RISK ANALYSIS AND THE PROBABILITY OF COLLISION

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ABSTRACT

In order to determine the probability of a collision, all risk factors which could lead to collision should be identified. Therefore, our paper analyses two different situations. The first one is the situation when the number of possible collisions can be estimated in case no avoiding manoeuvre is performed. In such a situation the consequences of the collision are influenced by the waterway and the involved ship's dimensions. We intend to emphasise here that the probability of a collision is influenced by a large number of factors related not only to the waterway but also to the ships involved and the human factor. The second situation is based on the identification of all factors involved in collision which could be divided in two groups: factors which can be controlled and uncontrollable factors. Factors which cannot be controlled are those related to environment conditions. Factors which can reduce or increase collision consequences should be also identified. Further on, this paper emphasises the point that collision consequences should not be related only to structural deformations of the ship, human safety should be also included in the analysis as well as the effects on the environment, the economic impact, the shipping company's reputation and the type and quantity of oil products spilled at sea as a result of the collision.

Keywords: *risk analysis, probability of collision, risk factors, consequences, safety*.

1. INTRODUCTION

One of the evaluation methods of risks in case of a collision may be a combined analysis of occurrence and consequences. In order to bring the ship from an intolerable situation to an acceptable one, occurrence and frequency must be reduced. Through this method, the risks involved in navigation may be compared with risks involved in other transportation fields.

Risk evaluation and cost benefit analysis may provide a decision instrument or recommendations for actions taken in order to reduce risks, we talk here about prevention actions such as those taken according to the Vessel Traffic System or protection actions such as new criteria for designing the structure of ships involved in possible collisions.

Performing an analysis of cost and benefit could be a way to quantify the consequences, and in this process it is necessary to measure the statistical values for human life, pollution and property. The term cost-benefit refers to costs involved in reducing risks compared to the resulted benefits. Analysis may be made:

- For comparing naval structures in view of a better absorption of energy;
- For human error effect, technical failures and environment conditions;
- For comparing seaways or systems for traffic control;
- For cost-benefit of fixed navigational routes;
- For comparing plans for possible routes.

2. THE PROBABILITY OF A COLLISIONS HAPPENING

The probability of collision may be analysed based on different situations. The first situation that we should consider is the one in which two ships are in a collision situation and none of them takes action in order to avoid collision. The probability for none of them to take avoidance action is called causality factor which may be defined as the collision report between the ships involved. The probability of a collision may be determined by the number of possible collision as further explained.

The number of possible collisions may be ignored during the analysis, assuming that all ships shall be confronted with the same level of traffic along their existence. This sounds reasonable if ships which are compared have the same dimensions and are of the same type, situation which is applied in the majority of the analyses. In order to calculate the possibility of choosing an alternative route for navigation, the probability of collisions should be calculated when it is related to the cost-benefit analysis for a fixed route for navigation. The analysis made for a traffic system includes technical, navigation and environment analysis as well as ship's types and dimensions analysis for ships transiting that particular area.

The number of possible collisions is defined as the number of collisions in case no avoidance manoeuvre is performed. One method to determine this number in order to compare the alternative routes or the difficulties' estimation for navigation on seaways was presented by Pedersen (1995). Using this reference we are able to determine that when considering all ships in particular class, say class A, traveling on a particular seaway risking a collision with all ships of an assumed class B in a particular period of time we may conclude the following:

- The probability of collision represents the report between ships involved in a collision. This number may be estimated based on the statistical data related to accidents. A different approach may be used, as in analysing the cause which determined the absence of action of the human factor or the one which leads to external failures using the Bayesian error tree.

- The probability of a collision is the distribution conditioned by the fact that one's own ship does not have to take any action, considering the fact that the second ship shall not take any action either. The reason for which no action is taken may be separated into: a) action is no possible or b) action is possible but the watch officer does not react or makes the wrong decision.

In these situations, we can talk about several factors which could affect the production phenomenon of a collision such as: mechanical malfunctions, human errors or mistakes due to environmental factors. When no action is possible, determinant factors may be mechanical failures and environment conditions. Mechanical malfunctions may affect the engine, the helm, the rudder or the steering engine. Such problems arising depend on the ship's maintenance or the crew's experience and training. When we talk about environmental factors we refer to the navigational system or location, in areas where there are restrictions related to water depth, wrecks, winds and currents.

In table 1, part of the causes which lead to lack or reaction are described when action is possible but the watch officer does not act or makes the wrong decision. In this table, information related to seaways, ships and human factor are presented.

The fairway system or location may considered visible or invisible factors equally, the traffic intensity and the number of ships possibly involved in collision are factors related only to location. If a ship transits an intense traffic area, the watch officer shall be, probably, more careful and aware of the situation. The human factor influenced by experience and training may be a causing factor. Also, fear and routine, without being directly mentioned, may have a special importance in causing an accident. Examples: the lookout is afraid to call the officer, the officer is afraid to call the Master or in case of an intense traffic situation or a medical problem, the office is afraid to ask for help. Many problems arise from lack of training of the crew on board the ship, such a situation actually signalling a problem within the navigation company's management.

Table 1. Causes leading to the impossibility to take action in case of a collision

Errors	**Causes**
Incompetence	Experience Education Incorrect reading on systems and instruments Breaking collision regulations Incorrect evaluation of wind and current direction
Lack of action	Experience Education
No reaction of the lookout	The lookout does not react Language barriers The lookout does not understand commands
Low visibility	Heavy rain Smoke Fog
	Thick sea water drops on the windows of the bridge Visibility angle
Lack of attention to the maritime traffic	Documents Improper bridge design Alcohol Falling asleep Fire Instruments' setting Radio communication Change of watch officers Chatting Tiredness
Inability to work	Sudden sickness Illness
Stress	Personal problems Heavy traffic Alarms and noises
Radar	Interference on the radar's screen due to rough sea state Interference on the radar's screen due to rain Heavy traffic
Radar failure	Mechanical malfunctions

Friis Hansen and Pedersen (1998) determined, by using the Bayesian network, the probability factor of a collision between two ships as being Pc=9,0*10-5.

Probabilistic graphical models are graphs in which the nodes represent random variables, and the arcs (or lack thereof) are assumptions of conditioned independence. As a result, they provide a compact representation of probability distributions cumulated. Non-oriented graphical patterns, also called Markov Random Fields or Markov Networks, have a simple definition of independence: two (sets of) nodes A and B are conditionally independent if, given a third (set) C, all paths between nodes A and B are separated by a node from C. Unlike the graphical models (also called the Bayesian Networks), have a more complex notion of independence, which takes in consideration the direction of the arcs; they have several advantages: the most important is that a bow from A to B can be interpreted as A "causes" on B. This can be used as a "guide" to build the chart. In addition, oriented models can encode deterministic relationships and are easier to be learnt.

3. RISK FACTORS IN CASE OF COLLISION

First of all, a system of interest, which involves structure identification, must be defined, grouping elements and defining the relationship between elements by defining the interest impact and exits from the system. In analysing the occurrence of an accident it is necessary to use in addition to the information already known the risk modelling. Risk modelling involves the human factor, the nature of the navigation path, description and modelling of ship structure deformations, ship movements and installations on board, all closely related to the ship and the navigation route.

Reducing the likelihood of a collision actually involves prevention of collision production. Preventing collision is one of the main goals in the navigation industry, because a collision leads to loss of life, loss of operating time, loss of income and insurance. Factors that can influence a collision can be divided into three categories:

- Waterway system including environmental conditions;
- Ships involved;
- The human factor.

Ships cannot be analyzed by isolating them from the navigable system. Also the navigable system cannot be analyzed separately without the involvement of ships. And both, the ship and the ship navigable system are a complex and interdependent system involving the human element. However, in order to identify the risk factors and then how to implement preventive actions, we need to perform a separate analysis.

The factors that influence the risks of a collision are presented below. They are represented separately in three groups: the navigable system, the ships involved and the human factor. Some factors are difficult to modify, but most factors are considered control factors and can be used as parameters in cost-benefit analysis.

3.1 Seaway system and environment conditions

The navigation system is analyzed from the point of view of maritime traffic in the management area and environmental conditions. Traffic analysis requires information about the type and size of the ships as well as information on traffic intensity in the area. Traffic conditions are factors which cannot be changed because they depend on the activities of the ports in the area. In most navigable areas, no restrictions on navigation are applied, only the rules of the sea, considered to be the free sea or crossing the oceans. In the other regions there is a Traffic Control System (VTS) or pilotage system. Their purpose is to ensure safe navigation in restricted areas, such as coastal areas, heavy traffic areas and areas where navigation hazards are present.

The VTS system is constituted as a complex service of surveillance, coordination, monitoring and management of ship traffic, the optimal operation of the operational information system, navigation assistance, organization and management of traffic and it is designed to contribute to the development of vessel traffic safety and efficiency in the VTS area. The main tasks of the VTS service consist in: monitoring, coordination, surveillance and management of maritime traffic with the purpose of ensuring safer navigation, making ship traffic more efficient and protecting the environment in the VTS area.

Most factors involved in trafficking management can be modified so they become risk control factors. We must also take into account environmental conditions. Navigation conditions can be restricted due to the depth of water or the complexity of the waterway system. Factors such as the wind and current can influence the speed and the route of the ship by the effect of drifting. Visibility may be affected by rain, fog, smoke, etc. In this case, the complexity of the navigable system and perhaps water depth can be risk control factors, while other factors normally cannot be changed.

3.2 The Ship

The ship's analysis includes design (projection), apparatus, and part management. Design and equipment are strictly related to the ship's particularities, while the management side can be linked to both the crew and the navigation company. The International Maritime Organization (IMO) has established conventions, training guides for on-board crew, equipment guides and contingency plans.

3.3 The Human Factor

The human factor directly involved in a shipping accident is, the watch officer. However, three types of human factors contributing to incidents can be distinguished in the maritime industry: individual factors, group factors and organizational factors. Thus, although most immediate causes are attributed to individuals, in fact, most of the factors that contributed to the incident must be attributed to the organizational context or group dynamics that influence the individual. Culture, incentives, operational procedures and organizational policies have important safety implications for the maritime transport.

Communications on board are very important, and can become an important risk factor for multinational crews. It is important that a ship uses on board only one language for communication. Other important risks are those related to the reduction of the number of crew members compromising the safety of the ship; the growth of bureaucracy on board ships; fatigue; an inadequate risk management; competitive pressures; deficiencies in crew's professional training. All factors here are risk control factors.

4. CONSEQUENCES OF A COLLISION

Consequences of a collision can be separated as consequence affecting the ship (minor, major or total loss), consequences on human safety or on the environment. These can affect the navigation company through a bad reputation or can have economic consequences. The consequences for each category will be detailed below individually:

Consequences for human safety

Human security is not normally directly affected by a collision, but in the case of a strong collision the ship may be capsized and thus life may be lost. Also during a collision there may also be minor ship damages which can only lead to injuries of the crew members. Losses of life or crew's injury affect the ship's reputation and that of the navigation company.

Consequences for the ship

We can discuss about four categories of consequences: minor, major damage, capsizing or total loss of the ship.

Minor damages do not lead to permanent deformations of the ship's body. The damage can be repaired and the ship will not suffer long delays. There will be no other consequences for minor damages.

In the case of major damage, cracks or holes in the ship's hull appear. Consequences consist of the repairs that need to be made, which affect the company financially, both through repair costs and the lost time the ship would have been operating. The ship will have delays, so charterers will consider changing the shipping company. After a collision, leakage of fuel or oil will result in pollution or the loss of ship's stability, which in turn leads to the capsizing of the ship. Capsizing of the ship may be a cause of major damage, but it can also be determined as a result of minor damage or as a result of the water inflow in the compartments of the ship affecting ship's stability. Capsizing of the ship also leads to fuel petroleum products loss or which leads to pollution. The total loss of the ship has serious effects on the economic situation of the shipping company.

Consequences for the environment

The environmental consequences are caused by fuel or oil products losses transported by the ship. They can affect the ecosystems, the fishing industry, and tourism; there are also economic effects due to costs incurred for cleaning of spilled products.

Consequences on the reputation of the navigation company

A collision resulting in pollution affects the image of a company through negative advertising. Also the loss of time for repairs on the damaged ship has the same effect on the company's image and can cause charterers to look for other companies to use to transport goods. Bad reputation leads to serious economic consequences.

Economic Consequences

Economic consequences in the case of loss of cargo and petroleum products transported by ship cannot be correlated only with the quantity and type of leakage, but also to the impact and the effect of the spill which can be included in the analysis. A way to quantify the consequences of a collision could be given by estimating the costs involved. These costs may arise from trade losses due to lost time for repair or cleaning of spilled products.

5. CONCLUSIONS

When a collision occurred, the damages, and the consequences of the damages may be affected by the human factor or his actions, the characteristics of the goods, nature of the ocean and coastlines and other physical conditions. Environmental conditions such as sea state, the presence of wind, currents can influence the size of the affected area. If there is a spill, the presence of ice or low water temperatures will make the area more difficult to be cleaned. Also the coastal and seabed structure, location and mode of operation can have effects on the time necessary for the polluted area to be cleaned. If the crew aboard ship is properly trained and familiar with emergency plans, immediate action can be taken on board ship, authorities can be warned on time and the response time to start cleaning the area could be reduced. Also the division into compartments of the ship and her resistance to collision can have a great influence on the quantity of spilled products. A hit-proof ship can lead to a smaller loss of spilled products, but high resistance means a larger amount of steel in the ship's structure, which increases the weight of the ship. A greater weight of the ship leads to higher fuel consumption, which leads to pollution and high operating costs. Use of new materials, design change or use of a buoyancy medium in lateral tanks may in the future decrease the consequences of a collision.

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