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A Study on the Accidents of Inland Water Transport in Bangladesh: The Transportation System and Contact Type Accidents

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Abstract

This paper presents a study on contact type accidents of water transport in Bangladesh using fault tree analysis as a tool. Based on the unique characteristics of the inland water transportation system in Bangladesh, a fault tree is developed to represent the chain of events resulting in collision and grounding. The factors triggering the mishaps are enumerated in a structured form, after scrutinizing the accident information. The chains of faults are elucidated here with the intention of executing groundwork for future database development. Thus, the developed database on the derived fault tree will help as a tool to trace top-level system failure back to initial reasons or faults. The paper further discusses the unique safety characteristics of the inland water transportation system in Bangladesh.

Keywords: Inland waterways, fault tree analysis, accident database system

1. INTRODUCTION

Bangladesh possesses a unique geomorphologic setting with an intensive network of around 700 rivers, covering a length of 24,000 kilometers, which is almost 7% of the surface of the country [1]. Bangladesh has about 9,000 square kilometers of territorial waters with a 720 kilometer long coast line and 20,000 square kilometers of economic resource zone (ERZ) in the sea. The navigable waterways of Bangladesh, 5,968 kilometer in length, were classified in 1989 according to the least available draft (LAD) [2].

Three mighty rivers the Ganges (local name Padma), the Brahmaputra (local name Jamuna) and the Meghna, converge to form one of the largest deltas, named Ganges Delta. These three rivers also generate one of the most complex river systems in the world [1]. This complex water network has spread in such a pattern that a huge portion of the country, especially the southern tip and the offshore areas, are hardly accessible by land transportation. As the land is ensnared with the waterway, almost all infrastructures in the country have always been river dependent. The inland water transport (IWT) system is well-connected with rest of the transport system.

IWT plays a vital role in the transportation sector of Bangladesh. A previous study reveals that around 102 million passengers covering 110 billion passenger-kilometers and 30 million metric tons of freight covering 18.6 billion ton-kilometers are transported by inland waterways [2]. A substantial portion (12.3%) of the rural population only has a reasonable access to the transportation system through IWT, which is half of all rural households (25.1%) who have access to river transport [3]. Thus, IWT plays a pivotal role towards government’s effort towards growth and reduction of poverty under National Strategy for Accelerated Poverty Reduction (NSPAR) [2].

Despite the vastness of the IWT network, it has many problems associated with safety and navigability. Natural obstacles cause a lot to inadequate navigability, as well as to marine disasters. It is a painstaking job to find the permissible routes for navigation, as routes vary in a wide range with the change in seasons. During the monsoon, the navigable inland waterways are approximately 5,968 km in length, which however, decrease to 3,600 km in dry seasons [1]. The problem gets intensified due to alluvial deposition, which is profoundly caused by geographical position of the country, deforestation and unplanned construction of dikes and embankments in the coastal region.

Table I: IWT Network Classification

Class	Indicated draft (m)	Length (km)	%	Classification Criteria
I	3.6	683	11	Major transport corridors where LAD of 3.6 m is required to be maintained round the year.
II	2.1	1,000	17	Links major inland ports or places of economic importance to class I routes.
III	1.5	1,885	32	Being seasonal in nature, it is not feasible to maintain higher LAD throughout the year.
IV	Less than 1.5	2,400	40	Seasonal routes where maintenance of LAD of 1.5 m or more in dry season is not feasible.
Total		5,968	100	

Over the years, different authorities and researchers have taken initiatives to improve the maritime safety situation. Nevertheless, most efforts still seem underachieved, and research on structured risk analysis is yet to be performed. Since there is no proper accident database system in Bangladesh, this paper focuses on the utilization of fault tree as a tool for prior identification of the dangers of water transports which can be used to develop an accident database system.

2. LITERATURE REVIEW

Literature review suggests that most research works are limited to the identification of major types of accidents, causal factors and statistical distribution. For example, Huq and Dewan only described different types of accidents in geographical context describing the river system of Bangladesh [1]. A statistical analysis of the hazards, involved with the indigenous technology based marine vehicles in Bangladesh, was featured extensively by Awal [4]. Another investigation by Awal et al., revealed some interesting findings, portraying the major causes of passenger vessel accidents [5]. In a similar type of research, Awal et al. demonstrated the distribution of accidents in month and time bands, including weather and visibility condition during casualties of various types of vessels [6]. An investigation on accidents conducted by Zahanyar and Haque, enumerated the factors triggering marine disasters, and later proposed some actions for the prevention of accidents [7].

A study by Baten [8] discussed irregularities in the IWT sector from the safety perspective, criticized the existing regulations of Inland Shipping Ordinance 1976 (ISO 76) for being incompetent and recommended some amendments of the law. He urged that formation of a classification society can boost a safer scenario by probing proper design and construction process of waterways. Bangladesh Inland Water Transport Authority (BIWTA) [9] conducted some notable studies where the safety and stability parameters of the passenger vessels were considered. Technical characteristics of various types of vessels like year of build, difference in dimension, passenger capacity, number of engine, and engine type of each registered passenger vessel were included in this study. Chowdhury used a GIS based accident information system for evaluating marine accidents and studied characteristics of the incidents [10].

To serve the purpose of obtaining a scientific and practical accident database system through comprehensive analysis of accident events, fault tree analysis (FTA) is a remarkable tool to start with. In the book named ‘Fault Tree Handbook with Aerospace Applications’, Vesely et al. propounded that FTA provides visual, logic model of the basic causes and intermediate events leading to the top event. The qualitative information obtained from an FTA is of equal importance to the quantitative information provided. This book also enunciates the use of FTA as a proactive tool to prevent the top event and an efficacious approach to detecting and correcting or improving the vulnerable areas [11].

FTA based researches have progressed considerably over the years. Amrozowicz et al. applied FTA on grounding and represented a probabilistic risk assessment (PRA) [12]. Antao and Soares identified hazards involved in collision type of accidents as the first step of formal safety assessment (FSA) and modeled the relationship among the relevant events using FTA [13]. Celik et al. addressed a fuzzy extended fault tree analysis to develop a risk-based modeling approach to enhance the execution process of shipping accident investigation [14]. Basu and Bhattacharya applied FTA to investigate the system failure of floating structures, particularly featuring structural failure and compartment flooding, and also performed a probabilistic calculation of structural and non-structural failures [15]. Presenting a fault tree on capsize issue, Webb performed risk assessment and reviewed human factors related to the risk of capsizing during design and operation of warships [16]. However, there is only one study on inland water transportation safety conducted using FTA, which was performed by Hossain, et al. who used it to reconstruct capsize type of accidents [17]. Other similar researches in Bangladesh are very difficult to refer to date.

One of the paramount issues about marine accidents is human factor. Rothblum performed an extensive statistical analysis on the contribution of human factors to marine accidents and observed that the lion’s share of accident factors is involved with human error [18]. Psaraftis et al. successfully enumerated the human factors which bring disasters to marine vehicles [19]. They recommended putting more emphasis on reducing human factor than technological solution for reducing the risk of marine accidents. Talley et al. concluded that human mistakes result in higher number of fatalities in passenger vessel accidents than environmental and vessel related causes [20]. Calhoun addressed the issue of shipboard operator fatigue and proposed incorporation of human factor to ship design to prevent fatigue, as well as reduce human error to a minimum level to ensure marine safety [21]. He also introduced the thought of modifying some classification societies’ rules to be more people-oriented instead of being job-oriented.

Based on the knowledge gathered from the abovementioned research works, together with the evaluation on accident data derived from various authentic sources, FTA should indeed be applied in contact events to determine the chain of accident events.

3. DATA COLLECTION

The pivotal part of the research work on marine accidents is data collection from legitimate sources and winnow the pertinent issues with extensive precision. Due to paucity of authentic data, data collection and preparation are the most arduous stage of the research work. Moreover, shortage of extensive analysis on accident events makes the data processing extremely difficult. Therefore, for this study, data have been collected from various sources to develop a good evaluation on the accident triggering factors in Bangladesh.

3.1 Data Source

In this study, the accident database tool was developed using both primary and secondary data. Primary data were collected either through a structured observation method, unstructured interview of the personnel at the corresponding expertise and survey with a questionnaire form for collecting data from the crews and regular passengers of inland water transportation system. In the book ‘Research Methodology: Methods and Techniques’, Kothari [22] defined structured observation method as an observation characterized by a careful definition of the units to be observed, the style of recording the observed information, standardized condition of observation and the selection of pertinent data of observation, while an unstructured interview is characterized by a flexibility to approach to questioning which does not follow a system of pre-determined questions and standardized technique of recording information.

The prime source of secondary data were research papers published in various journals and conference papers. Other sources included the accident data, compiled at Accident Research Institute (ARI), and various publications of the governing bodies such as BIWTA, Ministry of Shipping (MOS) and Department of Shipping (DOS). The data were also collected from the reports of various newspapers.

In order to conduct case study, several accident investigation reports, conducted by the committee of MOS, were collected and studied. Several accident cases from the accident investigation reports published by Marine Accident Investigation Branch (MAIB) and Marine Accident Reporting Scheme (MARS) together with Safety Digest published by MAIB were also studied to gain a proper insight to factors contributing to the marine accidents. Likewise, different editions of the magazine ‘Alert!’ also served this purpose.

3.2 Some Findings Regarding Marine Safety in Bangladesh

Structured observation, unstructured interview and literature study revealed some facts threatening marine safety in Bangladesh.

3.2.1 Extremely High Siltation Rate

As the country is located in the vicinity of the nadir of the Himalayas, which is comparatively young and vulnerable to soil losses due to both natural and man-made causes, high rate of sediment transport is prevalent here. Since the river gradient within Bangladesh is very low, a significant amount of that sediment load cannot be naturally transported to the Bay of Bengal and is deposited on the river beds, as well as flood plains, each year. The Ganges River mobilizes a total of 729 megatons of sediments annually through a narrow zone within its river valley. Under the present hydro-geological conditions, the river sedimentation is climatically controlled and is predicted to produce a 2000 km long, 2 to 40 km wide and 25 to 50 m thick ribbon-shaped, well-sorted symmetrically skewed fine sand body [23]. The river of Ganges is marked by its second highest siltation rate in the world.

3.2.2 Inadequate Dredging Service

The current situation of the waterways demands for a prominent dredging service. The Government is also trying to stretch to the limit in fighting this problem. However, the transportation sector in Bangladesh has been developed markedly in a biased manner, emphasizing more on the roads and highways department (RHD). Therefore, fund allocation for the IWT development is not satisfactory compared to roads and highways. In 2007-08, 79.64% of total ADP was allocated to RHD while IWT was given only 1.37%. In the same year, BIWTA spent 33.5% of its money for dredging related works. However, the repentant fact is that 56% of this money was spent to maintain ferry terminal and channel dredging, which actually serves the RHD, leaving the main waterways in a miserable state [2].

Annual dredging demand in core waterways network is estimated as 18 million cubic meters, while the annual productivity of the dredgers, currently in work, is 6.36 million cubic meters only. This is due to the dearth of dredgers as well as the aged state of most of the dredgers, resulting in reduced efficiency [2].

3.2.3 Deficient Hydrographic Surveys

Due to low budget allocation, hydrographic surveys to all classified waterways remain impossible. Only a limited number of navigation routes of 965 km, 16% of the total, were surveyed in 2006-07 according to a need-based priority. Thus, due to all the shortcomings stated above, the current classification system of inland waterways is believed to outlive its usefulness [2].

3.2.4 Scarce Navigational Aids

Navigational aids like beacons, lighted & unlighted buoys, iron & bamboo marks etc. are used to mark shoals, while channel bends, shallow patches etc are used in waterway routes for the vessel safety. Only 1,561 km of waterways, 26% of total, have been provided with the navigational aids for night navigation, while 3,256 km, 55% of total, have been equipped for the day navigation. Moreover, to provide navigation support in case of uncertainties in channels, pilotage service is provided with only 24 pilot boats and 26 pilot stations, which are not sufficient at all for such a long river network [2].

3.2.5 Insufficient Manpower

IWT sector suffers not only from low budget allocation but also from insufficient manpower. Even though DOS started its journey with 45 personnel and one inspection boat in 1976, nowadays, based on ratio, it is provided with lesser man power and no inspection boat, in spite of a rapid increase in the number and type of vessels. The impact is obvious as it is extremely difficult for such a small number of individuals to conduct inspection of vessels and to take necessary steps in order to ensure marine safety.

3.2.6 Intense Traffic Density

Observation at various river ports exposed that the intense traffic density in the ports prevent the vessels to berth alongside the pontoon and persuade them to resort to nose berthing. Due to acute congestion, the vessels keep colliding with each other recurrently, causing damage to the fender as well as the hull. These collision events are often ignored as long as these do not result in human death or severe hull damage. Other hazardous effects such as crack formation and propagation, metal fatigue and so on, leading to ultimate hull damage, often seem to be underrated.

4. DEVELOPMENT OF FAULT TREES ON CONTACT TYPE OF MARINE ACCIDENT

In order to develop the fault tree various accident factors such as design failure, structural failure, navigational error etc. had been analyzed. A meticulous compilation of the data from previous accidents from different authentic sources was carried out. Based on these, the chains of faults and irregularities which fetch marine accidents were marked. Keeping a categorized top-level system failure at top position, the branches of its immediate earlier factors were then arranged in a descending order, which ended up with the initial faults. The fault tree is shown in Figure 1.

In this paper, the term ‘contact’ is composite of ‘grounding’, referred to contact with shoreline, and ‘collision’, referred to contact with vessel or other structures. As extreme alluvial deposition is prevalent in the river beds of Bangladesh, navigability of waterways is a major issue involved with marine mishaps in the country. Since the rivers volume is dependent upon the snow-melts from the Himalayan range and the monsoon rains, the water discharge from upstream and the corresponding water levels not only differ from year to year but also fluctuate throughout the year. Thus, one single river displays dual nature, once with a large discharge during the monsoon and another with a low discharge during winter, which creates problem for navigation. Thus, insufficient or wrong information about routes will lead vessels steered through unsafe track and subsequent grounding or collision. Position estimation error also leads vessels astray from right track.

Apart from the probability of grounding or collision becoming intense, another problem is insufficient navigability, associated with environmental disruptions such as unsafe wind (Nor’wester) or current. Machinery failures and operational faults trigger loss of control over ship, which drives the ship into contact with shoreline or other vessel. A striking resemblance can be observed between the approaches when analyzing the factors working behind grounding and collision.

4.1 Powered Contact

Powered grounding or powered collision occurs mainly due to navigational error and remiss of watchman. This type of accident usually occurs to ship being steered through restricted waterways. Powered contact type of accident does not encompass the mechanical faults and failures of the vessel. It mainly refers to steering through inadequately navigable route either by directing the ship or due to deviation from the right path. In the fault tree, the type of ‘powered contact’ branches into two factors; PG1- Choosing unsafe track and PG2- Deviation from safe track.

PG1 is defined as being enmeshed with the information available about the route through which the ship should be navigated. Human factors are solely accountable for the conduction of wrong information. PG1 branching into PG11- Wrong or insufficient information or PG12- Improper use of information is traced back to the human faults, such as lack of updated charts, authority's heedlessness to waterway navigability, erroneous use of information or so on. PG2 is directly involved with the human faults working during incident, such as delayed or insufficient actions.

4.2 Drift Contact

Drift contact commonly refers to mechanical faults and failures and incapability of steering vessel through the correct path due to environmental cataclysm. DG- Drift contact branches into one environmental factor, which is ENV- Unsafe wind or current, and three human and mechanical factors, which are DG1- Loss of steerage way, DG2- Assistance or Pilotage error and DG-3 Anchor failure.

DG- 1 corresponds to machinery failure which is profoundly liable to human factors such as improper selection of machineries, improper maintenance & protection and operational error. DG-2 resembles the errors involving with prior requesting for navigation assistance and but improper execution of this assistance. Absence and misuse of suitable communication device like VHF radio often inhibit a vessel to inform other vessels, coming into its way, leaving it vulnerable to collision. In addition, no request for pilot ship during journey through channels brings about uncertainties and inability of the pilot ship, resulting in grounding or collision with underwater structures. DG-3 is traced back to machinery failure, erroneous action and material failure. Material failure is the product of allowing crack formation and propagation. Crack formation is liable to stress development as a result of selection of unsuitable material, corrosion, excessive vibration, critical resonance, improper construction or repairing and mechanical shock.

5. DISCUSSION

Since accidents are not usually caused by a single failure or mistake, but by cumulative action of a whole series of errors, accidents should be very rare to happen. The analyzed fault tree clearly shows how the implicit and explicit factors add up to cause an accident. For the respective authority and researchers, this tree can assist to understand the accident propagation and suggest proper corrective measures to prevent a disaster.

This paper highlights how unique the water transportation system in Bangladesh is and the challenges ahead to overcome. As most accident reports in Bangladesh focused only on finding out the liable personnel instead of discovering the accident factors in detail leading to an indistinct idea about the accident mechanism, the research findings of this paper can lead to a proper accident mitigation and thus help minimizing the blame culture.

6. RECOMMENDATIONS AND LIMITATIONS

Some important recommendations are mentioned in this study, which are believed to have positive impact on the safety scenario of inland water transport accidents in Bangladesh. Reviews and findings from this study help put insights to the accident prevention scheme.

First of all, a rich and powerful database has to be developed as soon as possible. All previous accidents should be investigated properly by the concerning authority. The fault trees, presented in this paper, can be groundwork for the investigation procedure.

A direct investigation of accidents through an interactive system may serve the purpose of both developing an authentic and reliable accident database and updating the current fault trees. Hence, this type of investigation is recommended to be carried out unceasingly. Thus, after certain period, a powerful accident database, as well as accurate fault trees, will be achieved.

As soon as the database is developed, the data should be processed using proper tools (e.g. fault tree). Careful analysis of the data will result in the discovery of certain chain of events that trigger a debacle. The accident mitigation process should be based on this analysis.

Since almost all the accidents are associated with human faults, this deadlock can be broken easily if proper steps are undertaken to improve the corresponding human elements.

Regular hydrographic survey on all navigable waterways should be carried out and the navigation aid service should be provided appropriately.

In spite of having some drawbacks, FTA has been proved to be an efficient approach for determining a system failure and error reduction technique. The fault trees, provided in this paper, are recommended to be refined and developed further by using authentic primary data source.

Certain events in the fault trees have not been further developed due to shortage of genuine data sources. Furthermore, most of the events, which are traced to factors related to the human element, have not been developed further. For future research, the above limitations need to be further studied.

7. CONCLUSION

This paper focuses on developing fault tree for collision and grounding type of accidents as a suitable tool for the collection and analysis of accident data to identify hazardous chain of events. The aim is to identify errors and hazards which are related to the accident process, both explicitly and implicitly. Such fault tree can be used as a foundation for extensive risk analysis. Besides, this paper discusses the unique features of IWT system in Bangladesh.

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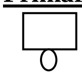
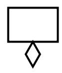
NOMENCLATURE

ARI – Accident Research Institute
BIWTA – Bangladesh Inland Water Transport Authority
DOS – Department of Shipping
ERZ – Economic Resource Zone
FTA – Fault Tree Analysis
IWT – Inland Waterway Transportation
MAIB – Marine Accident Investigation Branch
MARS – Marine Accident Reporting Scheme
MOS – Ministry of Shipping
NSPAR – National Strategy for Accelerated Poverty Reduction

FAULT TREE ANALYSIS EVENT SYMBOLS

Primary Event Symbols


BASIC EVENT - A basic initiating fault which requires no further development.


UNDEVELOPED EVENT - An event which is not further developed either because of insufficient consequence or because information is unavailable.

Gate Symbols


AND - Output fault occurs if all of the input faults occur.


OR - Output fault occurs if a least one of the input faults occurs.


EXCLUSIVE OR - Output fault occurs if exactly one of the input faults occurs.

Transfer Symbols


TRANSFER IN - Indicates that the tree is developed further at the occurrence of the corresponding TRANSFER OUT (e.g., on another page).

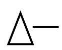

TRANSFER OUT - Indicates that this portion of the tree must be attached at the corresponding TRANSFER IN.

Figure 1: Contact FTA

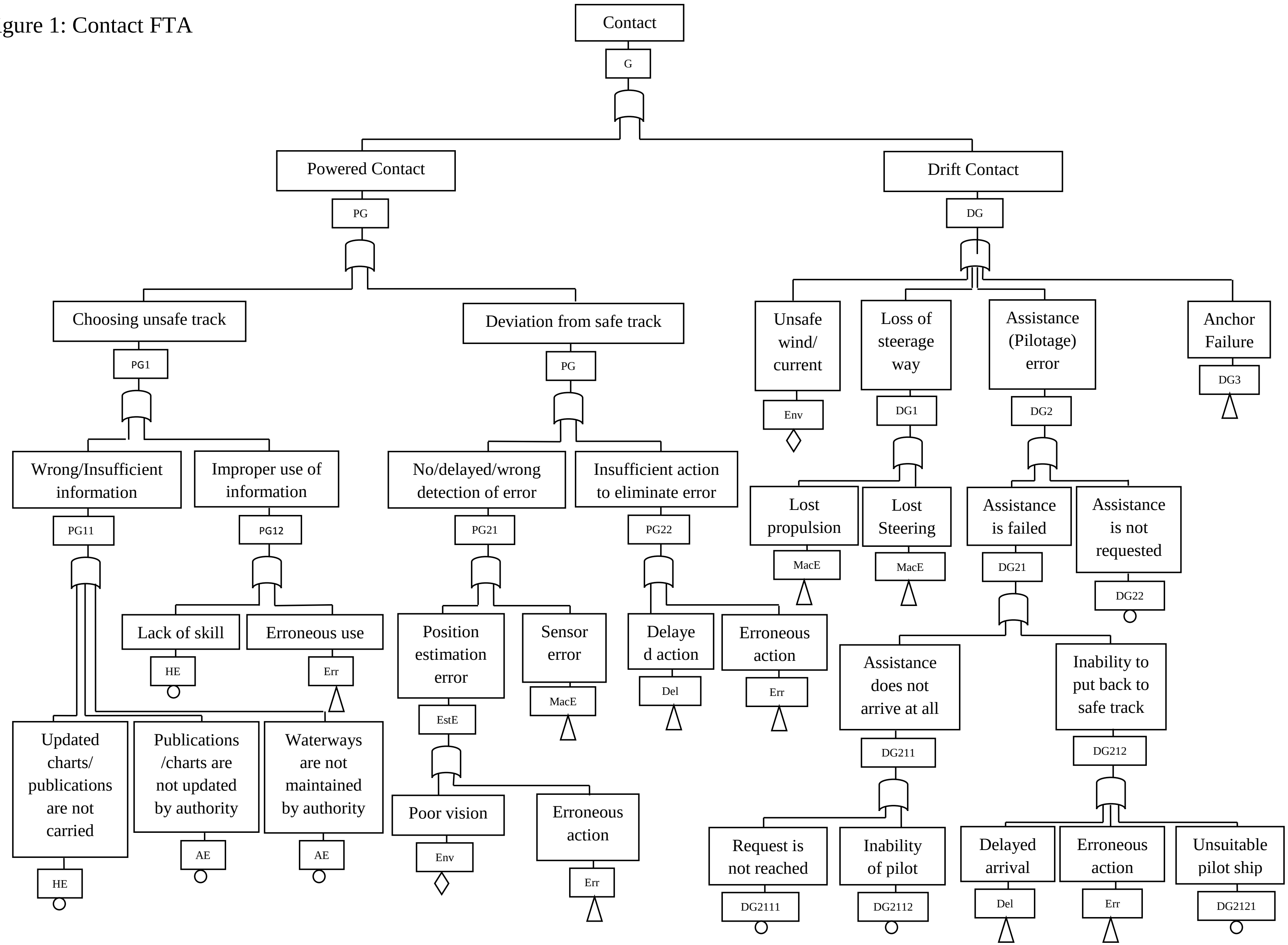


Figure 1: Contact fault tree

(Continued)