**ADVANCED BARRIER MANAGEMENT USING BOWTIES**

Elise Roovers, MSc.

**ABSTRACT**

Advanced barrier management addresses three fundamental questions of risk management: 1. Do we understand what can go wrong? 2. Do we know what our safety measures are to prevent this from happening? 3. Do we know whether these safety measures are working effectively?  
  
Bowtie risk assessment is widely used in high hazard industries. Bowtie modelling has proven to be a successful method to visualize risk scenarios and the existing control measures (barriers). Bowties help to identify gaps in risk control by highlighting information that is lacking or unknown. The bowtie methodology can be used for safety, occupational, security and quality issues. Bowtie diagrams can be used to answer the above mentioned first and second question.  
  
Bowtie diagrams can have additional benefits. By displaying maintenance data, incident data and audit data on the bowtie diagrams, the diagrams can also be used as a framework on which all big (safety) data comes together. Uniting risk assessment and risk assurance data in one central place allows the user to prioritize improvements, create targeted recommendations and to make risk-based decisions. To accomplish this, all data need to be translated to the same “language”, namely “Barrier-based Risk Management”. Advanced barrier management has proven to be an effective language for integrating risk assessment and risk assurance data. Displaying risk assurance data on the bowtie diagrams will help answer the third question.

1. **INTRODUCTION**

Advanced barrier management addresses the three fundamental questions of risk management: 1. Do we understand what can go wrong? 2. Do we know what our safety measures are to prevent this from happening? 3. Do we have information to assure they are working effectively?  
  
The first two questions can be answered by applying the bowtie method. By mapping out all possible threats and consequences, we can understand what can go wrong (1). In order to prevent threats from turning into consequences, barriers should be implemented (2). However, according to James Reason’s Swiss Cheese Model [1], not every barrier is 100% effective. How, then, do we assure the effectiveness of a barrier?   
  
(3) The key to barrier effectiveness is performance data, which comes in many forms: audit findings, incident recommendations and maintenance backlogs. Common difficulties with performance data are that it is often hard to standardize across different branches of operations. Hereto, the bowtie method stands out, as it serves as a common denominator, allowing for maximum learnings from all data sources.   
  
In this paper, it will be explored how the bowtie method can be used as a foundation for performance data so that organizations may answer the 3 questions using onecentral method.

1. **BOWTIES**

A bowtie is a diagram that visualizes the risk you are dealing with in a singular, easy to understand picture. In short, it provides a simple, visual explanation of a risk that would be much more difficult to explain otherwise. It consists of 8 elements:  
  
1.Hazard: A hazard, in bowtie terminology, is a neutral term designed to reflect the everyday operations. Without the hazard, a company cannot run its operations. A hazard has the potential to cause harm.  
2.Top Event: The very first moment control is lost over the hazard. There is still time to recover, however.   
3.Threats: Threats lead to the top event. They are often external forces acting upon an organization’s operations.  
4.Consequences: Consequences result from the top event. These are the outcomes organizations want to avoid from happening.  
5.Proactive barriers: Barriers are what organizations undertake in order to prevent the threats from turning into top events proactively.   
6.Recovery barriers: Barriers can also stop top events from turning into consequences reactively.   
7.Escalation factors: Barriers are not always effective. Escalation factors are entities that reduce or nullify the effectiveness of a barrier.   
8.Escalation factor barriers: These are designed specifically to downsize the escalation factors.   
  
Using these 8 steps, the first two questions can be answered:   
1. Do we understand what can go wrong? By mapping out all possible threats and consequences, we can understand what can go wrong.  
2. Do we know what our safety measures are to prevent this from happening? By including the barriers in the bowtie diagram, we know what should be done to prevent the unwanted events.

To answer the 3rd question “Do we know whether the safety measures are working effectively?” performance data must be included into the bowtie diagram.

**3. BARRIER BASED INCIDENT ANALYSIS**

Despite the differences between incident analysis (being primarily reactive) and bowtie methodology (being primarily proactive), in this paper it is argued that the bowtie can serve as a foundation for the incident data.   
  
Since bowties are barrier-based risk analysis models, barrier-based incident analysis methods can be used in addition, where barriers function as the common denominator. There are various barrier-based incident analysis methods available such as Tripod-Beta, BSCAT and BFA to actively identify barriers in incident analysis. In this paper, we will focus on BFA (Barrier Failure Analysis) but the same effect can be achieved with any barrier-based incident analysis method.

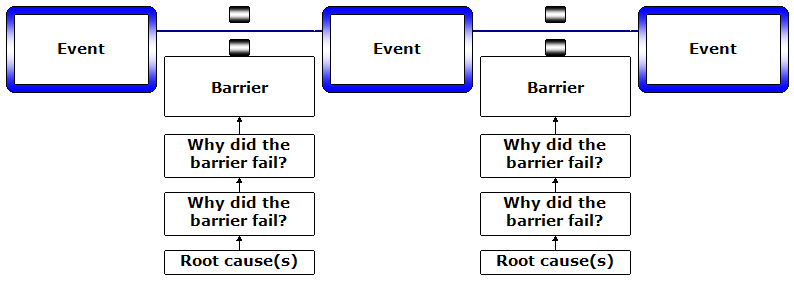


Figure 1 - Generic BFA model

The BFA incident diagram shows how each event was supposed to be stopped by one or multiple barriers. However, as we are dealing with incident analysis it is likely that one or more barriers failed to do so. The next step in the BFA process is to perform a small Root Cause Analysis on the failure reason of a barrier, generating recommendations.   
  
Often, the barriers in an incident show similarities and overlap with the barriers found on a bowtie diagram. As such, a direct link can be made between these two, allowing for aggregation of barrier effectiveness (see figure 2).

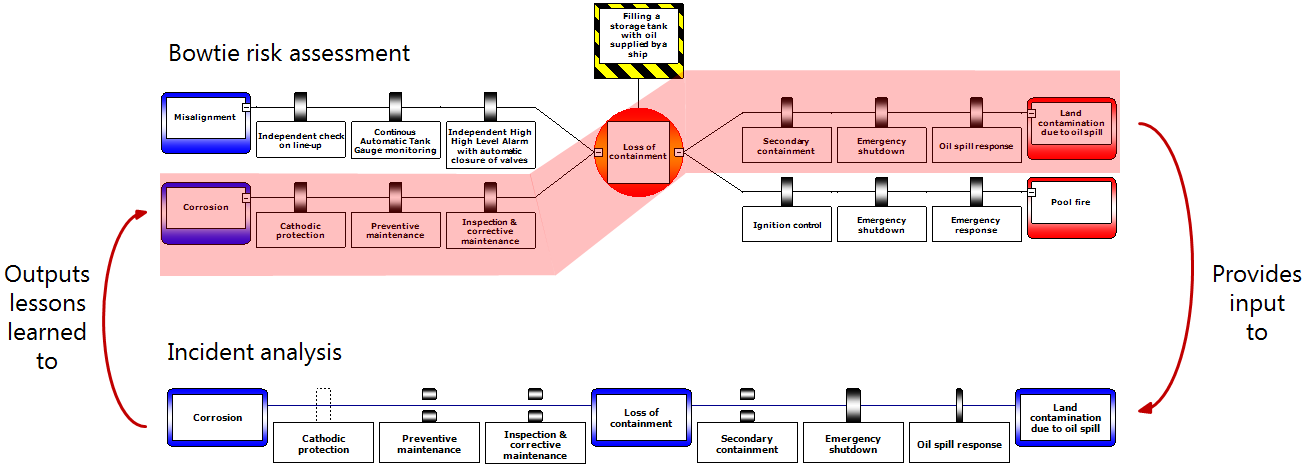


Figure 2 - Relationship between bowties and incidents

Instead of looking at an incident as a single occurrence, the lessons learned from multiple incidents can be traced back to the same diagram, thus providing information on the barriers effectiveness at each occassion.

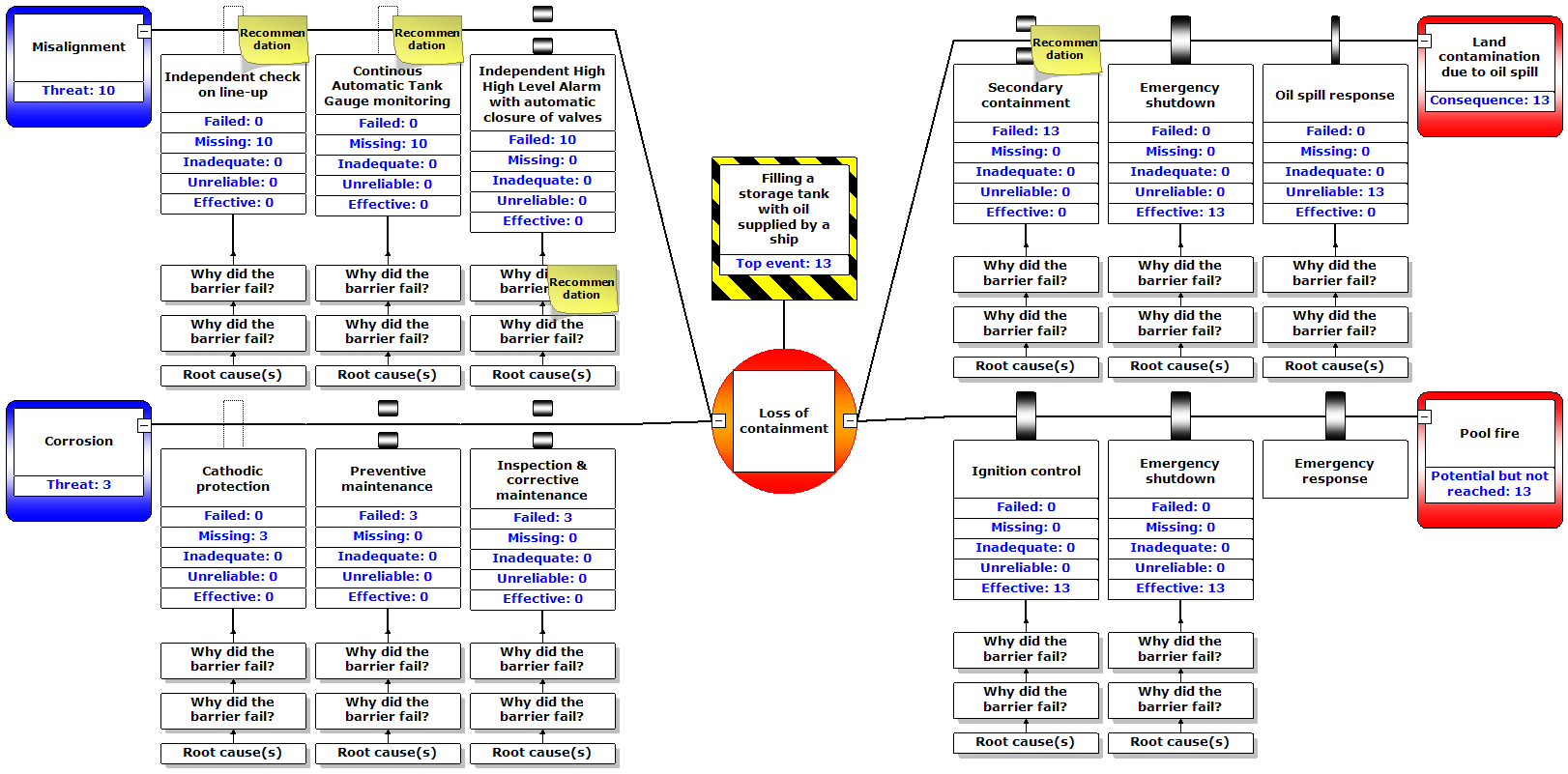


Figure 3 - Trending of incident data on a bowtie diagram

**4. BARRIER BASED AUDITS**

A possible downside of incident data is that it is reactive. Audits therefore, as a more proactive approach, can be more suitable to identify the functionality of safety measures in advance. Again, in this paper, it is argued that the bowtie can also serve as a foundation for this audit data.

Where traditional audits tackle risk management one silo at a time, barrier-based auditing aims to collect information on all aspects of risk management *per barrier*. As an example, take the act of using a fire extinguisher (see figure 4).

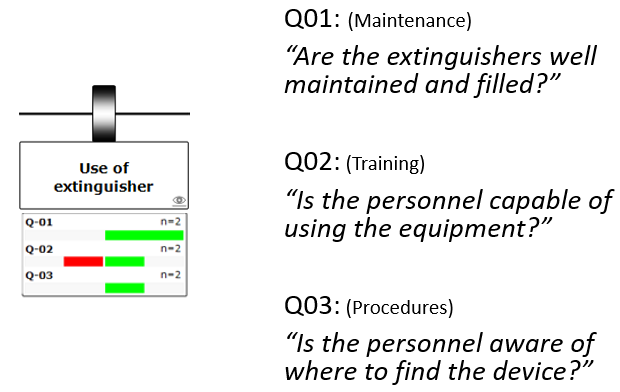


Figure 4 - Barrier-based audit verification questions

In this example, it shows that risk managements parts ‘maintenance’ and ‘procedure’ have been well-covered. ‘Training’, however, is underperforming as indicated by the red bar. This manner of barrier-based auditing, as opposed to traditional auditing has the following advantage to it:

By auditing aspects of risk management through silos, it is harder to see where the overlap of failures lies. Barrier-based auditing circumvents this issue. In Figure 5, there is a 5% failure on maintenanceapparent, and a 10% failure on training when it comes to compliance. Both failures can be considered within tolerable risk boundarieswhen considered separately.

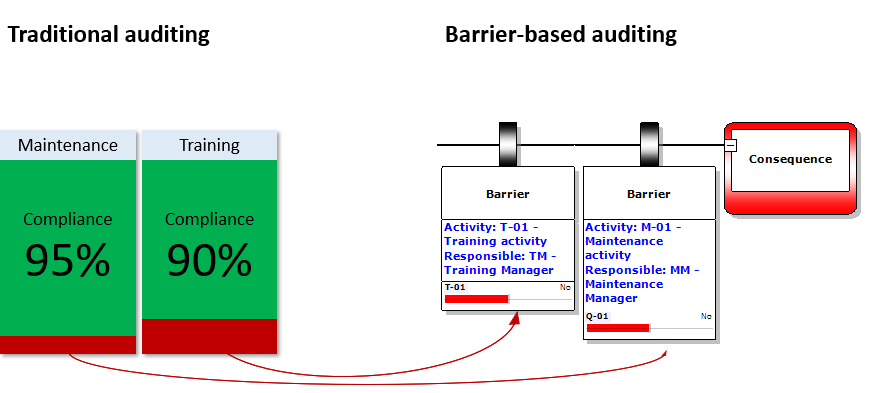


Figure 5 - Barrier-based audit verification questions

However, what would be the risk-wise effect if these ‘maintenance’ and ‘training’ malfunctions align within a single scenario? An organization would be overly exposed to possible unwanted events. We therefore argue that the barrier-based auditing, combined with the bowtie methodology, can work better than a more traditional way of auditing. If this learning process is repeated frequently, it will eventually provide a clear overview of every risk scenario in one visual, thus answering the 3rd question (see figure 6).

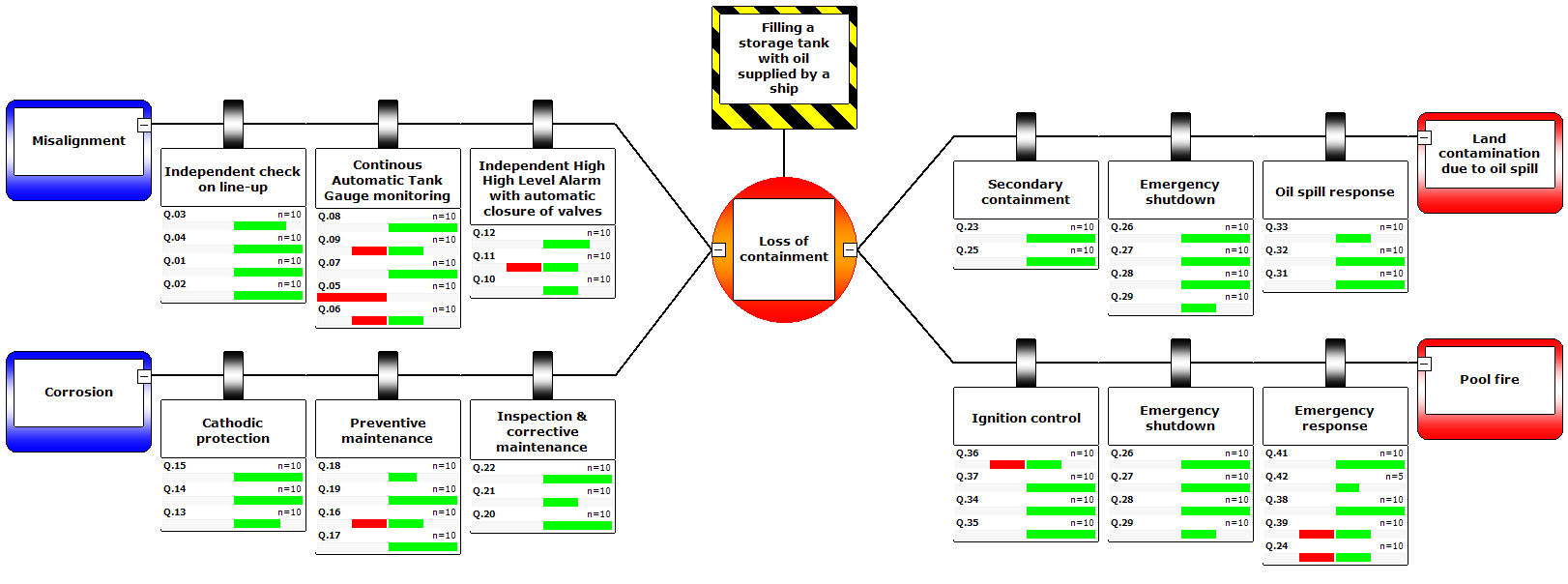


Figure 6 - bowtie with an audit result overlay

**5. INTEGRATING MAINTENANCE DATA WITH BOWTIES**

Most organizations in the process industry have programs to capture their maintenance data. Each machine, computer, tool or equipment is mapped in detail within these systems. This allows operators to have a dynamic view of which parts of their systems are currently available. It can be said that each of these parts together make up a safety system (or barrier). By mapping this maintenance data additionally onto the bowtie, a dynamic view can be created in order to determine which barriers are ‘online’ and which ones are ‘offline’ (see figure 7).

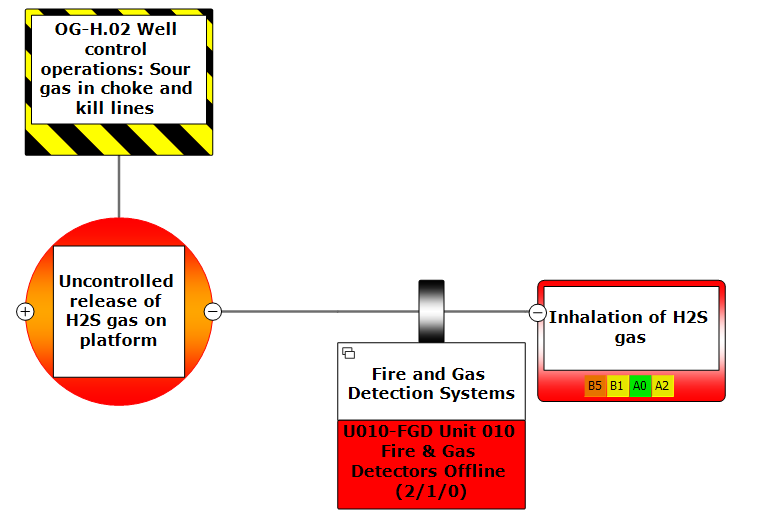


Figure 7 – bowtie with maintenance data

In this example, the ‘fire and gas detection systems’ barrier is ‘offline’. The available maintenance data has configured an unacceptable amount of parts that are currently not functioning as is intended to, thus the threshold of tolerable risk has been breached. This is another way of having operators beinginformed of their barrier effectiveness.

**6. CONCLUSION**

To successfully answer the 3 questions on risk management, organizations can make use of the bowtie methodology as a foundation for performance data with all the info in one clear picture. The bowtie lends itself well for the first two questions “Do we understand what can go wrong?” and “Do we know what our safety measures are to prevent this from happening?” on its own account. However, for a more advanced approach, organizations need to gather performance data (e.g. incident data, audit data and/or maintenance data) to attach to their bowties. By displaying this performance data, an organization can successfully answer the third question “Do we know whether these safety measures are working effectively?”

**7. REFERENCES**

[1] JAMES T. REASON, *HUMAN ERROR*,Cambridge University Press,Cambridge, United Kingdom (1990).