Exploring Applicable Models and Tools to Analyze Accidents of Inland Water Transports of Bangladesh

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Abstract

Millions of people use Inland Water Transport (IWT) as a cheap mode of vehicle in Bangladesh. Due to various reasons it is found that the passenger vessels in river routes are not as safe as it should have been. Reflections are vivid to public through media reports regularly. Although accidents at inland water ways in Bangladesh are not as frequent as those happening on roads, but on many occasions, it has been found that losses of life and damage of property on waterways are quite high. Sometimes accidents on board passenger vessels cause immense damage to the environment as well which has a long-lasting effect on nature. Study reveals that the ways in which accident cases are investigated and analyzed, the root causes of accident cases are not revealed. The author feels that so far the issue has not been addressed well in Bangladesh using the right tool or model based on any theory. This paper gives a guideline towards framing a model which can be used to analyze accidents which operators of passenger vessels face on a regular basis in Bangladesh.

Key words: vessels, safe, waterways, accident, model.

Background of the Study

Rivers are considered as gifts of nature and vessels running over it are the cheapest mode of transport compared to road and railway. There is not much study carried out in recent past on the actual contribution of water way transport in the country. World Bank report (WB 2005) shows (Table - 1) a comparison of three different types of commonly used transport systems.

A report received from Bangladesh Inland Water Transport Authority (BIWTA) shows millions of people still use major river routes (Figure-1). But the author feels that passenger vessels are not safe enough at inland waterways in Bangladesh. Both major and minor riverine accidents occur in

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Bangladesh almost every year. Many of these accidents are not reported on time and some of those are never investigated and remain as mere statistic. Causes of accidents are not analyzed properly using appropriate tools.

Table 1: Modal Share of IWT Passenger Vessels in Bangladesh

<table>
<thead>
<tr>
<th>Year</th>
<th>Total</th>
<th>Road</th>
<th>%</th>
<th>Rail</th>
<th>%</th>
<th>IWT</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975</td>
<td>17.0</td>
<td>9.2</td>
<td>54%</td>
<td>5.1</td>
<td>30%</td>
<td>2.7</td>
<td>16%</td>
</tr>
<tr>
<td>1996</td>
<td>66.0</td>
<td>52.0</td>
<td>79%</td>
<td>3.9</td>
<td>6%</td>
<td>10.1</td>
<td>15%</td>
</tr>
<tr>
<td>96/05 annual growth</td>
<td>7.1%</td>
<td>6.6%</td>
<td>0.7%</td>
<td>-1.3%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>111.5</td>
<td>98.4</td>
<td>88%</td>
<td>4.2</td>
<td>4%</td>
<td>8.9</td>
<td>8%</td>
</tr>
</tbody>
</table>

[Source: Bangladesh Integrated Transport System Study, Planning Commission.]

There is no proper recording system of accidents in the office of DOS. However, a report collected from the Chief Inspector’s office of DOS shows the number of recorded accident cases over last 40 years at figure-2. These records are not directly contributing to the objective of the study, but it gives an impression about the importance of the issues where there are not enough considerations by the respective stakeholders. Apart from official recorded accidents, there are many incidents on IWT passenger vessels on the breach of safety regulations which are ignored and not recorded by the safety departments.
The study of 1000 recorded accident cases in the office of Department of Shipping (DOS) of the government of Bangladesh reveals that many of the cases were incomplete and reports were never made public and analyzed using any internationally accepted methods or models. The method of accident analysis is not revealed and root causes are hardly identified. Several Case studies of accident reveals that investigation procedure is a kind of blame game. Once blame is established, the study finishes. There is not much research work happened on operational challenges faced by the operators and consequences they suffer. Accident Research Institute under Bangladesh University of Engineering and Technology (BUET) has been formed over a decade but they mostly conduct research on road accidents. There is no functional maritime safety administration which can conduct research on maritime or riverine safety related issues. After a major river accident in 1986 (MV SAMIA and MV ATLAS STAR), the DOS took an initiative to bring consultants from International Maritime Organization (IMO) and they recommended to form a safety organization named ‘Inland Ship Safety Administration’ (ISSA) under Inland Shipping Ordinance (ISO) 1976. But ISSA never became functional. Formulation of policies is generally based on practical and theoretical knowledge on the subject. This paper shows developments of accident theories, models/tools available to researchers and which may be most suitable model for analysis of accident cases occurring while operating IWT vessels in Bangladesh.
Background for Development of Accident Theories

With the rapid industrialization in general and the development of nuclear and aviation technology, the investors demanded allocation of special fund for research work on safety related issues. As a result, the researchers embarked on developing new models, theories to investigate and analyze accident causes by the middle of the twentieth century. The phenomenal development of computer technology and statistical tools and concepts eased the researcher to formulate their ideas for better solution of accident problems. Accident research analysts have been trying and testing these tools and theories for different types of accidents.

Safety Management and Safety Culture

Safety Management is a vast and complex field of study. Generally speaking, Total Quality Management (TQM) covers many aspects of safety management in any organization whether that is industrial or non-industrial. In the field of shipping, International Safety Management (ISM) code is utilized by shippers mostly for ocean going ships and vessels. But unfortunately, no such things exist for IWT passenger or cargo vessels in Bangladesh. People generally learn lessons through the happening of major accidents where safety management have been ignored or paid less attention. Apparently, it seems that safety culture is missing in transportation sector in Bangladesh. Hardly people take lessons from past accidents, which is so important. Accident cases as in Bhopal (1984), Chernobyl (1986), the capsize of the RoRo passenger and freight ship, Herald of Free Enterprise (1987) have shown how poor safety management could result huge damage to property and human lives (Krishtiansen, 2005).

The passenger vessels’ safety management in Bangladesh is lacking due to several reasons. Focused Group Discussion (FGD) by the author with key personnel of DOS and BIWTA reveal that safety management system for IWT in Bangladesh has many grey areas which need attention. There is no actual accident prevention strategy as there is no strong safety administration in existence. In the safety Management scheme there are different concepts to prevent or avoid accident. In this context, Morone et al. (1986) concept of accident prevention strategies have been checked during survey, interview and case studies done by the researcher and discussed in the following paragraphs:
a. Protection against Potential Hazards: Protection against potential hazards can prevent or minimize accidents. For example, collision between two vessels in the river may cause oil spillage and subsequent damage to the environment and property. Use of double bottom tanks can avoid such loss or damage. Two cases of oil spillage at Shella River (2014) and at Kirtonkhola (2017) reveal the matter.

b. Proceed Cautiously: There is always a better result when operators are cautious. Formal Safety Assessment (FSA) may identify all hazards and accidents scenarios. Only proven technical solutions are the best answer for operation of passenger vessels. No proven solutions have been found so far in context of facing challenges while operating passenger vessels in Bangladesh.

c. Test the Risks: This strategy implies that simulations and testing should be undertaken under realistic conditions in order to assess how the system responds to certain conditions and situations. Unfortunately, not a single passenger vessel in Bangladesh has been constructed in local yards after testing the models in hydrodynamic laboratory or towing tanks.

d. Learning from Experience: This strategy is all about developing procedures for reporting, analysis and corrective response to nonconformities. In Bangladesh it is extremely difficult to take the least serious incidents into consideration. Although these incidents have the largest learning potential by being the most frequent. For example, overloading of the passenger vessels in IWT sector is a common phenomenon and shown as one of the major causes of accidents.

e. Setting Priorities: The safety management bodies should continuously assess the alternative risks the operators generally face and give priority to the critical ones. In order to have safe transportation for passenger vessels’ operation in Bangladesh, standardization in every aspect is essential. Management needs to have a safety programme with definite goals. A management process, basis for safety work, safety activities, safety organization, plans and appropriate documentation are most essential.

Organizational Culture

Safety aspect for any operation depends a lot on organizational culture of that particular group or organization. The culture concept originated from
organizational theory by Peters and Waterman (1982) and corporate culture: The Rites and Rituals of corporate life by Deal and Kennedy (1982). Again, activities with the organization depend on organizational culture or corporate culture or management system as shown in block diagram at figure-3.

![Figure 3: Causation of incidents (Source: Krause et al., 1990).](image)

In Bangladesh any outsider or visitor may opine that there exists no safety culture if they see how people travel by different modes of transport. This can be a huge research topic on how to measure the quality of safety culture in IWT sector. Weigmann (2002) proposes a set of organizational indicators that may help to measure safety culture as follows:

a. Organizational Commitment: Top management should identify safety as a core value.

b. Management involvement: Day to day participation by management to observe how employees conduct operation. Not like in Bangladesh that the operation of passenger vessels is monitored during special occasions only.

c. Employee empowerment: Employees are given substantial power of influence and responsibility.
d. Reporting system: Degree of free and uninterrupted reporting of safety matters.

e. Rewards or Punishment system: The manner in which rewards or penalties are set.

In the shipping industry rules and regulations have been involved over time through occurrences of major incidents or accidents which caused loss or damage of property and life. These events prioritized formation of maritime safety management regime. Majority of the maritime communities have focused primarily on the consequences of accidents resulting from failures made in relation to safety. In most of the cases efforts have been made to blame someone and this has created a culture of punishment. The people in the last chain of events are generally found responsible. The safety management regime needs to impose priorities for safety. Culture of punishment still prevails in every organization but the method of accident analysis and tools they use differ.

**Evaluation of Accident Theories**

Not many theories are in existence which may explain the operational challenges faced by the passenger vessels’ operation in IWT sector. In order to study safety matters, examining, investigating and analyzing accident causation various accident investigation theories have been developed over the years. Following paragraphs show a list of theories which may relate the researcher’s purpose.

**The Domino Theory:** Accident causation theories have evolved from the old Domino Theory (Heinrich, 1931) to more popular multiple causation theories for accidents. According to Heinrich (1931), there is a domino effect for every accident. He identified five factors responsible for accidents, which are:

a. Ancestry and social environment  
b. Workers’ level of knowledge and attitude  
c. Unsafe act together with mechanical and physical hazard  
d. Accident  
e. Damage or injury

His findings say: 88% of all accidents are caused by unsafe acts of people, 10% by unsafe actions and 2% by ‘Acts of God’. One limitation of this theory was unavailability of any data. Data analysis of accidents indicate
that the percentages provide by Heinrich (1931) vary greatly across industries and occupations. As such theory of Heinrich is no longer accepted by safety profession as a valid one. In the recent past, in the light of changing world economic circumstances, Heinrich’s accident causation theory has been given a vital update- by adding a sixth Domino, by the British Safety Service (BSS, 2010). This new domino has been the ‘External Factor’ at the very beginning of the process. This new concept emphasizes that external pressures provide a major impact on any business or operation and should be considered from safety perspective issues such as recession, business environment, low price and high competition. The author finds it very logical and vital to consider this sixth domino e.g. political economy, socio-economy, education level etc. have influence to the operation of passenger vessels in the waters of Bangladesh.

Kristiansen (2005) gives a comprehensive summary of related theories:

a. The pure Chance Theory: Everyone of any given set of workers has an equal of being involved in an accident. In this theory, all accidents are treated as corresponding to Heinrich’s Act of God, and there exist no interventions to prevent them. This theory has never been justified to study maritime accidents.

b. The Biased Liability Theory: Everybody is subject to the same risk and has same liability to accidents within a given set of workers; there exists a subset of workers who are more liable to be involved in accidents. Researchers have not been able to prove this theory and not accepted.

c. The Energy Release/ Transport Theory: (Haddon, W., 1968) This theory is useful for determining injury causation and evaluating energy hazards and control methodology but it is not proven in case of maritime operation.

d. The Multiple Causation Theory- Reason (1990): Causation is an interaction between latent and active failures. To avoid this interaction proactive involvement is essential. Active failures are immediate observable causes and are easily identified, and latent failures may be present in the system for many years, as are hidden in the organization. Examples drawn from the survey and case studies of accidents of IWT passenger vessels show that problems of design, gaps in supervision, repeated noncompliance of rules are old
problems within. This theory suggests that for a single accident there may be many contributing factors, causes and sub-causes, and that certain combinations of these give rise to accidents. Factors are grouped into two groups/ categories:

(1) Behavioral: Factors pertaining to the worker such as improper attitude, lack of knowledge, lack of skills, and inadequate physical and mental condition of staff and workers in reverence environment.

(2) Environmental: This category includes, improper guarding of the other hazardous work elements and degradation of equipment through use and unsafe procedure (Rhodes, 2015).

e. Epidemiological Theory: Accident is a conjunction between operator (Victim), toll (agent) and working environment (situation). These involve a wide variety of factors which can be subject to improvement on each area of individuals, technology and working environment.

f. Human Factors Theory: Heinrich (1931) posed his model in terms of a single domino leading to an accident. The human error which may cause accidents are categorized as:

(1) Overload: Workers over worked which include physical and psychological factors, these are influenced by environmental factors, internal factors and situational factors.

(2) In Appropriate Worker Response: Incompatible work station says, management faults, environmental faults.

(3) Inappropriate Activities: Lack of training and misjudgment of risk. The structure of this theory is still a cause/effect format.

Human factor theory also introduces ergonomic trap, system failure (policy, training etc.)

**Tools and Techniques for Accident**

Most of the tools for safety analysis are 40 to 65 years old. But there has been phenomenal improvement and change over technology and peoples’ aspiration and demands have also been changed. Majority of the tools have been developed after world War II. Figure: 4 shows how the evolution has taken place. Some of the popular major tools are discussed in the following paragraphs:
The techniques which have been usually studied before arriving to a decision to choose the best model or technique are as follows:

a. Preliminary Hazard Analysis (PHA): The preliminarily hazard analysis methodology is used to identify possible hazards that may result in any severity. This is known as pro-active risk management and has some use in ships and craft-operation. This may not give enough benefit to the operator of passenger vessels during operations. But this is a good tool to the designer of simulators for training purpose of crews of modern vessels.

b. Hazard and Operability Studies (HAZOP): A more comprehensive and detailed method than PHA is HAZOP. Its principle is to systematically search for deviation from normal operations. For example, if intentions for a vessel’s operation are clearly defined, possible deviation from the system intentions may lead to hazardous situation. In case of a ship, causes and effect for any equipment or system failure may be analyzed for a whole system. Intention of each part of the system needs to be identified.

c. Failure Mode Effect and Criticality Analysis (FMECA): The FMECA is a systematized inductive method to determine equipment function functional failure mode, assessing the causes of such failures and the effects, reliability, safety, quality etc. on a component level (say for a ship or craft). It is a quantitative method.
The FMECA can be used systematically to identify the most effective, risk-reducing measures, which assist the process of selective design alternative in an early design phase of vessel, system, or equipment. However, to analyze the overall challenges of a passenger vessel operator, this tool may not be a suitable option.

d. Fault-Tree Analysis (FTA): By the use of logical diagram FTA methodology can be used to identify subsystem that are most critical for operation of a given system (Watson, H, S. 1962). This type of analysis has limited option and is used for probability of component failure of any ship of system having linear relationship. FTA was done on capsize issue by Hossain, et al. (2014) but never tested.

e. Events Tree Analysis (ETA): To analyze the consequences of an event or function, Event Tree Analysis has been used by Accident Analysts, which is a binary technique.

Event-based models have certain limitations. Event/ Fault Tree tools have been involving a partial or limited item of a whole system e.g. component failure, human error, any other single event like propulsion or engine failure of a ship. Forward sequences (As in FMEA or Event trees) or backward ones (as in Fault Tree) are for linear problem. But these are not good enough to deal with non-linear relationships. Some important causal factors, say external influence, management commitment, environmental factors, human factors are difficult to fit into simple event models.

**Formal Safety Assessment**

United Kingdom Marine Safety Agency in 1998 first proposed a five-step approach (Kriestiansen, S., 2005) called Formal Safety Assessment (FSA) to IMO as a basis for rule-making. The FSA procedure has five steps, namely, Hazard Identification, Risk Analysis, Study of Risk Control Options and Assessment of Cost Benefit and finally recommendation for decision making, Flow chart for FSA.

The approach/methodology is shown at *figure-5*.

While carrying out accident analysis of river boat capsize in Indian Inland Waters, FSA was carried out (Kalyani, T., et al. 2015) to identify the hazards and it also required expert opinion to prioritize the same by making a risk ranking matrix. With the application of concordance coefficient some qualitative decisions are taken. This helps the policy makers to some extent
but how the operational challenges can be eliminated and root causes are identified still may remain a question. The experts’ criteria are also not clear from the assessment. Moreover, cost benefit analysis was not shown.

**Figure 5: FSA Approach and Methodology (Kriestiansen, S., 2005)**

From the discussions above, it may be summarized that methods or processes may not be useful to find the root cause of system failure or operational challenges in passenger vessel. Once the immediate cause is identified for a failure, the investigator assigns blame and backward chain of events often stops. As a result, the analysis at times remains superficial. To explain why accidents occurred to prevent similar losses, here concentration lays on the proximate events immediately preceding any loss. But the root causes of accident often laid much before.

**Accident Model Based on System Theory**

Another fairly recent accident model is called System Theoretic Accident Model and Process (STAMP) introduced by Leveson, N. (2004). She explained this concept to analyze system accidents or failures. She suggested that accidents occur when there is a lack of constraints. This theory addresses some external factors while analyzing accidents. According to this theory accidents may occur from inadequate control on enforcement of safety related constraints on the development design and operation of the system. Here safety is viewed as a control problem and is managed by control structure embedded in an adoptive socio-technical system. Accidents result from a lack of appropriate constrains on the interactions.
Modeling complex organizations and industries using system theory involves dividing them into hierarchical levels with control processes operating at the interfaces between levels (Rasmussen, 1997). A generic socio-technical control model is shown at figures: 6a and 6b for operation and one for development. This may be a guide or reference for the model the author is looking for his research.

Model for IWT Passenger Vessels’ Operation and accident analysis:

![Socio Technical Model for System Development](image)

*Figure 6a: Socio Technical Model for System Development*
The figures, ‘6a and 6b’ shown above, are a model which may be used to analyze the IWT system and accidents with appropriate modification as deemed feasible from case to case. These have structure to examine from both the regulatory framework, and operational aspect of the vessel. Socio-technical factors will have effect on overall operational efficiency of the model. Technical issues for operation may be controlled through design of appropriate software. So the whole process includes two major divisions. One is for system development. This will include the whole governance aspect of the organization, regulatory frame work and all external factors. The second part includes the complete operational aspect of the vessel. Both human controller and automated controller may be used. Feedback from operating process would be fed to operations’ management to analyze data for review and examine the drawbacks. The whole process appears little complex but it is possible.
External factors as constraints will be multiple and each one has to be listed as received from the reports of different sources. External factors such as legal and regulatory, economic, cultural and societal, political, corruption, ownership structure and accountability may have influence on the possibilities of untoward incident leading to accident.

Any new approach or strategy out of the considerations should have a cost-benefit analysis based on basic ALARP (As low as reasonably practicable) risk principle as developed by UK Government’s safety department (Kristiansen, S., 2015).

A Case Study

An effort has been made to analyze an accident case at in Bangladesh at river The Padma on 22 February 2015. It was a collision case between two vessels namely MV NARGIS (M-10238), a cargo vessel and MV MOSTAFA (M-2475), a passenger vessel. The accident resulted loss of 81 lives. Major constraints have been as follows:

a. Propulsion machinery tested as per regulation prior sailing and has all maintenance completed as per classification rules.

b. Vessel built as per design, built at authorized yard, surveyed, and found fit after annual docking prior operation.

c. Master, Driver, and crews having requisite training prior getting their last certificate of competence.

d. Maximum number of authorized passengers can be carried.

e. Minimum number of life saving appliances to be held.

Based on the constraints, the case was examined and analyzed and the passenger vessel operation was found faulty. Origin of the problem lies with the vessel itself and the attitude of the owner. The authorization of the vessel to operate under such condition was beyond any principle of safety. Details of the study would be projected in further works of the author.

Suggested Model

Several external factors may be examined to arrive at a decision to reduce or stop future accidents. Considering the discussions above, a simpler model for IWT system and accident analysis has been designed by the author as shown at figure-7. The test of the model is to be done, once the
constraints are set. The variables or external factors are to be identified clearly through survey and study to make the correlations and then hazards are to be analyzed with the use of the relevant tool.

Figure 7: Model Recommended for Accident Analysis for Passenger Vessels

Conclusions and Recommendations

Bangladesh is a land of rivers and people are highly dependent on these. IWT will continue to have a role to take a role on the overall transportation sector of Bangladesh. There is no guarantee that accidents will not occur in IWT sector but the recurrence of similar accidents may be minimized if appropriate measures are taken by the concerned authorities. This study may help accident researchers and analysts to advance their researches goals. The
research outcomes would feed the safety administration. Every accident must be analyzed to bring out the root cause and prevent the same in future. The model/tools which may be used to analyze accidents and operational challenges faced by the operators will bring useful results to the regulatory body as well as the operators. External factors which are not discussed in previous researches in carrying out on IWT cases would be useful input to carry out further researches on the subject. The external factors can be multiple where issues like safety culture, education, political, economy, transparency, education, socio-cultural etc. have specific roles to play.

Operational challenges at IWT sector in Bangladesh are unique in nature. This is because safety culture is almost missing. People never hesitate to risk their lives and board a crowded vessel. The administration gives a blind look most of the times. Accident cases are not well analyzed and root causes are not found. General enquiries reveal almost similar findings but situation does not improve. It is, therefore, recommended to use STAMP to analyze accident cases and identify the root causes. It is expected that the whole system of operation of IWT passenger vessels would improve if the control body gets the system running and it would improve the safety aspect of the passengers’ travelling through the IWT vessels.

It is recommended to use simpler model for IWT system and accident analysis as designed by the author and shown at figure-7.

References


Bird FE, Loftus Rg, LOss Control Management Loganville, GA, USA International Loss Control Institute, 1976.


