved in the overall operation of an inland passenger ship.

The following conclusions can be drawn from the study:

i) STPA being a top-down approach distinctly identifies the hazards (needed to be controlled to mitigate accidents) within the passenger ship by separating the operation into two main phases i.e. operation of the ship at inland river terminal and during the voyage condition. The voyage condition is again divided into six sub-phases namely Master acting as the conning officer, OOW acting as the conning officer, anchoring process of the ship, anchored condition of the ship, Pilot acting as the conning officer and mooring or unmooring operation of the ship.

ii) At the beginning of the STPA analysis the loss, hazard and safety constraints related to each sub-phase are identified. A safety control structure is then constructed to determine the Unsafe Control Actions (UCA) in all phase and sub-phases. By analyzing the feedback control loops within the safety control structure, several causal scenarios are created to identify the causal factors. Accordingly, a wide range of causal factors related to human and technical aspects are identified that are responsible for the occurrence of hazardous states in the operation of an inland passenger ship. Finally, based on these causal factors a number of safety requirements are recommended that includes design, training, engineering, and management related issues.

iii) To mitigate the effects of the causal factors, the effective implementation of the possible safety requirements are needed. These requirements not only cover the technical aspects but also the non-technical aspects. Implementation of these requirements can improve the safety situation of inland passenger vessel operation in Bangladesh.

iv) The results of the study indicate that the number of hazards and associated Unsafe Control Actions (UCA) are higher during the voyage condition in comparison to the stay of the vessel at inland river terminal.

v) Considering the pattern of accident it is revealed that most of the hazards are associated with the collision of the passenger ship.

vi) The majority of the Unsafe Control Actions (UCA) generates from the bridge deck. During the two sub-phases of voyage condition i.e. anchoring operation and pilot acting as the conning officer, the maximum number of Unsafe Control Actions (UCA) generates from the passenger ship.

vii) The Human Factor (80%) is the most contributing causal factor responsible for the occurrence of the Unsafe Control Actions (UCA). In addition to that, the most significant category of the safety requirements has been found to be the team management.

7.3 Recommendations

Based on the results and findings of the study, the following recommendations can be made:

i) Traditional hazard analysis methods like Swiss Cheese model, Fault Tree Analysis (FTA), Event Tree Analysis (ETA), Failure Mode and Effects Analysis (FMEA), and Hazard and Operability studies (HAZOP) etc. can also be applied independently to compare the results with that of STPA.

ii) It is recommended to apply STPA before developing a new waterway route or expansion of fleet in a particular route to ensure safer water transportation system.

iii) Inside a ship, there are more than thousands of small machinery equipment, instruments and connections that are used to run lots of specified processes. Application of STPA for such huge number of machinery equipment is not possible in this research. However it is necessary to perform such analysis to ensure safety of a ship. Therefore it is recommended that the crews and other expert operators of the passenger ship should extend the analysis for each sub-phase of the ship operation.

iv) Apart from the operation of the inland passenger ships, STPA should be applied to other types of ships i.e. cargo ships, container ships, oil tankers, dumb barges and so on, so that the overall safety of inland water transport can be assessed properly.

v) Passenger vessel safety is not only related to the internal safety aspects but also other external factors like movement of other types of vessels and nature or condition of the waterway route. Therefore, all these factors should be taken into consideration for ensuring the safe operation of the inland passenger vessel.

vi) An area that was not possible to explore in this research is that of CAST (Causal Analysis based on STAMP) method of accident analysis. This is due to the fact that the present accident investigation and documentation process possess technical deficiencies. Hence the formal or scientific accident investigation process is seriously handicapped at present. In order to improve this scenario, the capacity building of human resources and modification of accident investigation and reporting system are highly recommended. It should not focus on blaming the operators; rather the emphasis should be given to improve the system. After improvement of the existing system, future research works can be performed on the accidents in the inland waterways of Bangladesh by applying the CAST method. It would provide deeper insights into the causes behind the UCA that could lead to accidents. Therefore the outputs of the STPA analysis can be assessed or validated in this manner.

vii) To extend the scope and depth of the analysis, STPA can be applied to practical ship operation with the aid of advanced video recording of the control actions and feedbacks of the crew. This will be supportive to apply CAST method of accident analysis after the occurrence of any accident.

REFERENCES

Abrecht, B. and Leveson, N. G., "Systems theoretic process analysis (STPA) of an offshore supply vessel dynamic positioning system". *Massachusetts Institute of Technology, Cambridge, MA*, 2016.

Akhter, S. (2017), "Unregistered vessels put public safety at risk", New Age, 21 May, available at: http://www.newagebd.net/article/15986/unregistered-vessels-put-public-safety-at-risk (accessed 10 May 2019).

Ali, M. T., Rahaman, M. M. and Zakaria, N. M. G. (2015), "Passenger launch accidents: Time to wake up", The Daily Star, 22 September, available at: https://www.thedailystar.net/op-ed/passenger-launch-accidents-time-wake-146956 (accessed 04 November 2019).

Aps, R., Fetissov, M., Goerlandt, F., Kujala, P. and Piel, A. (2017), "Systems-Theoretic Process Analysis of Maritime Traffic Safety Management in the Gulf of Finland (Baltic Sea)", *Procedia Engineering*, Vol. 179, pp. 2-12.

Awal, Z. I., Islam, M. R. and Hoque, M. M., "An analysis of passenger vessel accidents in the inland waterways of Bangladesh", in *Proceedings of the Marine Technology Conference,* Hasanuddin University (UNHAS), Makassar, 2006, pp. 211-219.

Awal, Z. I. (2007), "A Study on Inland Water Transport Accidents in Bangladesh: Experience of a Decade (1995-2005)", *International Journal for Small Craft Technology (IJSCT)*, The Transactions of The Royal Institution of Naval Architects (RINA), Vol. 149, Part B2, pp. 35-42.

Awal, Z. I. and Hoque, M. M., "Some Aspects of Water Transport Accident and Injury Problems in Bangladesh", in *Proceedings of the 10th Pacific Regional Science Conference Organisation (PRSCO) Summer Institute,* May 2008, pp. 15-17.

Awal, Z. I., Islam, M. R., and Hoque, M. M. (2010), "Collision of marine vehicles in Bangladesh: a study on accident characteristics", *Journal of Disaster Prevention and Management*, Vol. 19, No. 5, pp. 582-595.

Awal, Z. I. and Hasegawa, K., “Accident analysis by logic programming technique”, *Safety and Reliability of Complex Engineered Systems: ESREL 2015*, September 2015, pp. 13-21.

Azad, A. K., *Riverine Passenger Vessel Disaster in Bangladesh: Options for Mitigation and Safety*, Thesis for Degree of Master in Disaster Management, BRAC University, Dhaka, Bangladesh, 2009.

Bangladesh Bureau of Statistics (2018), Gross Domestic Product (GDP), available at: bbs.portal.gov.bd/sites/default/files/files/bbs.portal.gov.bd/page/057b0f3b_a9e8_4fde_b3a6_6daec3853586/F2_GDP_2017_18.pdf, (accessed 10 May 2019).

Bangladesh Inland Water Transport Authority (2019), *About Us*, available at: http://www.biwta.gov.bd/site/page/aea3e3d9-0e99-4bcd-9330-a0a9961c793c/aboutus, (accessed 10 May 2019).

Banglapedia (2015), *Water Transport*, available at: http://en.banglapedia.org/index.php?title=Water Transport, (accessed 11 June 2019).

Baten, A. S. M. A. (2005), “Internal Water Transportation System: Safety of Inland Passenger Vessels”, *NDC Journal*, Vol. 4, No. 1, pp. 131-157.

Billings, C. E. (1996), *Aviation automation: The search for a human-centered approach*. CRC Press.

Bird, F. and Loftus, R. (1976), *Loss Control Management*. Loganville, GA: Institute Press, 1976

Chowdhury, A. S., *Waterway Accident Characteristics Assessment and Information System Development*, Master of Engineering Thesis, Bangladesh University of Engineering and Technology, Dhaka, 2005.

Dekker, S., (2007), *Just culture: Balancing safety and accountability, Ashgate Publishing.*

Del Pozo, F., Dymock, A., Feldt, L., Hebrard, P., and di Monteforte, F. S., “Maritime surveillance in support of CSDP”, The Wise Pen Team Final Report to EDA Steering Board, 2010.

Dong, A., *Application of CAST and STPA to Railroad Safety in China*, M. Sc. Thesis in System Design and Management Program, Massachusetts Institute of Technology, Cambridge, 2012.

Edwards, M., (1981), "The design of an accident investigation procedure", *Applied Ergonomics*, Vol. 12, pp. 111–115.

Ericson, C. A., (2015), *Hazard analysis techniques for system safety*. John Wiley & Sons.

France, M. E., *Engineering for Humans: A New Extension to STPA*, Master of Science Thesis, Massachusetts Institute of Technology, Cambridge, 2017.

Fujita, Y., "What shapes operator performance", In *JAERI Human Factors Meeting, Tokyo*, November 1991.

Hossain, M. T., Awal, Z. I., and Das, S., (2014), "A Study on the Accidents of Inland Water Transport in Bangladesh: The Transportation System and Contact Type Accidents", *Journal of Transport System Engineering*, Vol.1, No. 1, pp. 23-32.

Hosseinian, S. S., and Torghabeh, Z. J., (2012), "Major theories of construction accident causation models: A literature review", *International Journal of Advances in Engineering & Technology*, Vol. 4, No. 2, p. 53.

Huq, N. A. & Dewan, A. M., (2003), "Launch Disaster in Bangladesh: A Geographical Study", *Geografia*, Vol.1, Issue 2, pp. 14-25.

Interferry (2019), *Committee Information*, available at: https://interferry.com/committee-information/ (accessed 11 November 2019).

Iqbal, K. S., Hasegawa, K., Bulian, G., Karim, M. M., and Awal, Z. I., "Passenger Ferry Accidents in Bangladesh: Design and Socio-economic Aspects", in *Proceedings of the 10th International Symposium on Practical Design of Ships and Other Floating Structures (PRADS 2007)*, 30 September - 5 October 2007, Houston, Texas.

Iqbal, K. S., Bulian, G., Hasegawa, K., Karim, M. M., and Awal, Z. I., (2008), "A rational analysis of intact stability hazards involving small inland passenger ferries in Bangladesh", *Journal of Marine Science and Technology*, ol. 13, no. 3, pp. 270-281.

Iqbal, K. S., Bulian, G., Hasegawa, K., Karim, M. M. and Awal, Z. I., (2008a), "Possible Remedies for Intact Stability Hazards Involving Contemporary Small Inland Passenger Ferries in Bangladesh", *Journal of Marine Science and Technology*, Vol. 13 No. 3, pp. 282-290.

Ishimatsu, T., Leveson, N. G., Thomas, J. P., Fleming, C. H., Katahira, M., Miyamoto, Y., Ujiie, R., Nakao, H. and Hoshino, N., (2014), Hazard analysis of complex spacecraft using systems-theoretic process analysis. *Journal of Spacecraft and Rockets*, Vol. *51*, No. 2, pp. 509-522.

Islam, M. R., *Techno-economic Analysis Applied to Safety of Inland Passenger Vessels*, M. Sc. Engg. Thesis, Department of Naval Architecture and Marine Engineering, BUET, Dhaka, 1997.

Islam, M. R., Rahaman, M. M., and Degiuli, N., (2015), "Investigation of the Causes of Maritime Accidents in the Inland Waterways of Bangladesh", *Brodogradnja/Shipbuilding Journal*, Vol. 66, No.1, pp. 12-22.

JPL Special Review Board (2000), *Report on the Loss of the Mars Polar Lander and Deep Space 2 Missions*. Nasa Jet Propulsion Laboratory.

Johnson, W. G., (1980), *MORT safety assurance systems*. Marcel Dekker Inc., New York.

Khalil, G. M., (1985), "A study of passenger launch disasters in Bangladesh", *The Journal of National Oceanographic and Maritime Institute*, Vol. *2*, No. 2, pp.1-14.

Khalil, G. M., and Tarafder, M. S., (2004), "Ferry disasters in the rivers of Bangladesh: some remedial measures", *The Journal of National Oceanographic and Maritime Institute*, Vol. 2, No. 2, pp. 33-53.

Kjellen, U., (1982), "An evaluation of safety information systems at six medium-sized and large firms", *Journal of Occupational Accidents*, Vol. 3, pp. 273–288.

Kjellen, U., (1987), "Deviations and the Feedback Control of Accidents", in Rasmussen, J., Duncan, K. and Leplat, J. (Ed.), *New Technology and Human Error*, John Wiley & Sons, pp. 143-156.

Kwon, Y., *System Theoretic Safety Analysis of the Sewol-Ho Ferry Accident in South Korea*, Master of Science Thesis, Massachusetts Institute of Technology, Cambridge, 2016.

Lederer, J., "How far have we come? A look back at the leading edge of system safety eighteen years ago", *Hazard Prevention*, May/June 1986, pp. 8-10.

Leplat, J. (1987), "Occupational Accident Research and Systems Approach", in Rasmussen, J., Duncan, K. and Leplat, J. (Ed.), *New Technology and Human Error*, John Wiley and Sons, New York, pp. 181-191.

Leveson N. G., (1995), *Safeware: System Safety and Computers*. Addison Wesley, Boston.

Leveson, N. G., (2004), "A new accident model for engineering safer systems", *Safety science*, Vol. 42, No. 4, pp. 237-270.

Leveson, N. G., (2004), "Role of software in spacecraft accidents", *Journal of spacecraft and Rockets*, Vol. 41, No. 4, pp. 564-575.

Leveson, N. G., (2012), *Engineering a Safer World: Systems Thinking Applied to Safety*, The MIT Press, Cambridge.

Leveson N. G., and Thomas, J., (2018), *STPA Handbook*, available at: http://psas.scripts.mit.edu/home/get_file.php?name=STPA_handbook.pdf (accessesd 10 May 2019).

Levitt, R. E., and Parker, H. W., (1976), "Reducing construction accidents-top management's role", *Journal of the construction division*, Vol. 102, No. 3, pp.465-478.

Lim, K., *Enhancing Vehicle Safety Management in Training Deployments: An application of system dynamics*, M. Sc Engg. Thesis, System Design and management program, Massachusetts Institute of Technology, Cambridge, 2008.

Machol, R. E., (1975), "The Titanic coincidence", *Interfaces*, Vol. 5, No.5, pp. 53–54.

Nauticexpo (2019), *Ship platform*, available at: https://www.nauticexpo.com/prod/fassmer/product-27585-453502.html, (accessed 01 September 2019).

Perrow, C., (2011), *Normal accidents: Living with high risk technologies-Updated edition*. Princeton university press.

Pickering, W. H., (1973) "Systems engineering at the Jet Propulsion Laboratory", In Miles R. F. Jr., editor, *Systems Concepts: Lectures on Contemporary Approaches to Systems*, pp. 125–150, John F. Wiley & Sons, New York.

Probha, N. A., *A Study on Transport Safety Perspectives in Bangladesh through Comparative Analysis of Roadway, Railway and Waterway Accidents*, M. Sc. Engg. Thesis, Department of Civil Engineering, Bangladesh University of Engineering and Technology, 2017.

Rahman, N. A., and Rosli, H. Z., (2014), "An innovation approach for improving passenger vessels safety level: Overload problem", *International Journal of Business Tourism and Applied Sciences*, Vol. 2, No.2, pp. 1-14.

Rahman, S., (2017), "An analysis of passenger vessel accidents in Bangladesh", *Procedia Engineering*, Vol. 194, pp. 284-290.

Rahman, S., (2017a), "Introduction of Bayesian network in risk analysis of maritime accidents in Bangladesh", in *American Institute of Physics Conference Proceedings*, AIP Publishing, Vol. 1919, Issue 1, p. 020024.

Raiyan, A., Das, S. and Islam, M. R., (2017), "Event Tree Analysis of Marine Accidents in Bangladesh", *Procedia Engineering*, Vol. 194, pp. 276-283.

Ramo, S., (1973), "The systems approach", In Miles R. F. Jr., editor, *Systems Concepts: Lectures on Contemporary Approaches to Systems*, pp. 13–32, John F. Wiley & Sons, New York.

Rashid, K., and Islam, M. R., (2017), "Reasons and remedies of inland passenger vessels accidents in Bangladesh", in *American Institute of Physics Conference Proceedings*, AIP Publishing, Vol. 1919, Issue 1, p. 020036.

Rasmussen, J., (1997), "Risk management in a dynamic society: a modelling problem", *Safety Science*, Vol. 27, Issue 2-3, pp. 183-213.

Reason, J., (1990), *Human Error*, Cambridge University Press, Cambridge.

Reason, J., (1997), *Managing the Risks of Organizational Accidents*, Ashgate Publishers.

Reason, J., (2008), *The Human Contribution: Unsafe Acts, Accidents, and Heroic Recoveries*. Burlington, VT: Ashgate.

Rokseth, B., Utne, I. B., and Vinnem, J. E., (2017), "A systems approach to risk analysis of maritime operations", *Journal of Risk and Reliability*, Vol. 231, Issue 1, pp. 53-68.

Sakalayen, Q. M. H., *Non-convention Ferry Safety and the Potentiality of Inland Waterways for Multimodal Transportation: A Comparative Analysis for the Betterment of Bangladesh's Situation*, M. Sc. Dissertation, World Maritime University, Malmö, Sweden, 2006.

Sarter, N., Woods, D., "Strong, silent and out-of-the-loop", CSEL Report 95-TR-01, Ohio State University, 1995.

Sarter, N., Woods, D. D., and Billings, C. E., "Automation Surprises", *Handbook of Human Factors and Ergonomics*, 2nd Edition, pp.1926-1943, Wiley, New York, 1997.

Stukus, P. D., *Systems-Theoretic Accident Model and Processes (STAMP) Applied to a US Coast Guard Buoy Tender Integrated Control System.* M. Sc Engg. Thesis, System Design and management program, Massachusetts Institute of Technology, Cambridge, 2017.

Sulaman, S. M., Abbas, T., Wnuk, K. and Höst, M., "Hazard analysis of collision avoidance system using STPA", In *Proceedings of International ISCRAM Conference*, May 2014, Pennsylvania, pp. 424-428.

Swift, A. J., (2004), *Bridge team management: a practical guide*. Nautical Institute, London.

The Maritime Executive (2019), *MAIB: Even Basic Tasks Benefit from Toolbox Talks,* available at: https://www.maritime-executive.com/article/maib-even-basic-tasks-benefit-from-toolbox-talks, (accessed 02 September 2019).

Uddin, M. I., Islam, M. R., Awal, Z. I. and Newaz, K. M. S., (2017), "A study of inland water transport accidents of Bangladesh: Lessons from a decade (2005-2015)", *Procedia Engineering*, Vol. 194, pp. 291-297.

Vicente, K.J., and Rasmussen, J., (1992), "Ecological interface design: Theoretical foundations", *IEEE Trans. on Systems, Man, and Cybernetics*, Vol 22, No. 4. pp. 589-606.

Vicente, K. J., "A Field Study of Operator Cognitive Monitoring at Pickering Nuclear Generating Station", Technical Report CEL 9504, Cognitive Engineering Laboratory, University of Toronto, 1995.

Watt, K. E. F., (1974), *The Titanic Effect*. Sinauer Associates, Inc., Stamford.

Wiener, E. L., "Human factors of advanced technology (glass cockpit) transport aircraft", NASA Contractor Report 177528, NASA Ames Research Center, 1989.

Williams, A. D., (2015), "Beyond a series of security nets: applying STAMP & STPA to port security". *Journal of Transportation Security*, Vol. *8*, No. 3-4, pp.139-157.

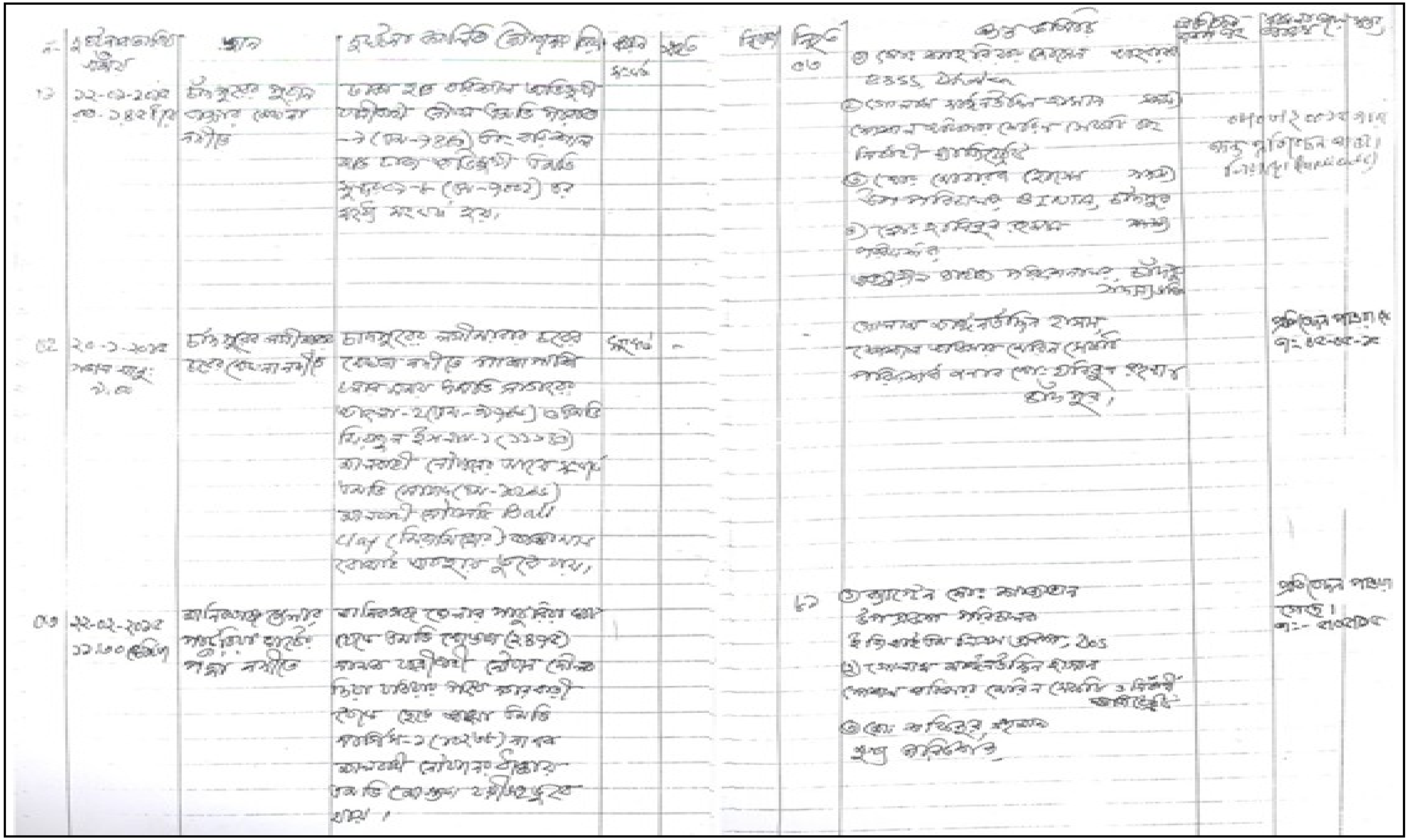
Worldwide Ferry Safety Association (2019), http://www.ferrysafety.org/ (accessed 04 November 2019)

Wrobel, K., Montewka, J., and Kujala, P., (2018), "System-theoretic approach to safety of remotely-controlled merchant vessel", *Ocean Engineering,* Vol. 152, pp. 334-345.

Zulfikar M. M., (2005), *Prevention of accidents of inland ships: Laws & Rules.* H. A. Publishers, Dhaka.

APPENDIX-A

Sample of Accident Data Recorded in the Register Book of Department of Shipping.



APPENDIX-B

Sample of Accident Data Recorded in the Register Book of BIWTA.