

Risk management with Bowtie diagrams

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Abstract. The Bowtie (Papion) analysis is a qualitative risk assessment methodology that provides a way to effectively communicate complex risk scenarios in an easy-to-understand graphical format and shows the relationship between the causes of unwanted events and escalation potential for loss and damage. Bowtie can display the commands, which prevents the top event from happening first, specific to each threat and also the recovery measures, which are ready to limit the possible effects once the event top has been achieved, specific for each credible result. *The purpose of the work* is analysis of oil spill scenarios. *Research and methodology:* 1) Bowtie analysis diagram that focuses on environmental losses and damage resulting from possible scenarios; 2) Threats and control measures for the threats; 3) Recovery and consequences measures. *Results:* 1) Bowtie risk treatment tools; 2) integrated tools for risk management processes. *Conclusions:* The main advantages of the approach of adopting the Bowtie in the risk analysis are: a) provides a solid technique of comprehensive identification of all risk events and promote an understanding of their mutual relations; b) uses a format in the form of an easy-to-understand scheme to communicate the cause relationships and the underlying effect of more complex risk scenarios.

1. Introduction

The Bowtie analysis is a qualitative risk assessment methodology that provides a way to effectively communicate complex risk scenarios in an easy-to-understand graphic format and shows the relationships between the causes of unwanted events and the escalation potential for loss and damage. Bowtie can display the commands, which prevent the Top event from happening primarily, specific to each threat and also the recovery measures that are ready to limit possible effects once the Top event has been accomplished, specific for each credible result.

The main advantages of the approach to adopting Bowtie (figure 1) [1] in the risk analysis are:

- Provides a solid technique of comprehensive identification of all risk events and promote an understanding of their reciprocal relations;
- Uses a format in the form of an easy-to-understand scheme to communicate the cause and effect relationships underlying more complex risk scenarios for a wide range of stakeholders;
- it helps to clearly demonstrate the level of control that exists on the risks and therefore provides a way of identifying weaknesses, gaps and opportunities for a continuous reduction of risks;
- Allows verification and connection to relevant sections of the management system that support controls (including critical security elements and critical safety activities);



- Increases the awareness of the workforce on the risks associated with their facility and how they are managed; and
- Uses the knowledge and expertise of the workforce, which best understands the actual state of operation of existing controls and threats.

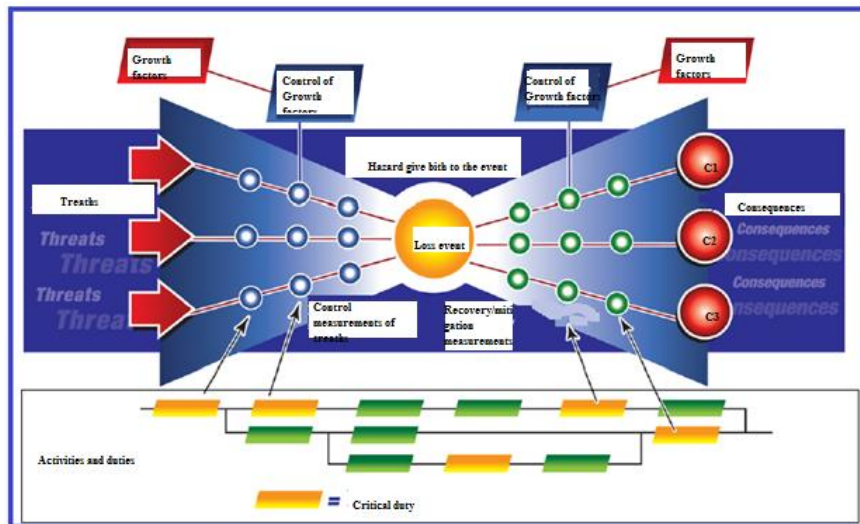


Figure 1. Scheme of the hazard Bowtie.[1].

To manage the risks, a helpful feature is that of the risk status. The risks are assigned one of three statuses: 1) inactive risks, when these have been identified but not accepted as actively applicable in the risk register; 2) active risks, are those that are currently recognised as open threats to or opportunities for the project; 3) past risks, are those have been assessed to no longer pose a threat or opportunity to the project's objectives [2].

For quantitative risk analysis, there are three types of risk's magnitude (exposure):

- pre-treatment (the magnitude of the risk if nothing is done),
- post-treatment (the magnitude of the risk successfully implemented) and
- target exposure (if all accepted treatments are implemented, preferably based on realistic assessments of the effects on probability and impact of the risk by each accepted treatment) [2].

Bowtie diagram has *two parts*:

1) One part represents the fault tree with principal causes of the top event and correlation between the initiator events and related events (AND and OR gates). The AND gate means that an event which is in progress involves the deployment of *all* other events related to it. The OR gate means an event which is in progress involves the deployment of *any* events related to it [4].

2) Another part represents the event tree with all consequences for top event. These consequences can be: primary consequences, dangerous consequences and major consequences.

In fault tree description each incident is defined with a specific initial letter which represents a different level in the block diagram. The first level is occupied by the main causes and the other levels are occupied by intermediate causes. The levels which are situated before the top event are called failure mode and level of causes.

The block diagram has the top event at which they start barriers/gates that have their own exits defining how to continue incidents at the top event. These constitute levels of intermediate consequences, which are completed with levels of final consequences.

The Bowtie method is important by introducing protective barriers in the block diagram of the event tree, reducing the severity of the consequences of these events.

2. Research and methodology

The purpose of the work is analysis of oil spill scenarios from a vessel. The construction of fault tree diagrams is similar to any type of vessel. For this is very important to define the barriers/ gates after the occurrence of the top event [5].

There are two types of causes of incidents: one comes from the equipment's status and other operational errors.

In order to draw up a diagram of the Bowtie analysis (figure 2) that focuses on losses and environmental damage resulting from possible oil spill scenarios for marine exploration drilling, it is necessary to analyse:

- possible hazards,
- measures of hazard control (figure 3) (left side of diagram),
- recovery measures and consequences, in the situation where the hazards have been triggered (right side of diagram) (figure 4) [3].

Failure mode level (1.6 levels) presents the failures of the equipments that can lead to the main event and a higher level of operational errors. There are two types of control: operator's control and government's control (figure 2).

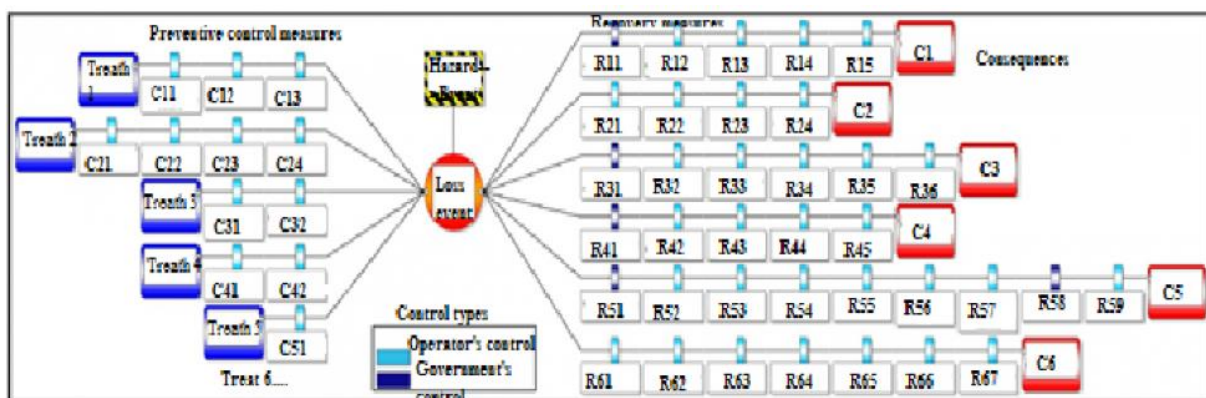


Figure 2. Losses and environmental damages for marine exploration.[2].

The gates/barriers of the event tree diagram in failure of equipments incidents are (figure 3):

- location on the vessel (machinery compartment),
- operational state of vessel (en route),
- time (night, day),
- consequent accident (e.g. structural failures: failure of tank integrity, corrosion),
- loss of water tightness,
- firefighting system (automatic/manual),
- firefighting assistance (from land or from another vessel),
- emergency plan of ship/crew evacuation.

The level in structural failure incidents can be (figure 4):

- poor design and construction calculation,
- poor endurance tests,
- poor maintenance,
- inadequate personnel,
- poor construction, poor conditions of structure,
- corrosion protection, deformation,
- poor inspection,

- adverse weather conditions,
- violation of regulations,
- misuse of equipment,
- navigational failures,
- operational errors.

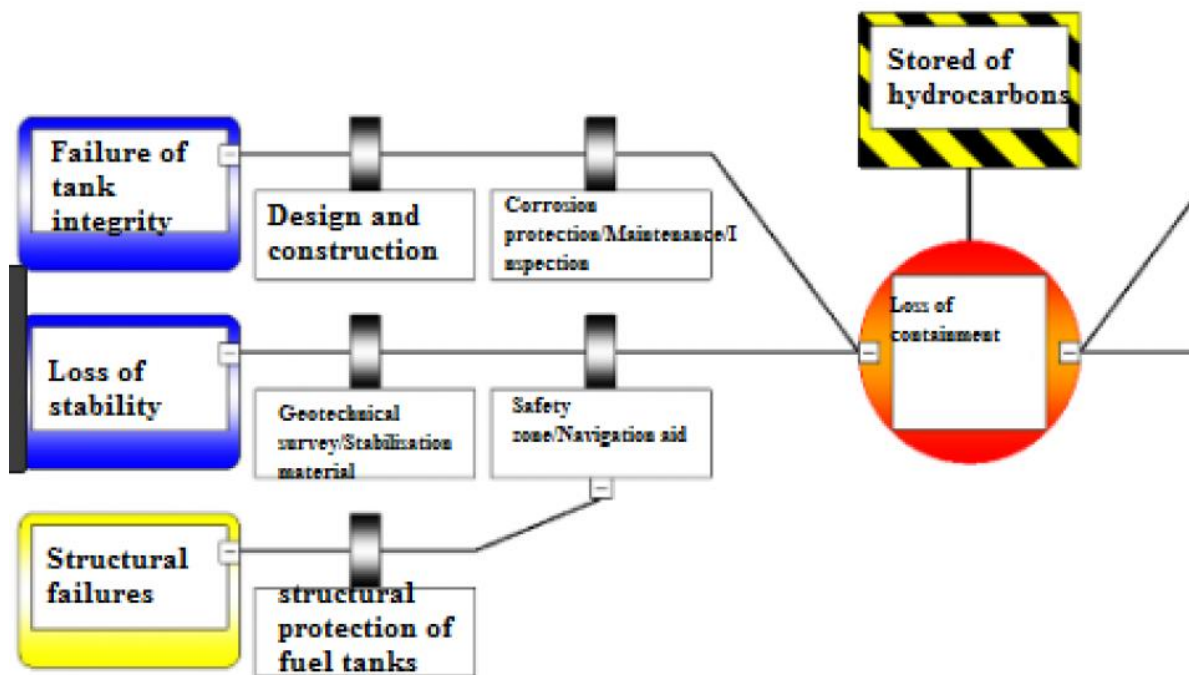


Figure 3. Hazard and measures of hazard control.[3].

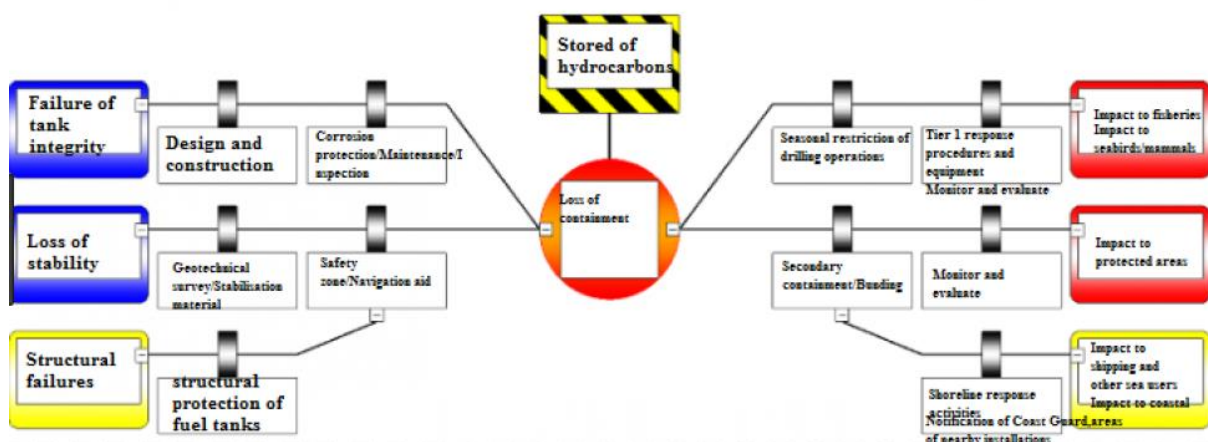


Figure 4. Recovery measures and consequences.[3].

The consequences in failures of equipments incidents are (figure 4):

- minor repairable damage to accommodation/possible injuries,
- extended damage to accommodation/injuries & possible fatalities,
- serious damage to accommodation/ damage to vessel/injuries/ fatalities,
- very serious damage to accommodation/injuries/ fatalities,

- minor repairable damage to accommodation/ possible injuries,
- worst case: loss of vessel/loss of crew.

The important consequences are in area of fisheries, seabirds, marine mammals, coastal area and other sea users (figure 4).

3. Results and methodology

- *Bowtie risk treatment tools*

To achieve the final Bowtie diagram (figure 2), an integrated risk management tools can be used (figure 5) [4].

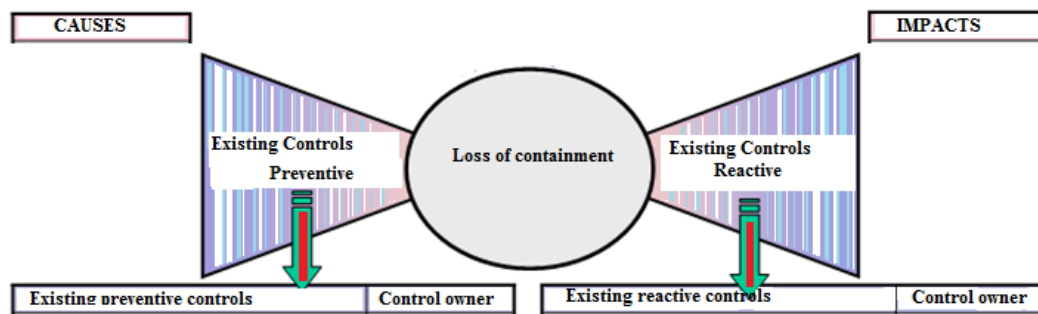


Figure 5. Bowtie risk treatment tool.

The hazard is: stored of hydrocarbons. The causes of this hazard are:

- failure of tank integrity (design and constructive standards, corrosion preventions, maintenance and inspections);
- loss of stability (geotechnical survey, safety zones, navigation aid);
- structural failures (measures/standards for structural protection of fuel/oil tanks, corrosive protection measures).
- the top event is loss of containment.

The elements of existing preventive controls can be: daily maintenance of equipments, supervision from the crew, training of personnel, updated documentation on board, weather conditions (figure 5, left diagram).

The existing components of reactive controls are: poor maintenance of machinery, poor supervision from the crew, inexperienced personnel, untrained personnel, deficiency of manuals, careless crew, insufficient attention to repairs (figure 5, right diagram).

- *Integrated tools for risk management processes*

For an effective risk management the risk control effectiveness are:

- Seasonal restrictions of drilling operations, secondary containment, source identification and termination, Tier 1 - response procedures and equipment;
- Restriction of drilling operations; monitor and evaluation; response of team;
- Aerial surveillance, notification of Coast Guarded, notifications of nearby installations.

The impact and consequences are:

- to fisheries;
- to marine mammals;
- to seabirds;
- to protected areas offshore;
- to coastal areas;
- to shipping and other sea users.

4. Conclusions

Evolution of deep water drilling and opening of new oil fields will lead to an increase of marine traffic and subsequently to an increase of oil pollution risk. The amount of drilling activities so far was moderate, leading to moderate risk. Nevertheless, along with the evolution of offshore drilling in the region, pollution risk value will rise.

The main advantages of the approach of adopting the Bowtie in the risk analysis are: a) provides a solid technique of comprehensive identification of all risk events and promote an understanding of their mutual relations; b) uses a format in the form of an easy-to-understand scheme to communicate the cause relationships and the underlying effect of more complex risk scenarios.

This is a serious issue that needs to be addressed in the near future to integrated tools for risk management processes.

5. References

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- [5] Popa C, Panaitescu F V and Voicu I 2014 History and analysis of incidents in the Black Sea Basin *Analysis of the Black Sea oil pollution* **171-175**