INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH & DEVELOPMENT

ISSN 2278 – 0211 (Online)

Accident Analysis of River Boats Capsize in Indian Inland Waters and Safety Aspects Related to Passenger Transportation

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Abstract:
Inland waterway transportation (IWT) is one of the oldest economically and environmentally sustainable modes of transportation for passengers and cargo. India has an estimated navigable length of 14,500 km of inland waterways, including river systems, canals, backwaters, creeks and tidal inlets, that can effectively support mechanized crafts. Besides this, country boats of various capacities also operate in various rivers and canals. In IWT sector, the environmental conditions, nature of operations, human error (crew and passengers) and lack of safety standards, etc., pose a number of risks to safety of passengers and vessels. Though this sector is economically viable, the rate of accidents are high and need to be focused to minimize the accidents. Formal Safety Assessment (FSA) is the scientific method that is being currently used for the analysis of maritime safety and for the formulation of related regulatory policies.
This paper discusses the methodologies involved in FSA, highlights the qualitative analysis in hazard identification and risk analysis process i.e., hazards that are identified during various operations in IWT sector and by using the expert judgment, these hazards are prioritized by the risk ranking matrix. Accident analysis of recent boat accidents that occurred at various locations of inland waters is presented by means of fault tree diagrams focusing the faults of the top event (capsize) as part of qualitative risk analysis. Further, it discusses the safety aspects related to the passenger transportation, highlighting the human errors and operational risks in IWT sector of India. This paper concludes by suggesting the measures to reduce the risk to the passengers and vessels related to various operational and environmental conditions.

Keywords: *Inland waterway transportation, formal safety assessment, hazard identification, risk ranking matrix, expert judgment, risk analysis, fault tree diagrams*

1. Introduction

Inland water transport (IWT) is an economic, fuel efficient, environmental friendly and a low cost transport mode [i]. There are five established inland waterway routes in India. Recently cabinet has approved declaration of 101 waterways as national waterways, yet to be introduced in the Parliament [ii]. According to the IWT statistics, there are thousands of traditionally designed boats of various capacities which operate in these national waterways by means of non-mechanical sources of power and sails, etc., and by mechanised vessels fitted with diesel engines. One of the major aspects of inland water transportation is passenger and cargo movement. This important mode of transport is ridden with tragic accidents every year, incurring a heavy toll of human lives and property. After each accident, authorities try to take drastic measures to review and restructure the existing rules and system but unfortunately nothing happens positively for the safety in this respect, since most of the boats plying in this sector are unregistered. With the development of technology and public awareness, it is the time demand issue to mitigate the risk involved in passenger vessel operations to minimize accidents. Based on the above concerns, a qualitative analysis for the river boat accidents is presented by applying the FSA methodologies.

2. Overview of FSA

Formal Safety Assessment (FSA) is a structured and systematic methodology [iii], aimed at enhancing maritime safety, including protection of life, health, the marine environment and property, by using risk analysis and cost benefit assessment. The FSA procedure (see Figure 1) consists of five steps, namely "Hazard identification", "Risk analysis", "Study of risk control options", "Assessment of cost benefits of RCO", and "Recommendations for decision making" [iii], [iv].

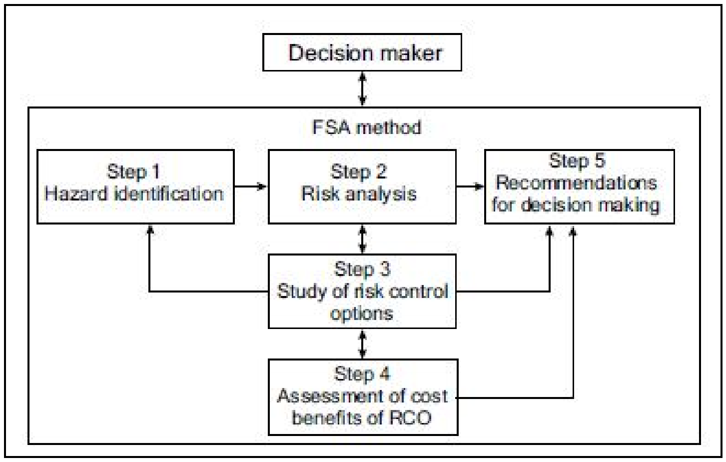

Figure 1: Implementation of FSA

3. Theory and Methodologies of FSA

3.1. Hazard Identification

For the problem being considered, based on the scenarios the series of hazards, as well as the risk level for each hazard are to be identified. Hazards are then ranked [v] by assessing the consequences and likelihood of occurrence [vi] as shown in the Figure 2.

Consequences (C)	How Severely Could Someone be Hurt?
Catastrophic	Death or permanent disability, Huge financial loss
Major	Extensive (serious) injuries, hospital treatment required, major financial loss
Moderate	Injury requiring medical treatment, and some lost time, high financial loss
Minor	Minor injury, First aid treatment, Medium financial loss
Insignificant	Injuries requiring no treatment or first aid

Likelihood (L)	How Likely are the Consequences?
Almost Certain	Expected to occur in most circumstances
Likely	Will probably occur in most circumstances
Possible	Might occur at some time or occasionally
Unlikely	Unlikely to occur, could happen some time
Rare	May occur only in exceptional circumstances

Figure 2: Assessing the Consequences and Likelihood of Occurrence

3.1.1. Risk Ranking Matrix

The risk ranking matrix [vi] [vii], is used to assess the likelihood and the severity or consequences of each hazard and to give it a "Risk Rating". A typical matrix has rows representing increasing likelihood of occurrences of these consequences and columns representing increasing severity of consequences (see Figure 3).

Risk Ranking Criteria

CONSEQUENCES

LIKELIHOOD	Insignificant	Minor	Moderate	Major	Catastrophic
Almost Certain	High	High	Very High	Very High	Very High
Likely	Moderate	Moderate	High	Very High	Very High
Possible	Low	Moderate	High	High	Very High
Unlikely	Low	Low	Moderate	Moderate	High
Rare	Low	Low	Low	Low	Moderate

Figure 3: Risk Rating Matrix

Risk Level Rating	Required Action
Very high	<u>**Immediate action needed.**</u> The hazard should be restricted until the risk can be lowered to an acceptable level. Short term action may be required to lower the risk level and then medium and long term plans to control the risk to as low as reasonably practicable.
High	Action needed quickly. The task should not proceed unless the risk is assessed and control options should be given depending upon the situation.
Moderate	Action required to eliminate or minimise the risk.
Low	Risk to be eliminated or lowered when possible.

Figure 4: Actions required

The matrix indicates the combinations of likelihood and consequence, and typically, there are regions as shown in the Figure 4, a broadly acceptable zone where risks only require to be managed for continuous improvement (low risk), an intermediate zone in which risks should be reduced to a level which is as low as reasonably practicable (ALARP) (moderate risk), and an intolerable zone (very high risk).

<u>3.1.2. Expert Judgment</u>

When a new scenario is observed and the associated risk needs to be determined, without sufficient data, an expert can classify this new risk as 'High Risk', 'Medium/moderate Risk' or a 'Low Risk'. This grouping is the qualitative determination of the risk. The expert judgment [iii], are sometimes used to rank risks associated with accident scenarios, or to rank the frequency or severity of hazards. To enhance the transparency in the result, the resulting ranking should be accompanied by a concordance coefficient (W) is formulated below (see Figure 5), and the level of agreement between the experts as shown in the Table 1.

$$W = \frac{12\sum_{i=1}^{i=I}\left[\sum_{j=1}^{j=J} x_{ij} - \frac{1}{2}J(I+1)\right]^2}{J^2\left(I^3 - I\right)}$$

Figure 5: Formula to calculate Concordance Coefficient [3]

W	> 0.7	Good agreement
W	0.5 – 0.7	Medium agreement
W	< 0.5	Poor agreement

Table 1: Range for concordance coefficient (W)

Where, J= Number of experts; i = Number of hazards (scenarios), $\sum X_{ij}$ = Summation of risk rank for each hazard given by the experts.

3.2. Risk Analysis

Risk is generally defined as the probability of occurrence of an event that could cause harm to people, property or the environment, over a specified period of time. One major objective of risk analysis is to measure risk for the purpose of risk control. Risk analysis can be carried out either qualitatively or quantitatively.

4. Hazard Identification and Risk Analysis Techniques

Several methods [iii],[v],[vi] exist for use in hazard identification and risk analysis techniques, a few of them are Fault Tree Analysis (FTA), Event Tree Analysis (ETA), Failure Mode and Effect Analysis (FMEA), Hazard and Operability Studies (HAZOP) and so on . Each technique mentioned above has its own capability to apply as the situation demands. This paper focuses on identifying the hazards, and on the boat accidents highlighting the faults of the top event using a qualitative fault tree diagram, a qualitative analysis of river boat accidents based on FSA methodologies.

5. Qualitative Analysis of River Boat Accidents based on FSA

5. 1. Focus on Boat Accidents

Accidents involving death or injury are an appropriate focus of study because these accidents are the most serious and are likely to have the greatest social/economic impact. There are thousands of vessels plying in the inland waters & coastal regions, which are operated and monitored by various agencies i.e. IWAI, state tourism departments, private operators etc. Even though there are rules and regulations for registration & operation of vessels. It is observed that accidents are occurring frequently and there have been several casualties in the past. The boat accidents scenarios are categorised into collision, capsize, sinking, grounding, fire/ explosion and other cases. These accidents in general occur due overloading, human error, bad weather, loss of control, jetty collapse, rush hours and others. From the above scenarios, hazard analysis for the river boats and risk analysis for Odisha boat capsize case study using fault tree diagram is presented.

5.2. Hazard Analysis

The hazards identified for the river boats are divided into nine categories. To name a few they are: At jetty- during departure, vessel movement, berthing, weather conditions, etc... Each category can be subdivided based on design, constructional, operational, maintenance, human behavioural perspective and others. Reference to the above Figure 2 and 3, list of hazards, their consequences and likelihood of occurrences [vi] for the river boats plying in various locations of inland waters is listed in the Table 2, below followed by the risk ranking criteria Table 3, which is prioritized by the risk ranking matrix.

No.	List of Hazards Identified	Consequence	Likelihood
1	No proper jetty	Damage to jetty, injury to people	Possible
…	………	………	………
27	No one to check whether the number of passengers …. over loaded	Loss of boat and loss of lives	Possible
…	………	………	………
35	Not enough LSA and FFA appliances onboard	May cause increase in loss of lives	Almost Certain
…	………	………	………
86	Passengers standing and moving onto one side, loss of stability	Loss of boat and lives	Likely

Table 2: List of Hazards Identified for river boats plying in IWT sector.

No.	List of Hazards Identified	Consequence	Likelihood	Risk Ranking
1	No proper jetty	Major	Possible	High
……	………	………	………	
27	No one to check whether the number of passengers …. over loaded	Catastrophic	Possible	Very High
……	………	………	………	
35	Not enough LSA and FFA appliances onboard	Catastrophic	Almost Certain	Very High
……	………	………	………	
86	Passengers standing and moving onto one side, loss of stability	Catastrophic	Likely	Very High

Table 3: Risk Ranking Criteria for the consequences and likelihood of occurrences

From the hazard analysis and risk ranking criteria, it is known that the hazards identified for the boats plying in various locations of IWT sector falls under very high, high, moderate, and low risk. From Figure 4, actions required to mitigate risks can be determined. The risk ranking which comes under very high category should be brought down to the broadly acceptable level i.e. from intolerable to tolerable by assigning risk control options. Hence from the above work, it is evident that the hazards which are identified lead to catastrophe if neglected. So safety measures must be considered to reduce risk to the passengers.
The ranking by the study has been checked with the expert judgement, based on the level of agreement and by concordance coefficient (W). Questionnaire has been prepared for the hazards identified and circulated to the experts (IWT authorities) requesting to assess the severity of risk. The response from the experts and the hazards ranking numbers are show in the Table 4.

Hazards (i) / Experts (j)	1	2	………	…….	23	24
1	20	21			1	2
2	14	18			6	23
3	21	22			2	14
$\sum X_{ij}$	55	61			9	39

Table 4: Representing number of experts and ranking of hazards identified for river boats

Finally, after formulating the ranking, by using Figure 5 and Table 1, the value of concordance coefficient (W) is 0.58**.** This value falls under "Medium Agreement" category of concordance. This signifies that the hazards identified in the present study for the boats is at medium level.

6. Risk Analysis by using Fault Tree Diagram

The area of risk analysis [iii] is mainly developed and used for major accidents. Major accidents have complicated cause-consequence chains and a potential of ending up in a catastrophe. Several methods exist for use in risk analysis. One of the methods applied in this paper is qualitative Fault Tree Analysis (FTA). Boat capsize in Odisha is taken as the case study and the fault tree diagram has been constructed to known the root cause of the boat capsize.

6.1. Accident Scenario - Statistics on Boat Accident's

According to the official statistics, Department of Inland Water Transport Statistics [viii], and National Crime Records Bureau (NCRB), Ministry of Home Affairs [9], and Ministry of Statistics and Programme Implementation (MOSPI) [x]. Total number of casualties reported during 2000-2013 were 9808 and the accident cases were 8903 for 28 states and union territories. Nearly 200 boat accident cases during the year 2000 to 2015 were collected from the internet archives and news channels. The data collected for study in this paper has been exhaustive, however a few of the accident reports may have been missed out. Since the data published is not sufficient to carry out quantitative analysis, work has been done by applying qualitative methods. Data obtained from IWT statistics and NCRB, graph representing the total number of accidents and number of causalities for the boat capsize in each state during the year 2000-2013 (see Figure 6), show that the boat accidents in the states of Bihar, Karnataka, Odisha, Andhra Pradesh rank in the high priority and the remaining states rank in the medium priority.

It has been found that different organizations have different types of data to meet their own requirements. Therefore, compilation of database by cross matching data from different sources is a tedious task. However, total number of accidents and causalities for nine states during the year 2000 to 2013, have been considered in this study.

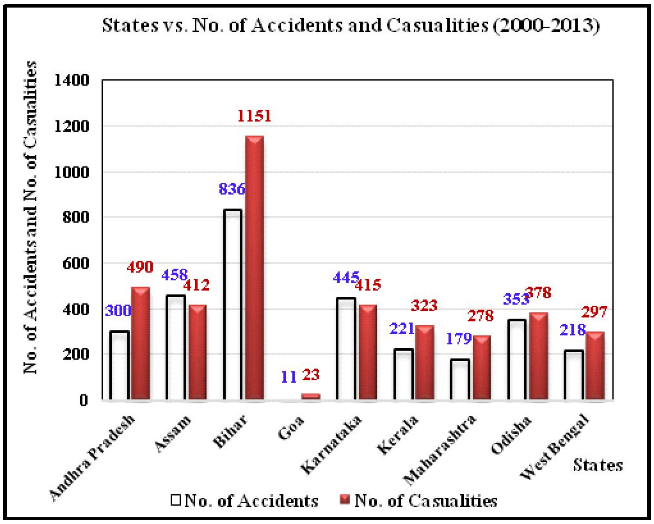

Figure 6: Graph representing States vs. Number of accidents and causalities- Boat Capsize Data (2000 -2013) – (Source: NCRB)

7. Case study – Odisha Boat Capsize

In this paper case study for the Odisha boat capsize, is presented to understand the severity of the accidents occurring in inland waters due to lack of safety, human activities on board etc., and the top events are represented by using fault tree diagram (see Figure 8), also graph (see Figure 7), representing the number of boat accidents and causalities occurred in Odisha during 2000-2013.

7.1. Description of Accident

The accident occurred on 9th February 2014, Sunday around 4 pm, near Pitapalli area inside the Hirakud dam reservoir, Sambalpur district, Odisha. The motor boat against its carrying capacity of 70, was overloaded with 144 passengers (114 lion's club members, 30 local people) and motor bikes. Due to overloading and panic situation of passengers the motor boat could not keep her stability upright and thereby capsized in the river Mahanadi. The death toll reached 31 lives were lost in the tragic event. Most of the victims were reported to be women and children who had absolutely no chance of swimming ashore.

Figure 7: Motor Boat capsized in Hirakud dam reservoir, Odisha (Source: The HINDU, Times, February 2014)

7.2. Accident Analysis

From the statistics and accident information of the vessel, it is evident that the vessel was overloaded against its carrying capacity. The time of occurrence of boat capsize is in the evening when the people were returning. One of the survivors quoted that the engine developed a snag mid-way and also water started entering into the boat. This created a panic situation among the passengers. Finally the observations of the accident scenario is as follows: the boat is fully overloaded with passengers and bikes, the boat did not have basic safety equipment. Figure 7, shows the graph representing the boat capsize accidents occurred in Odisha during the year 2000-2013 [viii] [ix]. Fault tree diagram highlighting the faults for the boat capsize is shown in the Figure 8.

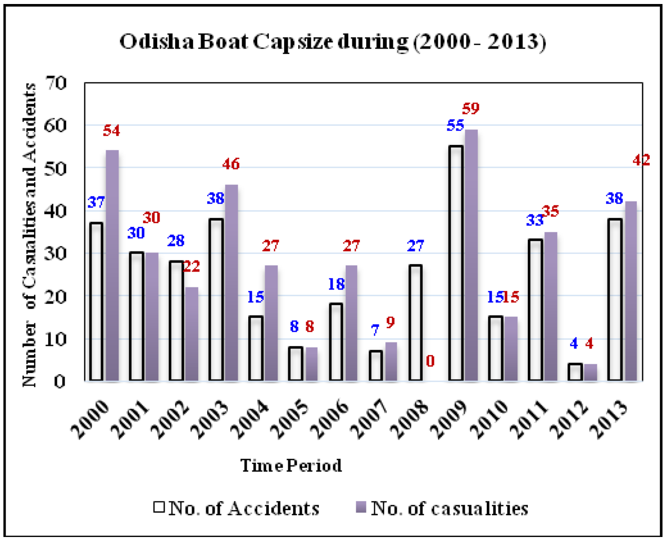

Figure 8: Graph representing number of boat capsize accidents and causalities in Odisha (2000-2013). (Source: NCRB and IWT statistics)

7.3. Qualitative Fault Tree Analysis

A fault tree is a logic diagram showing the causal relationship between events which singly or in combination occur to lead to a higher level event. FTA is a top down approach, used to determine the probability of a top event. The symbols used in FTA [iii] are shown in the Table 5.

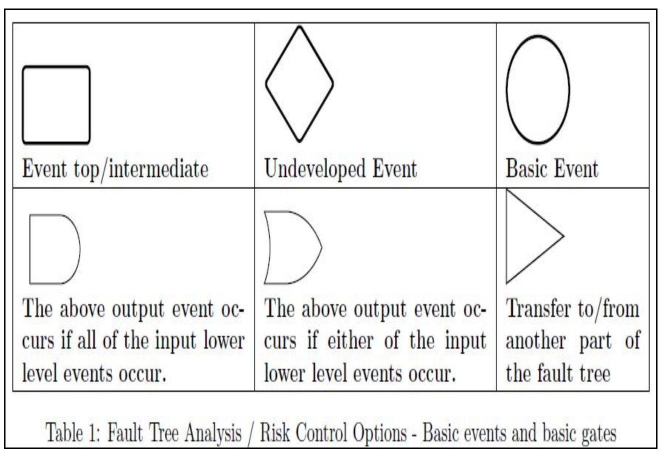

Table 5: Symbols used in Fault Tree Diagrams

From the case study, it is evident that the severity of the boat accidents are very high. From the accident analysis it is observed that main reason for boat capsize is overloading, human activities on board, hull breach and engine failure. Total elimination of accidents is not possible, but measures could reduce the number and intensity of the accidents and related consequences.

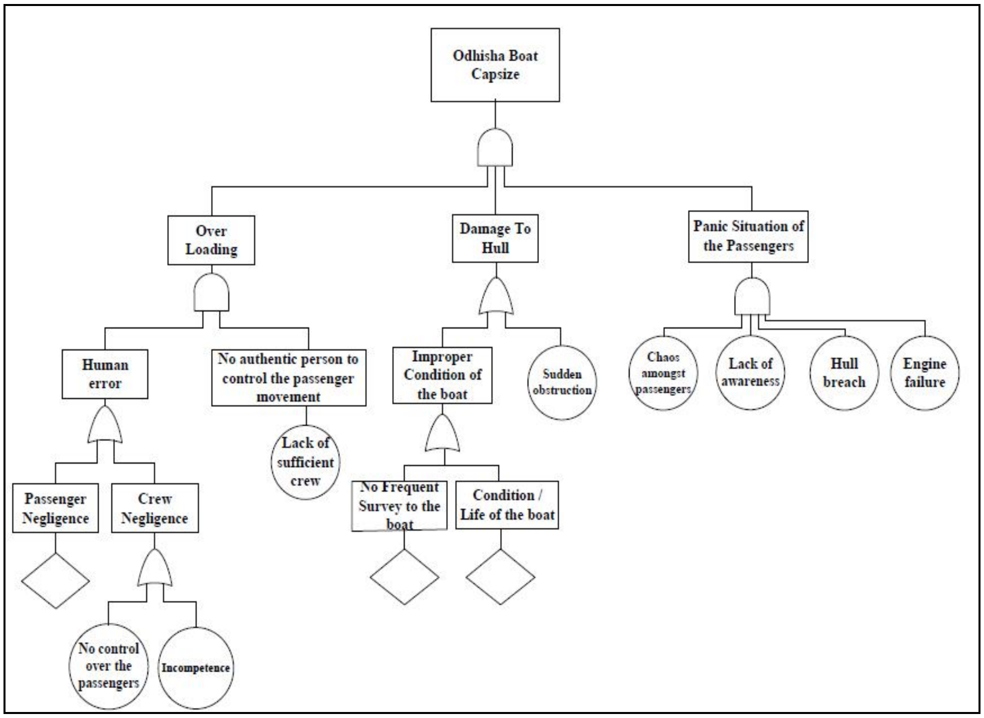

Figure 9: Fault Tree Diagram for Odisha Boat Capsize.

8. Risk Control Options (RCO)

The main purpose of RCO is to provide effective [iii] and practical risk control options by focusing on the risk areas needing control and suggesting control measure to mitigate risk. Few reasons for the boat accidents and possible ways to mitigate the risk is presented below.

8.1. Reasons for the Boat Accidents in IWT Sector

8.1.1. Poor Quality of the Vessel

In India, most of the boats, plying in inland waters are traditional country crafts. These vessels are constructed by local craftsman and builders. Unfortunately the practices adopted by the boat operators are not in the best interest of the safety of these boats. Another important point from the study is, in most of the places aged country crafts are used for transportation, and also due to construction fault the stability of the vessel becomes questionable and leads to accidents.

8.1.2. Violation of Rules / Procedures

Most of the vessels operating along the inland waterways are not registered and are operated at the will of the boat owner. Registration of only few boats takes place. Vessels which are registered need to be surveyed at regular intervals, however lack of proper government machinery puts this daunting task at bay. Taking the advantage of this, operators are operating the vessels, without getting approvals from the competent authorities.

8.1.3. Overloading

Overloading is another important cause for accidents to happen. It is observed that majority of the accidents are due to overloading. During festival seasons, there is a huge crowd. Passengers and boat operator disregard safety considerations and travel in the overloaded vessels leads to capsize.

8.1.4. Lack of Control on Vessel Traffic

Traffic density is one of the major risk factor which leads to collision. In some areas of inland waters, it is observed that there is heavy vessel traffic during office hours, and also during melas and festive seasons. Passengers rush into the boats, neglecting the boat capacity and no authority is present to monitor the vessel movement and to restrict the passengers.

8.1.5. Human Factor

Human error is the predominant factor for the cause of boat accidents be it crew or the passengers. Most of the boat operators are poor and illiterate. There is no formal training in vessel operations, as the profession was transferred from the predecessor. They are not aware of the safety procedures which need to be followed in case of emergency situations. In some cases, the passenger's excitement, panic situations, lack of awareness (Ex: Thekkady boat accident in 2009) resulted in accidents.

9. Possible Ways of Mitigation

The passenger safety is one of the important aspects to be considered [xi]. All concerned parties are responsible to adopt mitigation approach to minimize these problems. It may not be possible to prevent the vessels fatalities completely but it is possible to minimize up to an acceptable level. Ministry of Shipping, Inland Waterway Authority of India, boat owners, private authorities, law enforcing agencies like police, panchayats etc., and individual passengers are to contribute significant effort for better future in this sector. Following are the few options to mitigate the risk:

9.1. Inspection

Periodic inspections and surveys of the vessel should be made mandatory. Authorities should enforce rules such that all boats must get registered. Checklist has to be prepared for the inspection of the boat by the regulating authorities. (Ex: Kerala Ports Department [xii], has introduced the Safe Boat List in Kerala Backwaters).

9.1.1. Overloading

Overloading of passengers should be made unlawful. Carrying commercial cargoes along with passengers should be prohibited unless the provision must comply with rules. Boat owners should be penalized if they are found to be hiring boat operators having false certificates.

9.1.2. Instructions to Passengers and Boat Operators

The boat owner/operator may provide the safety instruction booklet to the passengers onboard. They should give instructions to the passengers about how to wear the lifejacket and must ensure all the safety appliances onboard the vessel are in working condition before plying.

9.1.3. Equipping Traditional Boats with Communication Instruments

In order to make the inland water travelling safer all boats, should carry appropriate communication instrument / equipment.

9.1.4. Active Traffic Management

To reduce the boat collisions, a vessel traffic monitoring system needs to be established and provide safety facilities like traffic separation. This can also help to maximize sustainable use of the channels.

In addition to the options mentioned above the authorities should look into the enhancement of manpower and infrastructural facilities like jetties and gangways which are in poor condition.

10. Concluding Remarks

This paper concludes by suggesting few control options which should be considered by the regulating authorities to mitigate risk in all aspects especially design, registration, safety aspects related to passengers, boats, infrastructural facilities etc. If neglected the risks may lead to catastrophe where severe loss to human lives, property and environment might create a major problem for this sector. FSA methodology applied to this case helped in assessing the problems and finding the root cause for the accidents to occur. Techniques like expert judgment and the fault tree diagrams are applied in this paper. The degree of level of agreement resulted in medium level for the rankings assigned to the hazards listed. The application of cost benefit assessment may or may not be implemented based on the economic necessity and recommendations. Findings from the work revealed that most of the boats operated in IWT sector are unregistered. If the boats were built as per the rules and regulations, the chance of occurrence of accidents can be minimized. Total elimination of boat accidents is not possible but to reduce accidents, boats must be registered and accidents must be recorded which helps in planning and implementing rules/laws for the boats plying in inland water transport sector.

11. Recommendations

To ensure better safety to the passengers traveling in this sector, few recommendations to mitigate future boat accidents are put forward herewith:

i. Overloading on board vessel shall be checked at starting points as well as en route [xi]. A dedicated work force may be formed for this purpose.
ii. One of the major limitations of the present study is data collection; very limited data is obtained from the sources mentioned in the paper. There is a need to create centre of expertise for the database [xiii], supporting scientific study, and also establishment of causality database with more detailed root cause information.
iii. Provisions of life insurance facilities for commuters' [xi], of waterways may be incorporated which will in turn help to implement rules and regulation of this sector.
iv. Proper navigational aids to control traffic and navigate through safe channels shall be provided by the appropriate authority.
v. Adequate Life Saving Appliances (LSA) and Fire Fighting Appliances (FFA) should be provided.
vi. Massive awareness campaign regarding safety of water transport may be arranged by all concerned authorities.

12. Acknowledgements

This study is part of the Study Project "Safety Assessment Studies on Passenger Vessels in Andaman Nicobar Islands, Lakshadweep Islands and Inland Waters", Sponsored by The Ministry of Shipping, Government of India awarded to Indian Maritime University, Visakhapatnam Campus.

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