Tenth MIT STAMP Workshop
JUNE 6-10, 2022

STPA for Passenger Ship Safety Analysis in Bangladesh

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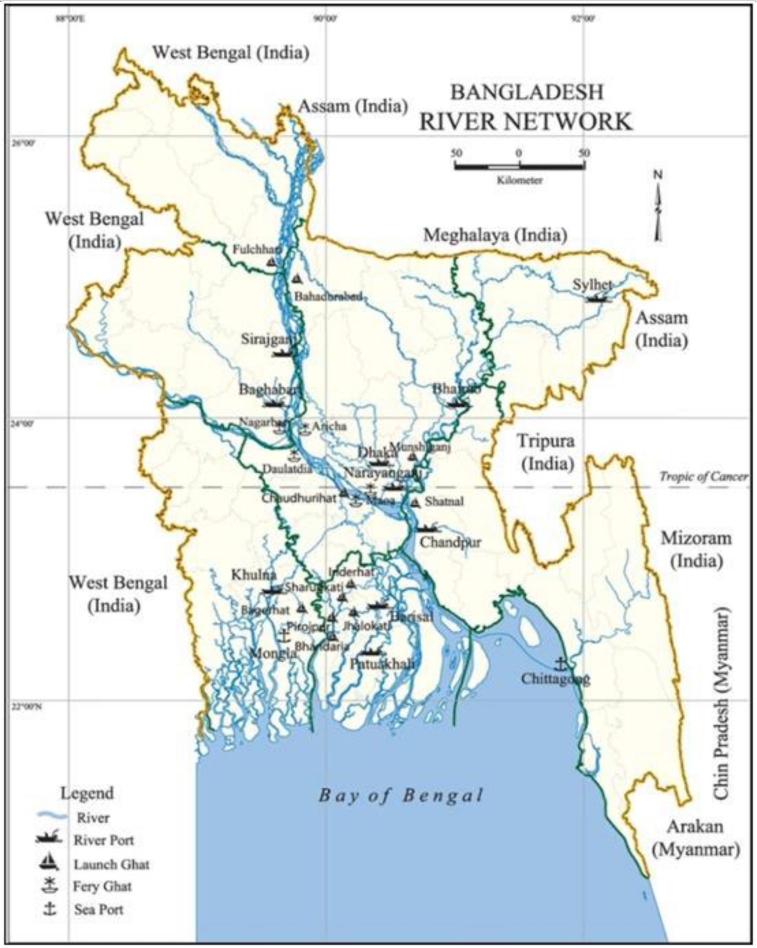
Introduction

- Bangladesh is low-income country located in the South-Asia region.
- The Bay of Bengal is located in the southern side of the country.
- She is a riverine country having almost 700 rivers.

Introduction

- Inland Water Transport (IWT) is cheapest mode of transport and allows easy access to any region within the country.
- IWT has significant contribution to National GDP of Bangladesh.
- Number of unregistered vessels is about three times higher than registered.

Source : BIWTA



Background

- There exists severe deficiencies on maritime safety.

- Apart from **significant underreporting** of accidents, 1098 people died, 457 were injured and 916 were reported missing in 474 accidents during 2012 to 2021.

Source: La Prensa Latina (2021)

Background

- Huge loss of properties cause adverse effect on national economy and often accidents put detrimental effect on environment.
- **Accident investigation committees** are formed after each accident to put forward some recommendations.
- However, safety scenario has not improved visibly.

THE BUSINESS STANDARD

37 die as Jhalakathi launch goes up in flames

At least 37 passengers perished after a fire broke out in "MV Abhijan-10", a river ferry, on the River Sugandha in Jhalakathi early Friday.

The number of casualties is likely to rise as many of the passengers have severe burns.

The incident took place around 3 am while the launch was on its way to Barguna from Dhaka.

The Business Standard (2021); PiPa News (2021)

Motivation

- More than 90% of fatalities are involved with the passenger vessels.

- Among all the passenger vessels, Passenger launch is the most vulnerable type causing 56% accidents and 76% fatalities.

- Considering this issue, the analysis will focus on safety of passenger launch operation only.

A Typical Passenger Ship in Bangladesh

Motivation

Existing methods of safety analysis could not capture the complete scenario of risks relevant to inland water transport safety in Bangladesh.

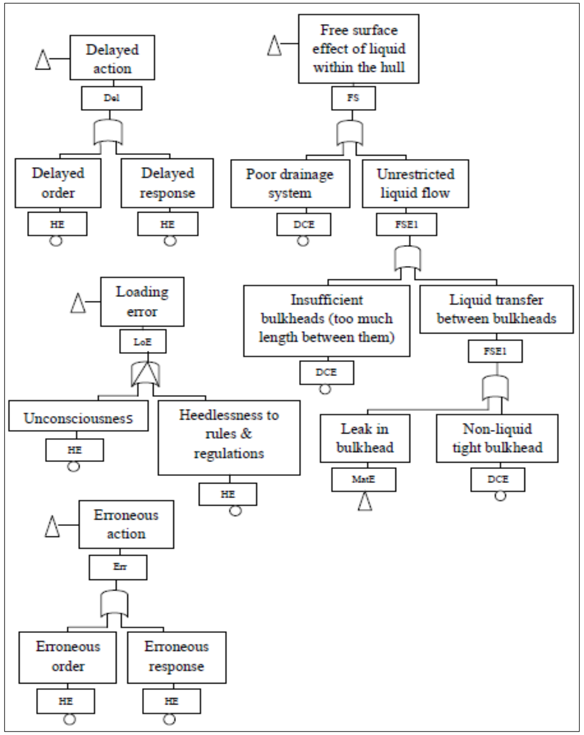


Fig.: Fault Tree analysis sequences for ship capsizing
Source: Hossain et al. (2010)

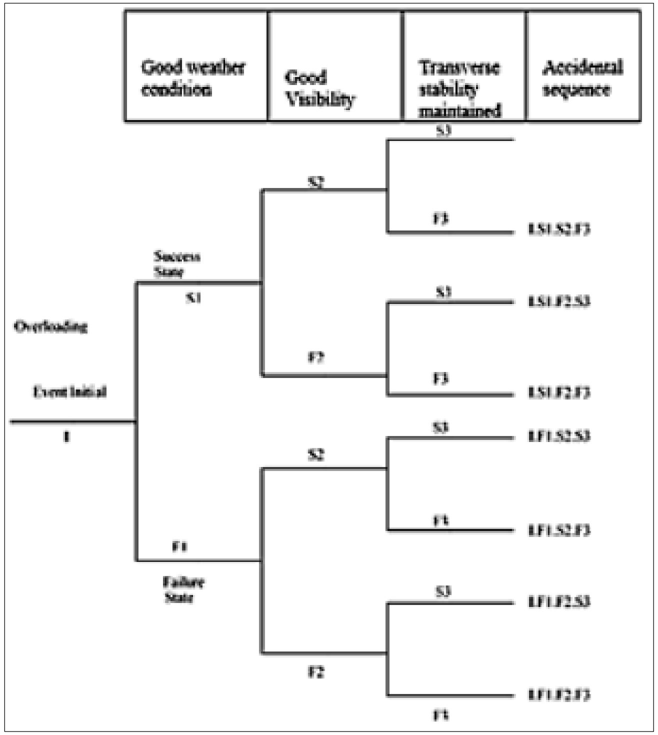
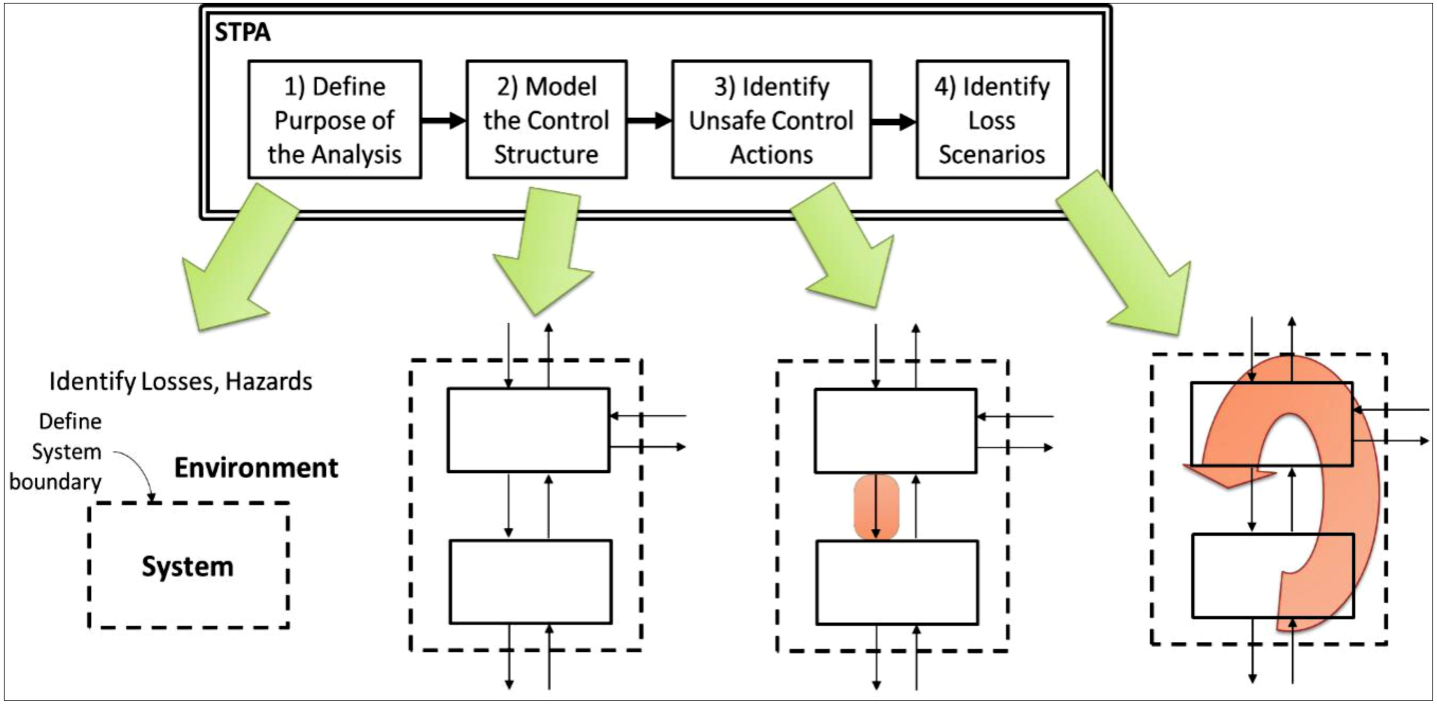


Fig.: Event Tree analysis sequences for overloading
Source: Raiyan et al. (2017)

Objective

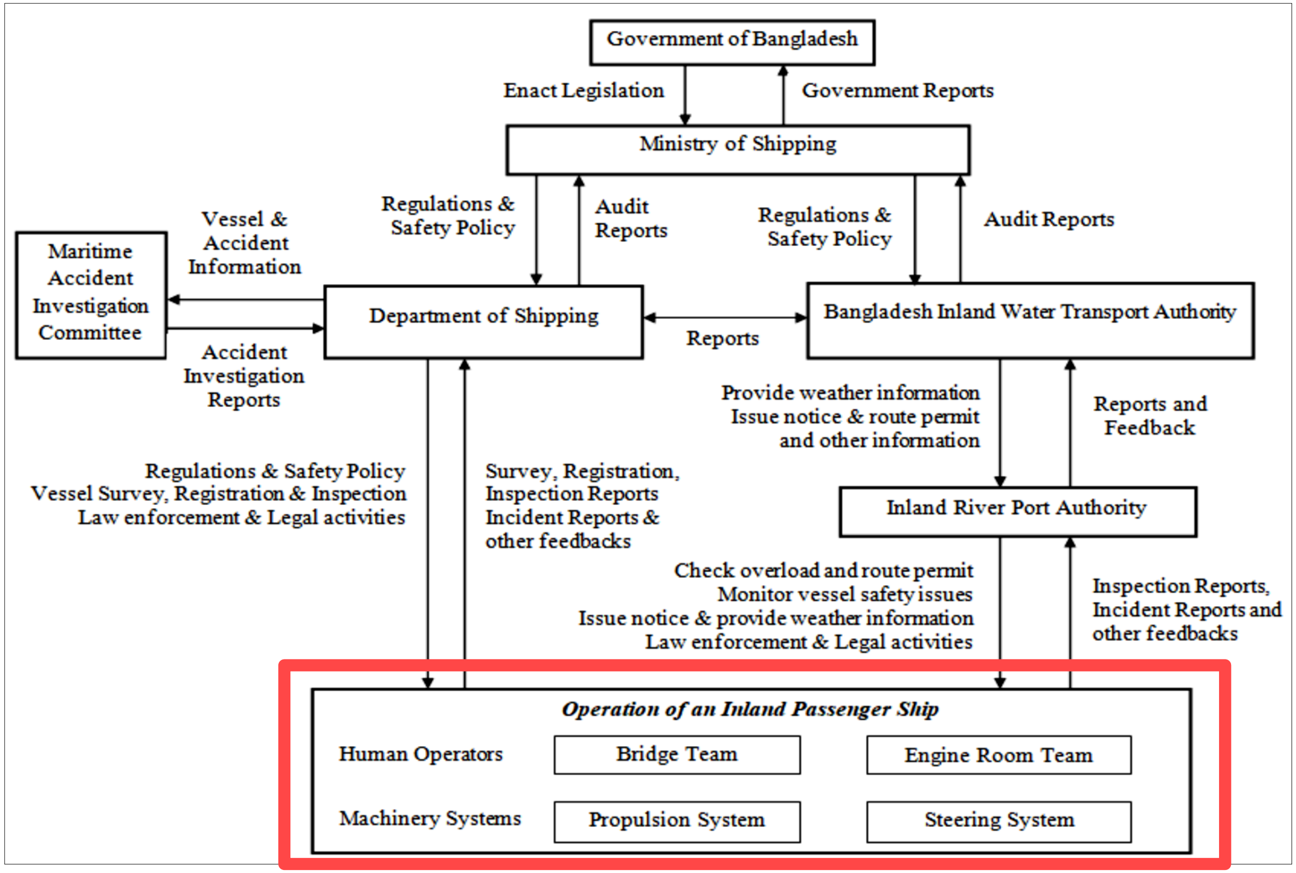
To perform Hazard Analysis of Passenger ship operation in Bangladesh using STPA Method.



Source: STPA Handbook (2018)

Step 1: Defining Purpose of Analysis

Defining Boundary of Analysis



Step 1: Defining Purpose of Analysis

Defining Boundary of Analysis

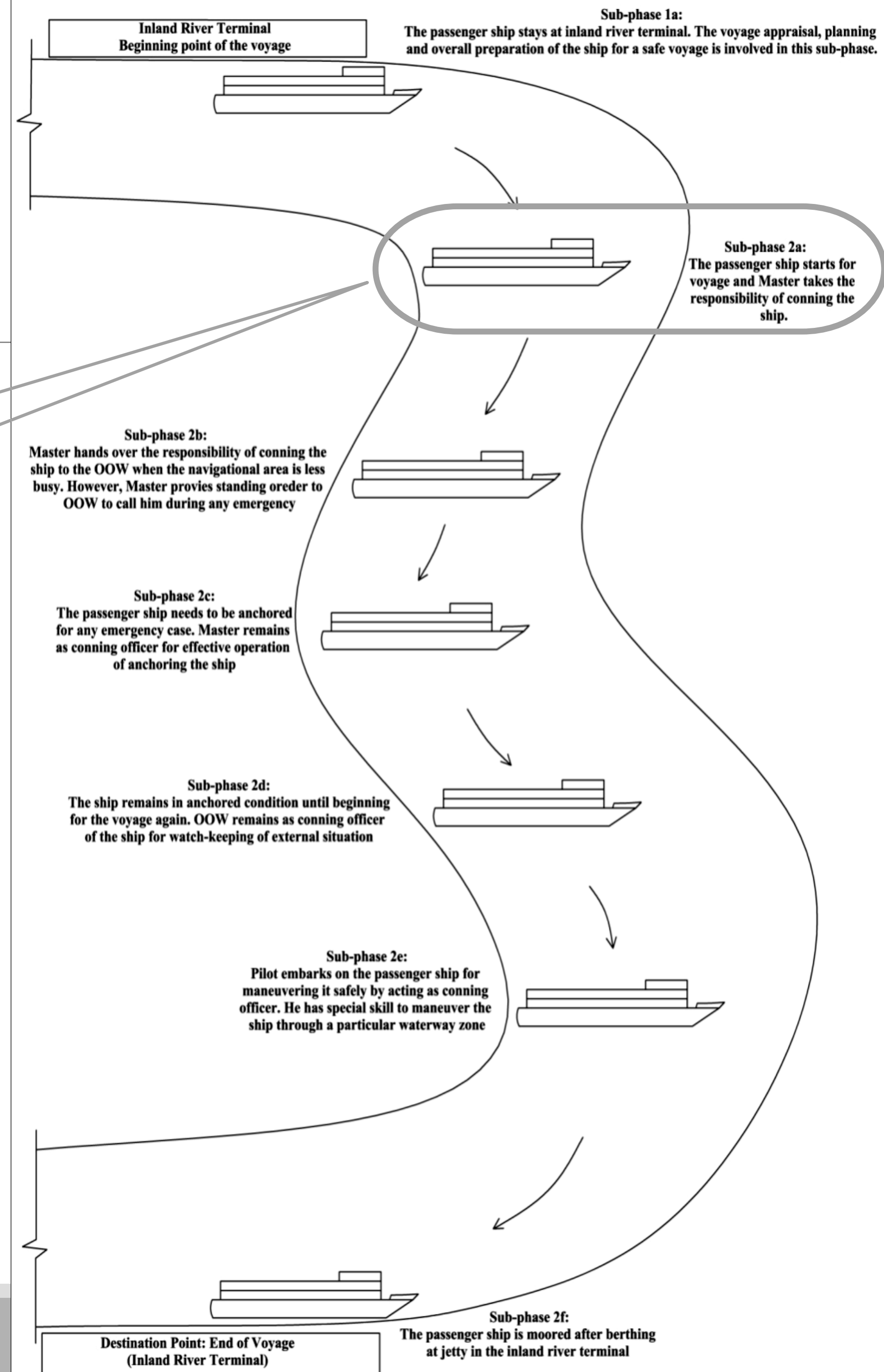
**Sub-phase 2a:
Master acting as the conning officer**

A passenger launch is considered for the following phases:

1. *Passenger ship safety during the stay at inland river terminal (voyage appraisal and planning stage).*

2. *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

Only two scenarios of the sub-phase 2a (Master acting as the conning officer) will be presented here.



Example 1

Step 1: Defining Purpose of Analysis

Identifying Losses

L1: Loss of life or serious injury to people.

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

Identifying System-Level Hazards

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 an unsafe area (low water-depth or stormy area). [L1, L2]

H5: Catching fire inside the ship. [L1, L2]

Step 1: Defining Purpose of Analysis

Identifying System-Level Constraints

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

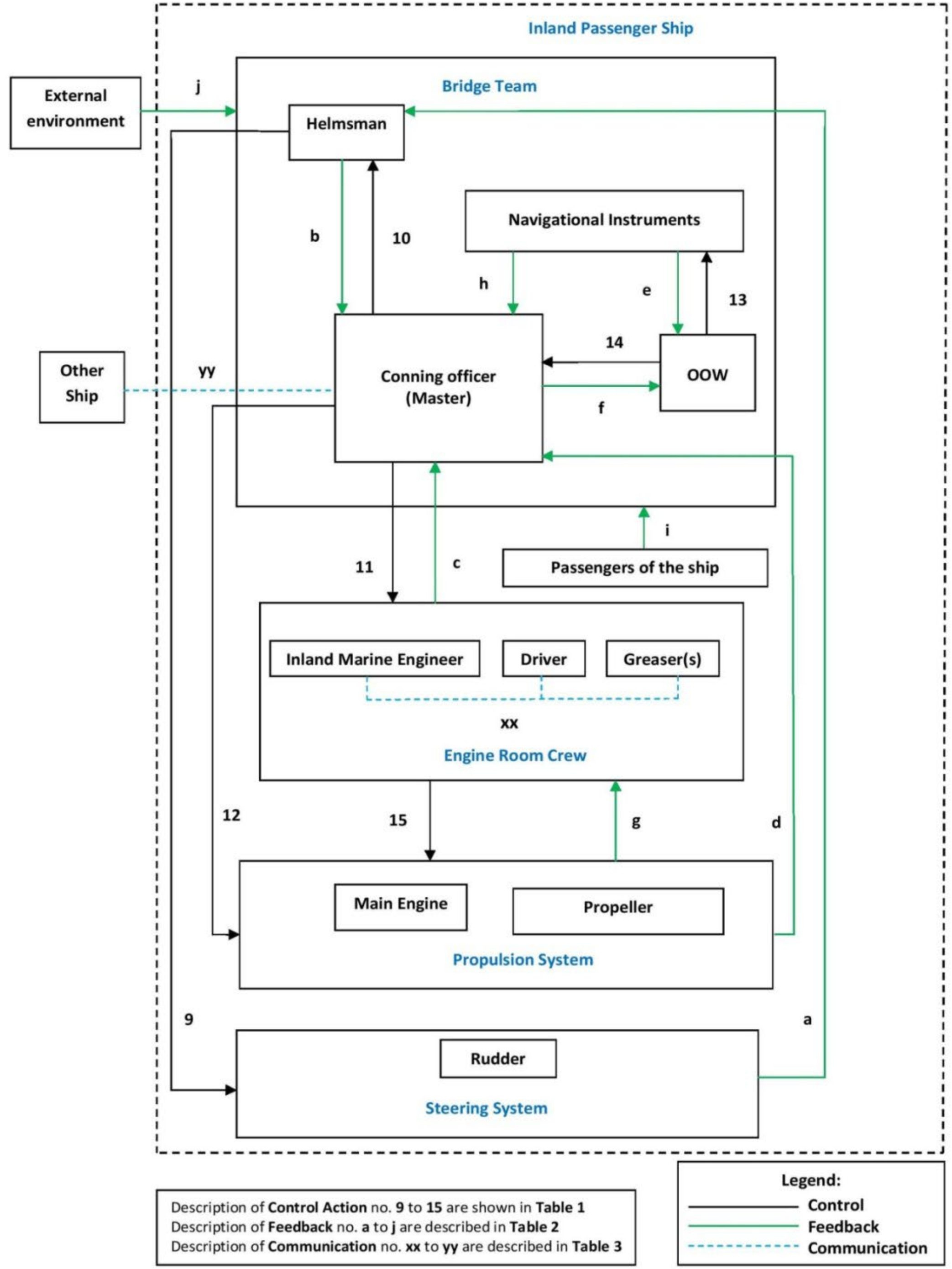
SC 2: Ship must not violate minimum separation from any stationary object or underwater object. [H2]

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 an unsafe area (low water-depth or stormy area). [H4]

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

Step 2: Model Control Structure of Passenger Vessel Operation



Step 2: Model Control Structure (List of Control Actions)

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

Step 2: Model Control Structure (List of Feedbacks)

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

Step 2: Model Control Structure (List of Communications)

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)

Step 3: Identifying Unsafe Control Actions (UCA)

Control Actions (CA): Providing the steering command (rudder) by the Helmsman			
Not providing CA causes hazard	**Providing CA causes hazard**	**Wrong timing/ order of CA causes a hazard (applied too early or too late)**	**CA stopped too soon/ applied too long**
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

Step 4: Identifying Loss Scenarios

Loss Scenario 2a-2:

Master (Conning officer) orders the helmsman to execute the 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:

- Steering system malfunctions due to component failure.
- Power supply failure occurs in the bridge or wheelhouse.

Possible Safety Requirements for Scenario 2a-2:

- ✓ A visual and audible alarm shall annunciate on wheelhouse if the steering system fails to deliver or maintain the ordered rudder angle.
- ✓ Means must be available to recognize the fault of the steering system and fixing it in a very short period of time.
- ✓ 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.

Example 2

Step 3: Identifying Unsafe Control Actions (UCA)

Control Actions (CA): Providing the command to increase rpm of propeller by the Master (Conning officer)			
Not providing CA causes hazard	**Providing CA causes hazard**	**Wrong timing/ order of CA causes a hazard (applied too early or too late)**	**CA stopped too soon/ applied too long**
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] UCA 2a-11: The conning officer (Master) commands to increase propeller rpm for increasing ship speed during rough weather condition. [H4]	N/A	N/A

Note: Step 1 & Step 2 for Example 2 are omitted here since those remain similar to Example 1.

Step 4: Identifying Loss Scenarios

Loss Scenario 2a-11:

During the voyage, 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:

- Operating the ship several times safely during stormy or rough weather in previous.
- Inadequate knowledge or lack of training on ship maneuvering in rough weather conditions.

Possible Safety Requirements for Scenario 2a-11:

- ✓ Specific guidelines should be updated and followed for safe navigation of the ship during rough weather. For instance, the ship should enter into the nearby specified *shelter zone* during the stormy weather condition.
- ✓ Proper training should be arranged regularly to enhance the quality of bridge team members to navigate the ship safely during rough weather.
- ✓ Updated information of weather forecasting should be informed to all ships in due time (e.g. after every 10-15 minutes).

Major Findings from STPA Analysis

- Majority (83%) of Unsafe Control Actions (UCA) exist during the voyage condition.
- The largest part of the UCA exist is the bridge deck of passenger ship.
- Human Factor is the most contributing causal factor (80%) for occurrence of UCA.
- Most significant category of safety requirements is team management (57%).

Comparison of results between HAZOP and STPA

The following table shows comparison between HAZOP and STPA analysis on inland passenger ship operation in Bangladesh which were done separately by different authors in almost similar time at Bangladesh.

Criteria for comparison	HAZOP	STPA
Number of unsafe control actions identified	32	170
Focus of analysis	Mainly focused on immediate failures.	Focused on in-depth analysis of all probable failures.
Issues covered in analysis	Mainly focused on technical factors; very few issues related to human factors are taken into consideration. No management factors are taken into consideration.	Human factor, technical factors and management factors- all are taken into consideration.

Conclusions

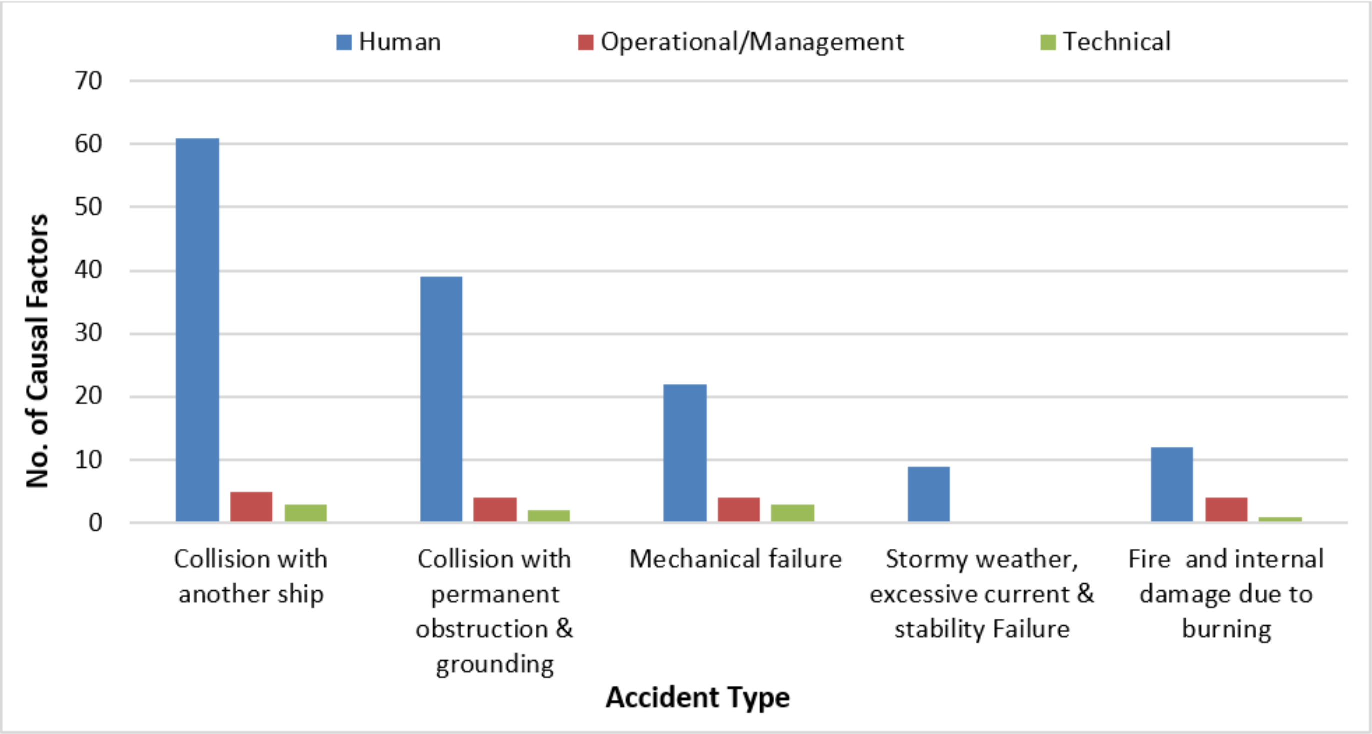
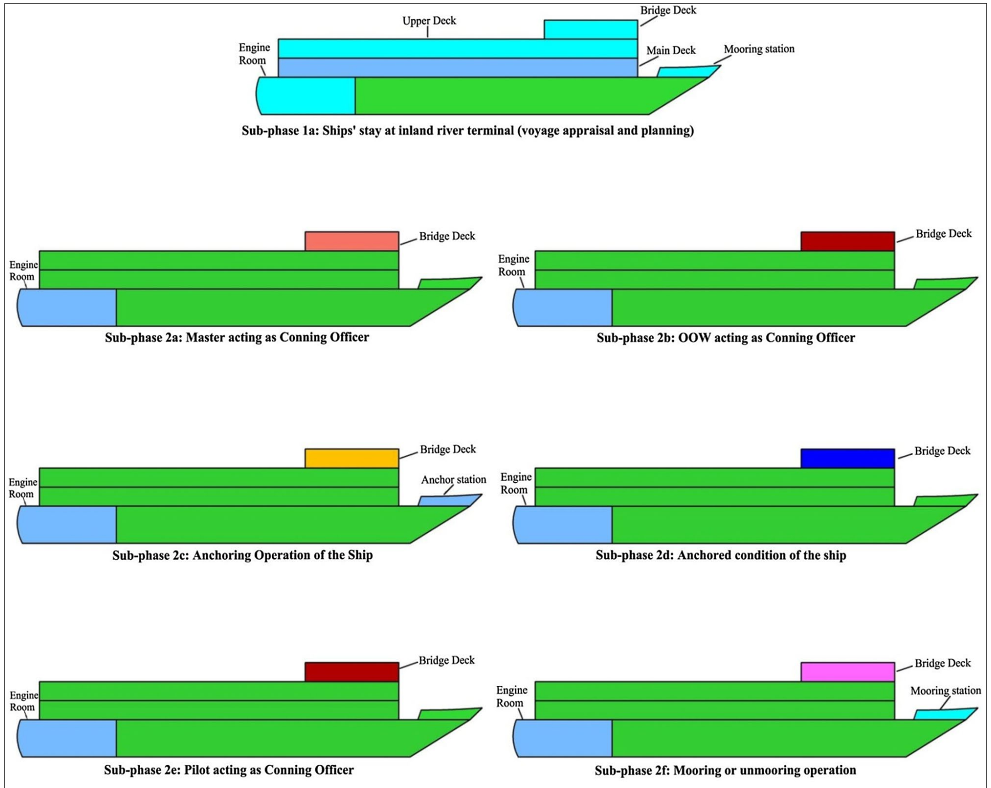


Figure: Distribution of causal factors based on accident types during the voyage condition.

Ship accidents involves human factors, technical factors and management factors which are very difficult to identify by a single method. However, STPA has been found to be successful in this case.

Conclusions

- STPA helped to streamline the effort and make this large problem easier to analyze. Specially the control structure is very effective to identify the probable grey areas related to safety.



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	

Figure: Zone-wise distribution of the number of Unsafe Control Actions (UCA) inside the passenger ship in different sub-phases.

Thank You

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