Opportunities to Enhance Barrier Management Through Incident Analysis

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Many high hazard industries use bowties to analyze and assess risks. In the bowtie risk analysis model, barriers are identified which aim to prevent, control or mitigate unwanted scenarios.

However, despite best effort risks assessments, incidents and near misses may still occur. When they do, organizations typically conduct investigations to come up with recommendations to avoid similar situations in the future. Unfortunately, in many cases these investigation reports end up as a collection of largely unstructured documents. They are often treated as single events, making it difficult to clearly identify trends over multiple events.

Scenario-based Incident Registration (SIR) aims to provide a more structured process. A user selects a specific scenario from a set of bowties and assesses the effectiveness of the barriers identified on the original bowtie. Specific questions are asked per barrier about the reasons of the failure. These findings are stored on a barrier level. If this process is repeated, the bowtie will accumulate barrier failure data of multiple incidents in a single diagram. This information helps the organization to identify the strength of their barriers, which in turn facilitates risk-based decision-making.

Some incidents require in-depth investigations and a registration only is not enough. However, this registration can be used as a starting point for the incident analysis. Doing barrier-based incident analysis allows you to learn from barrier failures and improve their performances in order to prevent similar incidents from happening. This incident data together with the SIR data can be linked back to the bowtie diagram in order to spot the strengths and weaknesses of your visual risk assessment.

SIR is a continuous process which is more than a reporting system. The reporter does not require knowledge about the bowtie methodology, while incident managers receive valuable insight to their pro-active risk assessment.

1. Introduction

Through the years, as organizations have focused more on safety, accidents have become less frequent. Overall, this is a good thing. However, for safety managers, this makes things more complicated due to the way safety is currently measured: the absence of incidents and accidents. Paradoxically, fewer incidents also means less data to measure whether the organization is safe or not. With the increasing complexity which hides the underlying factors in organizations, merely the absence of accidents no longer guarantees that we are safe (Hollnagel, 2014). Many examples of organizations with incidents after a long absence of incidents exist: the 1986 Space Shuttle Challenger explosion, the 1997 Hindustan refinery explosion in India, 1999 Paddington train crash, the 1998 Morton explosion and the Three Mile Island nuclear plant accident. Therefore, rather than relying on the number of accidents as an indicator of safety, we need a more proactive metric. A proposed solution to this paradoxical problem of too few incidents is a larger focus on lower severity incidents as these generally happen more frequently, e.g. near misses. Near miss reporting can quickly build up a large database of would-have-been accidents. In this paper, a near miss reporting system will be presented. The effectiveness of near miss reporting in general will be examined, before exploring how the bowtie method can be used to enhance the effectiveness of near miss reporting. The bowtie methodology is a risk analysis tool and if used well, can help to answer at least the first two questions from the three

questions raised by Gordon MacDonald of the UK Health & Safety Executive from the aftermath of the Buncefield incident in 2005 (ODN, 2010).

"Lessons must be learned from this incident. From the boardroom down, companies must ask themselves these questions:

1.   Do we understand what can go wrong?
2.   Do we know how what our systems are to prevent this from happening?
3.   Do we have information to assure us they are working effectively?"

"Many organizations are able to answer these questions to some extent" (Smit, 2017). Various risk management tools and methodologies can be used to answer these questions, where the bowtie methodology is one of them. However, to be able to answer the third question, organizations should use more than only the bowtie methodology. Audit methodologies or incident analysis techniques are often used to verify whether the barriers are working effectively. SIR is one methodology that can help to answer MacDonald's third question.

1.1 Evidence in favor of near miss reporting

Critiques of incident reporting have questioned whether organizations actually become safer after implementation of an incident reporting system. As such, it may still seem unclear whether near miss reporting should be pursued. These critics have suggested that incident reporting can be more successful if there is an emphasis on "analysis of incidents and organizational learning" but can fail if there is too big of an emphasis on just the counting of incidents (Vincent et al., 2008; Clarke, 2008; Davies, 2000; Braithwaite et al., 2011). In order to properly refute these critiques, the causal link between near misses and accidents must be demonstrated through the use of the iceberg model.

The basic premise that more information regarding (minor) errors can hold predictive value for larger accidents rests on the assumption that near misses and accidents have the same set of root causes. This is also known as the 'iceberg model' (after Hyden, 1987). The iceberg model shows a "continuum of events ranging from normal behavior via conflicts and deviations to actual accidents" (Van der Schaaf, 1992, p21.). Van der Schaaf (1992) has simplified this model into the one seen in Figure 1.

The events at the bottom of the triangle occur first, i.e. the earlier you detect the behavioral acts and near misses, the higher the chance you can prevent an accident from occurring. Another assumption here is that the behavioral acts and near misses have the same root causes as the accidents. Therefore, if the detection of a certain event happens later 'up' the triangle, the analysis of that event should lead to largely the same root causes as if the event was detected earlier 'down' the triangle. Likewise, the recommendations should be of a similar nature.
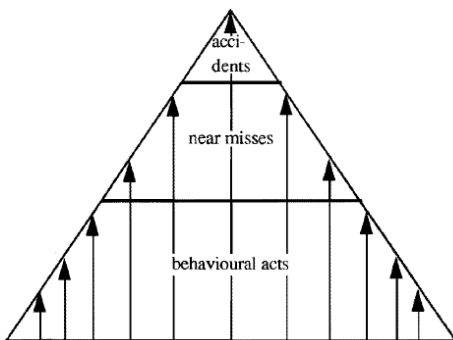

Figure 1 - Simplified qualitative version of the iceberg model by Schaaf

Supportive evidence for the qualitative assumptions of the model comes from numerous studies across multiple industries (construction, aviation, railway and oil and gas among many others) that indicate that an increase in near miss reporting decreases not only the occurrence of minor injuries, but also that of larger so-called OSHA (Occupational Safety & Health Administration) injuries (Mckay, (2013). Thus, the pursuit of near miss reporting can make an organization safer as the information resulting from near misses holds predictive value for preventing accidents.

In conclusion, this paper proposes that near miss reporting can help make organizations safer. This paper explores how a near miss reporting system can be used to support the process of learning from near misses. The foundation of the design is the bowtie method and must be looked at in more detail.

2. Method

CGE Risk Management Solutions has developed a tool, Scenario-based Incident Registration (SIR), to improve the quality of incident reporting and allow trend analysis for improved risk-based decision-making. SIR uses the bowtie methodology and bridges the gap between bowtie risk analysis and incident analysis.

2.1 The bowtie method

Using SIR in the organization requires bowtie knowledge and expertise from the middle to low management of an organization, usually the safety and risk department. Operational personnel, who eventually report the incidents, do not necessarily require this knowledge and expertise.

The bowtie methodology, presented in Figure 2, is a proactive risk assessment tool to analyze potential incident scenarios and assess risks. "Once constructed, the bowtie purpose is best used to support risk management and risk communication" (the American Institute of Chemical Engineers, 2018). The bowtie also fits as a framework to structure incident data if the incident is analyzed using a barrier-based incident analysis technique, such as Barrier Failure Analysis, Barrier-based Systematic Cause Analysis Technique (BSCAT) (DNV GL, 2015) or Tripod beta (Stichting Tripod Foundation, 2014).
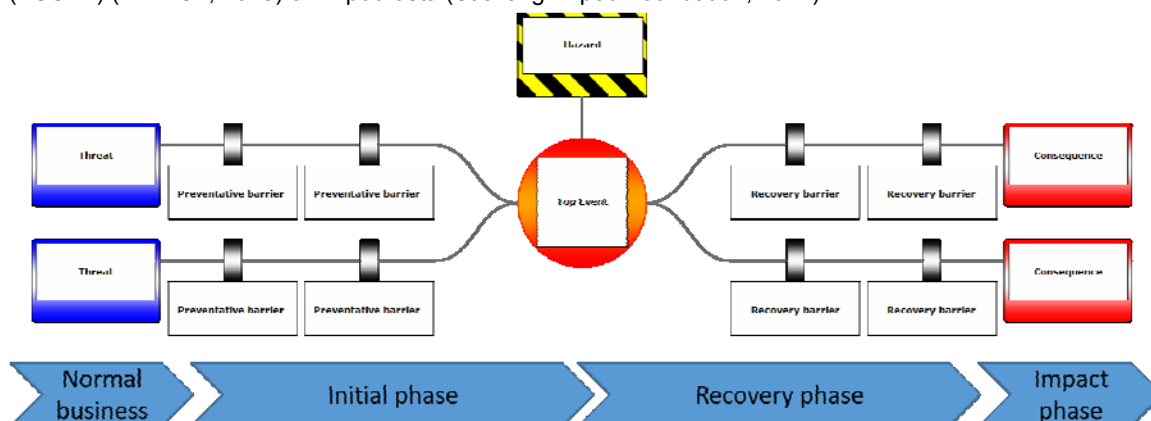

Figure 2 - The bowtie model

The bowtie methodology is a combination of two risk analysis tools (FTA, preventative and ETA, reactive) and James Reason's Swiss Cheese theory. The Swiss Cheese metaphor is developed by James Reason in 1990. The model represents layers of defenses to stop an incident. However Swiss Cheese has holes in it and so does each layer of defense or barrier. The holes are created by active failures and latent failures (Reason, 1997). SIR helps to identify active failures during an (near-) incident scenario with the help of the bowtie.

The bowtie model is represented in Figure 2. The hazard defines the operation of where the risks are analyzed.

Examples are 'Working at height' or 'Storage of hydrocarbons'. The hazard should be described in a controlled state, as it is part of an organization's normal business. The reason of referring to normal business is to be able to link risks back to process optimization. The top event related to the hazard is the moment of loss of control. Examples are 'Person falls from scaffold' or 'Loss of containment of hydrocarbons'. It is an unwanted event but not the actual incident or accident. When the top event is understood completely, it can help an organization to recover faster from a loss of control moment to prevent the actual incident or accident.

On the left side of the top event, the threats, are the causes of the loss of control (top event). Examples are 'slippery surface' causing a person to fall or 'corrosion' causing a loss of containment. Threats may lead directly to the top event.

On the right side of the top event, the consequences, are the actual incidents like a 'Fire', 'Hydrocarbon spill resulting in environmental damage', or 'Person falls on hard surface resulting in fatality'.

The next most important step is to define the barriers. "*Safety barriers are physical and/or nonphysical means planned to prevent, control, or mitigate undesired events or accidents*" (Sklet, 2006 2.2). Barriers consist of multiple activities that maintain the barrier function and effectiveness, such as training or maintenance. Barriers on the left side, preventative barriers, may stop the threat from occurring or prevent the threat leading to the top event. Examples of preventative barriers are 'anti-slip surface' or 'anti-corrosion painting'. Barriers on the right side, recovery barriers, may stop these consequences or reduce the impact on these consequences. Examples of barriers are 'fall harnesses' or 'fire extinguisher'.

SIR helps to understand what went wrong in the barrier supporting activities.

2.2 Scenario-based Incident Registration (SIR)

SIR is a methodology which collects meaningful data about barrier failures. This data can be collected through incident investigations. However not every incident can be completely investigated, due to time, resources and expertise constraints. Figure 3 is an illustration of the usual follow up process of an incident. Organizations normally try to learn from accidents by time-consuming investigations. Incidents with a lesser severity, e.g. near misses, are stored individually in a database, with limited to no learning.
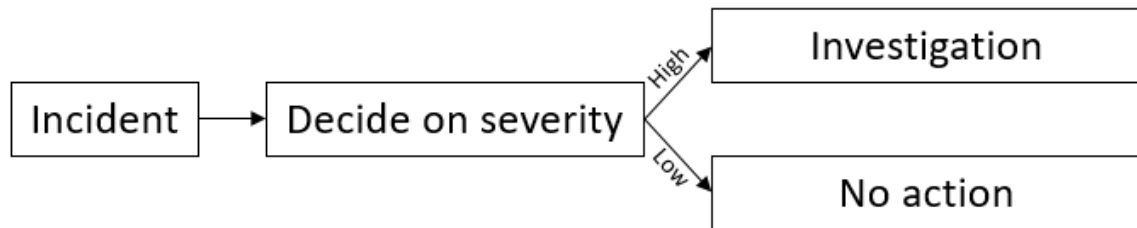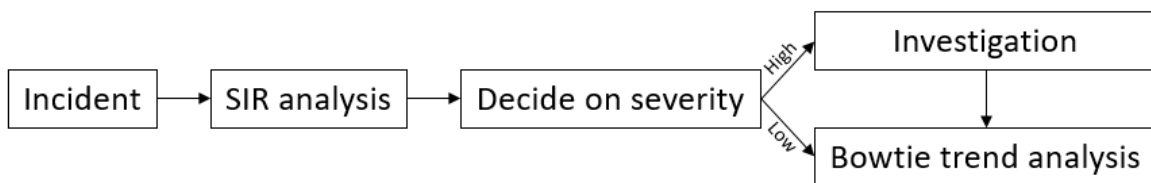

Figure 3 - Incident follow up process

Figure 4 - Incident follow up process including SIR

In Figure 4 the SIR-analysis compliments the incident decision process by storing low severity incidents on a bowtie. Additionally, SIR helps to decide whether an investigation is needed during the follow up process.

In the initial form, the reporter enters the details about the location, date, time, and a short description of what happened. SIR starts after the initial incident form is completed. A wizard guides the reporter through 3 steps:

> Reporter selects the operations at the time of the incident
> Reporter selects the scenario of what happened
> Reporter assesses each barrier in that scenario

Each step is based on existing bowties and links data back to these bowties.

Reporter selects the operations at the time of the incident

In this step, the reporter chooses the operation he or she was doing at the time of the incident from a set of pre-built bowties. Behind the scenes, this will select a hazard and top event combination. The reporter does not necessarily need to know this, as knowledge of the bowtie methodology or how the bowtie is constructed is optional. Examples of hazards are working at height or lifting objects with a crane.

Reporter selects the scenario of what happened

From the selected bowtie in the previous step, the reporter chooses the relevant scenario. The relevant scenario starts on the left side, from a threat, all the way to the right to a consequence. It is optional to choose multiple threats or multiple (potential) consequences, as there might be multiple causes or multiple (potential) outcomes.

Reporter assesses each barrier in that scenario

The reporter is then taken through all the barriers that are in the selected bowtie scenario. Each barrier is assessed, and the primary cause is identified.
The reporter first decides on the barrier state and chooses one of the following options per barrier:

> This safety measure functioned correctly
> This safety measure failed
> This safety measure was not applicable in this scenario.

When the reporter indicates a barrier as 'failed', a question appears about why the barrier failed, i.e. the primary cause of the barrier failure. These questions can be customized and will differ per barrier.

As an example, the reporter selects the barrier: 'Restricted access to lifting area'. The primary cause can be all types of human error, i.e. slips, lapses and mistakes (Reason, 1990). Optional answers could be that the restricted area was not set up or the restricted area was not adhered to. The barrier specific questions indicate the primary cause of the failure of the barrier. According to the Tripod Beta incident analysis methodology (Stichting Tripod Foundation, 2014), the primary cause is "An action or omission of a person, or group of people, that causes a barrier to fail." Thus, by performing SIR analysis for every low severity incident, time can be saved for the follow up investigator and if not further investigated this data is now permanently captured onto the bowtie.

3. Conclusions

In this section, using three purposes defined by Reason (1997), academical critiques of near miss reporting are examined and how they relate to the presented SIR design. Limitations of the design are mentioned.

3.1 Can SIR be an effective near miss management system?

Reason (1997) identifies three purposes of collecting and analyzing near miss data:
1.   to gain qualitative insight into how (minor) errors can result in near misses or even major accidents
2.   to gain enough data for statistically correct trend analyses to find out the combinations of factors leading to accidents
3.   to remind organizations of the hazards challenging their systems and so "slow down the process of forgetting to be afraid" (Reason, 1997, p119), especially very safe organizations which have low occurrences of incidents

3.2 Qualitative insight – Does near miss reporting prevent larger accidents?

As we saw, using the iceberg model, studies in different industries (McKay, (2013)) found evidence in favor that near misses can hold predictive value for larger accidents. However, Reason (1991) critiques that information regarding near misses and accidents, only relates to the last steps of a long chain of causal events. The information is therefore not useful enough as it is both too noisy—it is difficult if not impossible to find the real root cause of the incident—and too late, as it encourages reactive rather than proactive safety management. Instead, Reason (as read in Van der Schaaf, 1992) proposes to use auditing with a focus only at the earliest events; management decisions. In response, Van der Schaaf (1992) agrees that any near miss reporting system by itself, would always be lacking considering the complexity and difficulty of incident analysis. This is where the bowtie methodology lends itself extremely well, as the barrier construct allows for both incident and audit data to be mapped onto itself. Thus, the limitations outlined by Reason above can be overcome through combining near miss results with audit results.

3.3 Trend analyses – How can trend analyses be ensured?

The presented SIR design tried to tackle two challenges in getting enough statistical data for effective trend analyses. The first challenge is getting enough data. By facilitating near miss reporting, SIR can quickly contain enough data, as: "Near misses are usually estimated to occur one or two orders of magnitude more frequently than actual accidents" (Van der Schaaf, 1992, p25).
The second challenge is standardizing the data, as incidents are often investigated in isolation. In many cases investigation reports of near misses or accidents end up as a collection of largely unstructured documents. They are often treated as single events, making it difficult to clearly identify trends over multiple events. As we saw, using the bowtie method, standardization becomes much easier through the barrier constructs. The barriers serve as a common denominator for more effective trend analyses. A shortcoming, though, is that bowties are usually of a much more generic nature, whilst incidents are much more specific scenarios. As such it is difficult to capture all possible events and some information might be lost in the process of switching from specific scenarios to generic ones.

3.4 Awareness - Does more information through near misses lead to a safer organization?

A challenge that organizations face when implementing or improving an incident reporting system, such as near miss reporting, is that there can be both 1) a lack of feedback on how the reported information is used and 2) the perceived difficulty of collecting enough data (Van Der Schaaf and Kanse, 2004). A lack of feedback in how the reports are handled can demotivate reporters to report again in the future, which can also result in more difficulty in gathering data. Therefore, SIR immediately feeds the reported information back onto the bowtie, for all to see. Moreover, according to Phimister (2003), a well-functioning system should also give feedback of the results and improvements of the near miss investigation to the reporter. In addition, these results should be communicated to as many other employees as appropriate in order to raise

awareness levels. Thus, SIR can be set up to allow the reporter and related users to be given updates of the recommendations. Furthermore, to address the perceived difficulty of data collection, the reporting forms should be easy and convenient and not require lengthy analysis for every near miss reported. Again, using the bowtie methodology, SIR can save a lot of time and avoid lengthy analyses, which should stimulate employees to report more. A limitation here, however, is that SIR might be confusing at first for employees.

In line with the importance of feedback, Swain (as read in Van der Schaaf, 1992) suggests that just the act of observing and reporting a near miss can be considered employee engagement, which should result in higher levels of awareness. Raised levels of awareness can in turn lead to a safer organization. Indeed, Cooper (2000); Glendon and Stanton (2000) and Jones, Kirchsteiger and Bjerke, (1999), have found that near misses can boost safety culture. Additionally, near miss reporting can help show that employees are exhibiting learning, as it demonstrates how employees have recovered and prevented errors from developing into incidents (Van der Schaaf, 1992). Therefore, organizations can become safer not only by analysis of the near misses through SIR but also by the increased feedback that SIR provides, stimulating further reporting of near misses.

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