Can we make safety (or its absence) predictable?

Analysis of potentially serious events (PSE)

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1. Summary

The gas transmission company Gasunie fortunately experiences only a small number of lost time accidents and serious incidents. The consequence however is that these very limited events generate few data for use in in-depth analyses for preventive measures. In order to learn from incidents, accidents and unwanted or dangerous situations it is useful to analyse potentially serious events (PSE) as a category. These are events that could have led to (more) serious consequences in just slightly different circumstances in another but nevertheless also credible scenario.
It is of interest to know if the results of PSE analyses can be used for preventive action so that PSE do not turn into actual incidents or accidents.

At Gasunie all accidents, incidents and dangerous situations are registered, and the record shows whether the event is a potentially serious event (PSE).
A PSE is defined as an event that could have led to a lost time accident with at least 5 days lost time.
In order to make a more qualitative analysis a list of High Potential Incidents (HPI) from the European gas industry was used. This list contains 15 types of HPI used to categorise the PSE. This demonstrates what type of serious events can happen if we do not take adequate measures to prevent them.

All reported accidents, incidents and dangerous situations are judged on their potential impact. In the period 2007-2013 we indicated and analysed 61 PSE affecting our own staff.
This resulted in a PSE top 5: uncontrolled release of gas, failure of vessel/pipe under pressure, collapse of a construction, electrical short cut and dropped load.
This top 5 includes 75% of all PSE.

Besides the number and type of PSE, every PSE is also analysed in more depth. The indirect causes (also called latent failures) are determined for every report and thus every PSE. Latent failures are hidden within the organisation for a long time (like a virus) but the negative impact (an incident) can suddenly become visible. Latent failures are categorised into 11 Basic Risk Factors (BRF). The dominant BRF for PSE are "Procedures", "Design", "Training" and "Organisation". Based on the theory of TRIPOD this means that in order to prevent the occurrence of serious or high impact events, these dominant BRF should be minimised or at least reduced.

This information can be used to prioritise preventive measures, so that hopefully such serious accidents or incidents can be prevented. By keeping a record of these PSE the data can be used for a (key) performance indicator for safety.

2. Introduction

Gasunie is one of the largest gas infrastructure companies in Europe. Gasunie has two subsidiaries that manage the gas transmission grid: Gasunie Deutschland in Germany and Gasunie Transport Services (GTS) in the Netherlands. Safety has always the highest priority at Gasunie; it is the basic principle of its "license to operate". Being aware of the existing barriers to reducing the impact of incidents, the absolute focus is on proactive

measures and the first links in the safety chain: pro action, prevention, preparation, repression, after care.
Fortunately, Gasunie only experiences a small number of lost time accidents and serious incidents. The consequence however is that these very limited events generate limited data for use in in-depth analyses for preventive measures.
Despite this, to learn from unwanted or dangerous situations it is useful to analyse potentially serious events (PSE). These are events that could have led to (more) serious consequences in just slightly different circumstances in another credible scenario.
Therefore, the question under examination in this paper is:

Can we get useful results from quantitative and qualitative information from this type of potentially serious events and can this information be used for preventive action and for generating performance indicators?

3. Methodology

Data collection

Gasunie uses a central database to report unwanted events with safety aspects. All employees have access to this database and can enter incident reports.
Incident reports are broken down into the following categories:
- dangerous situations (events without damage and without injury)
- incidents (events with damage)
- accidents (events with injury, with or without lost time, which also include accidents in the category internationally defined as "reportables")

All reports are judged by the line management and/or by the safety department. This also includes proposals for preventive or mitigating action. On all these reports the safety officer gives an indication whether the reported event could have led to (more) serious consequences. That means that he or she decides, usually after consultation, if the event is a PSE or not.
For a correct decision two concepts are relevant:
- Potential: Meaning that in a certain credible scenario at Gasunie the consequences could have been more serious. This includes a kind of probability.
- Serious: Meaning the maximum credible consequence of that scenario.

Finally a PSE is defined as an event that could have led to a lost time accident with more than 5 days lost time.

Quantitative analysis

The following method is used to determine whether an unwanted event is a PSE:
1. We determine which "maximum credible " scenario ("worst case") could have taken place in that specific situation.
2. The consequences of effects are assessed for this scenario.
3. The potential ("P") is determined on the basis of the probability that this kind of scenario could take place. It is important to take into account the presence of a last "line of defense" and the degree of robustness of this last "line of defense".
4. These three steps are taken by an "expert judgement" of safety professionals. A list of incidents, accidents and dangerous situations is discussed every week, and a joint decision is taken on the basis of steps 1,2 and 3.
5. The final result can be checked on the basis of the list of PSE that were determined in the past ("jurisprudence"). This also involves checking whether similar events have taken place in the past and how they were assessed. This gives a correct historical overview for a better and more objective judgment.
6. The line manager is informed about this decision.
7. If there is a difference of opinion, the manager of the safety department will decide.

Figure 1 is an overview of the total number of PSE (own staff and contractors over the period 2007 – 2013).

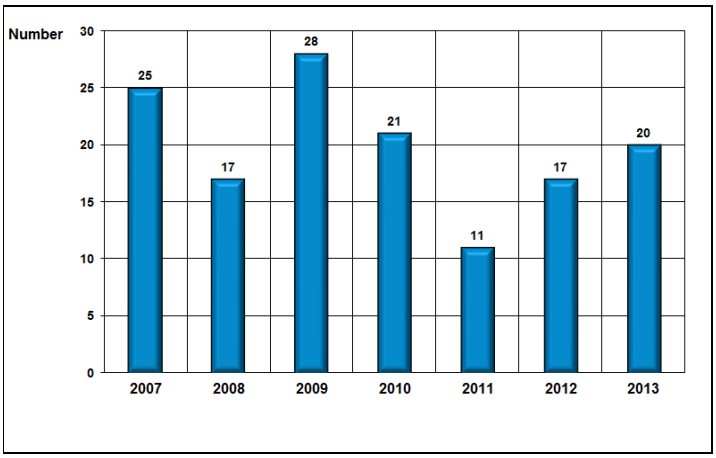

Figure 1: Number of PSE 2007-2013

Qualitative analysis

In the beginning only the number of PSE was collected. A more qualitative analysis was necessary in order improve and to deepen the analyses for proactive measures. To perform such an analysis a search was conducted to find a usable measuring methodology. The gas transmission company in the UK, the National Grid, was already using a list with High Potential Incidents (HPI's) specific for the gas industry for this purpose (table 1).

Table 1 Qualitative classification of PSE by the National Grid [Nat10]

Type	Description of potentially serious events
1	Lifting Operations involving a collapse, overturning or failure of load-bearing parts of lifts and lifting equipment - this would include fork-lift trucks, excavators, slings, lifting tackle, HIAB or similar vehicle.
2	Dropped Load - the uncontrolled fall or partial fall of any equipment, tools, materials etc. being raised, lowered or unrestrained.
3	Vehicle Overturn where any vehicle, transporter, earth-moving equipment or mobile plant fully or partially overturns.
4	Failure of vessel or pipe work under pressure resulting in explosion, clasped or bursting or causing projectiles. Includes boilers high pressure gas holders, storage vessels, air receivers and cylinders for compressed or liquefied gases.
5	Plant or equipment coming into contact or close proximity (i.e. within specified clearance distance) with energized overhead power lines.
6	Electrical short circuit or overload causing fire or explosion including arc flash incidents or catastrophic failure of high voltage equipment resulting in widespread distribution of porcelain on site or into a public area.
7	Failure of equipment used during mechanical movement e.g. winching (not lifting), spacer trolley.
8	Dangerous occurrence at a gas main or pipeline such as an uncontrolled or accidental release of gas, or damage to the pipe such as gouging, denting or buckling even if there is no release of contents.
9	Unintended collapse of any building or structure under construction, alteration or demolition where material falls; a wall or floor in a place of work; any falsework .
10	Collapse of trench, tunnel or shaft - any collapse or partial collapse of trench tunnel or shaft which is part of construction activity.
11	Dangerous work at height – not secured, collapse or partial collapse of any scaffold.
12	Explosion or fire causing suspension of normal work.
13	Sudden, uncontrolled release of flammable substance.
14	Failure to apply proper control methods (violations of clearance and control procedures/permits and authorization procedures, grounding/ earthing and lock out/ tag out procedures).
15	Accidental release of any substance which may damage health. Substances such as asbestos, acetylene and nitrogen could also be included, depending on the nature and amount of the release.

The description of the incidents in this list seems to be more or less based on the presence of a high quantity of energy, such as physical energy (high pressure), potential

energy (falling objects, lifting/hoisting, working at heights) and chemical energy (fire, explosion). This energy can potentially be released unintentionally and therefore forms a high risk for serious damage or injuries. The description concerns occupational safety as well as process safety

4. Comparing PSE with reported accidents

Reported (real) accidents are classified in categories as mentioned in the official corporate Risk Inventory and Evaluation (RI&E). The purpose of this categorisation is to assess the risks in the company and to prioritise the risks in our safety management system.
To improve our knowledge about the causes of accidents in order to prevent them, we want to know whether more information could be gathered from potential incidents or unwanted events that have not yet actually happened compared to reported actual accidents. Therefore we analysed the types of accidents (with and without lost time) that took place in the period 2007 – 2013 and compared them with the PSE in the same period.

5. Results

Number and type of PSE

Gasunie has outsourced a lot of work and activities to third parties (contactors, temporary staff etc.). This means that some elements of safety are also outsourced to those third parties. During the procurement of all services Gasunie takes care that only qualified personnel is hired and that only qualified contractors are used. Therefore all reports of accidents, incidents and dangerous situations from contractors are included in our safety statistics. However due to the wide range of contractors (type, size, organisation), it was not possible to obtain complete and more detailed accident data from contractors for this comparison. Therefore the analyses in this paper have only been conducted for Gasunie's own staff.
In the period 2007 – 2013 a total of 101 PSE were reported: 61 involving our own staff and 40 involving contractors. The graph below shows how the PSE of our own staff are categorised based on the classification in table 1 (the numbers between brackets refer to the categories in table 1).

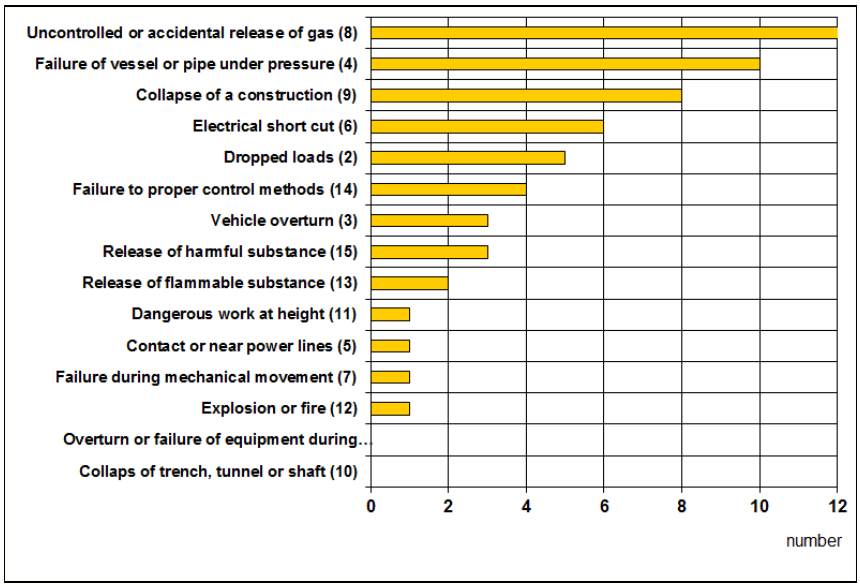

Fig 3. PSE involving our own staff

The graph shows that the top 3 were PSE with:

- uncontrolled gas release
- failure of vessel or pipe work under pressure.
- collapse of a construction

It is clear that maintenance of the gas transport system with a pressure between 8 and 66 bar constitutes a potential high risk. However, due to the many preventive technical and organisational measures taken in the past and today, these risks have fortunately seldom caused serious incidents or accidents. This does not mean that Gasunie is not constantly looking for ways of maintaining or even improving safety.

Comparing PSE with reported accidents from our own staff

In principle every report of an accident, incident or dangerous situation is reviewed or analysed. Reports that are indicated as a PSE receive extra attention from the Safety Department. To make a comparison all accidents in the same period 2007-2013 were analysed. Accidents are defined as incidents where the human body was involved, including with lost time, without lost time, cases requiring medical treatment, cases leading to restricted work and other accidents with minor injuries (including first aid). In that period we had a total of 111 of these accidents.
As already stated, reported accidents are classified in categories as mentioned in the official corporate Risk Inventory and Evaluation (RI&E). As can be seen in figure 4 this risk classification differs from the classification of the PSE list. Actually, the RI&E is mainly meant for "normal" occupational risks based on the Law on Working Conditions, while the PSE list focuses on more severe (process) safety risks.

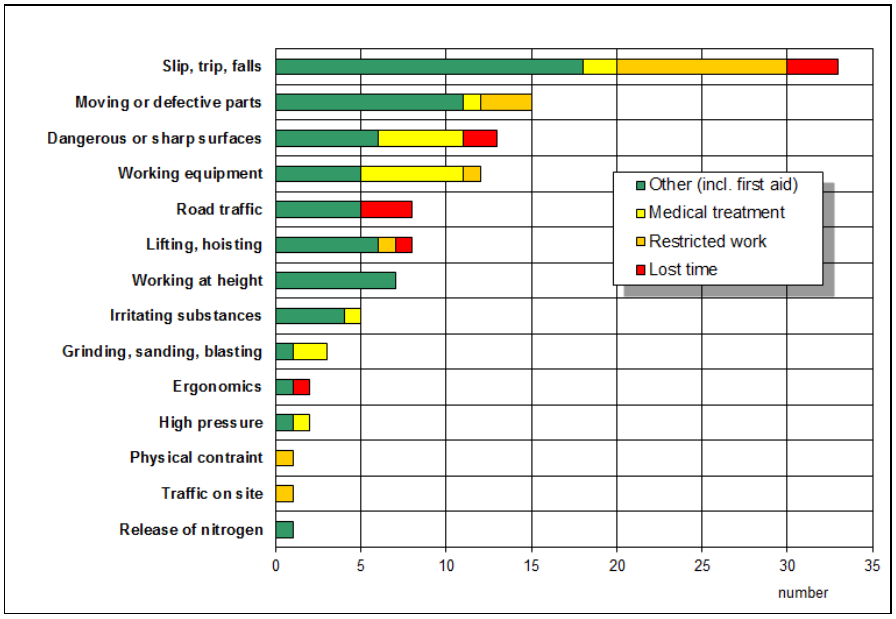

Fig. 4: Number of accidents 2007-2013

By comparing the reported accidents and the analysis of the potentially serious events, it is clear that there is a difference between accidents and PSE in the types of risks involved.

As can be seen there is a clear difference between the type of events that potentially could have happened (gas release, failure of vessel/pipe) and the type of accidents that really did happen (slip, trips, falls, moving objects and dangerous surfaces).
These differences are summarised in table 2, where the top 5 of both categories are shown.

Table 2: Top 5 risks PSE and reported accidents

Top 5 risk PSE	%	Top 5 risk accidents	%
Uncontrolled release of gas	26	Slip, trips, falls	30
Failure of vessel/pipe under pressure	16	Working equipment	14
Collapse of a construction	13	Moving/defective parts	12
Electrical short cut	10	Dangerous/sharp surfaces	11
Dropped load	8	Road traffic	7

This table shows that high potential risks are not "visible" in the statistics of accidents. One of the main reasons is that accident statistics show the "low impact, high frequency" incidents (related to occupational safety), while the "high impact, low frequency" incidents (related to process safety) remain under water, rather like an iceberg. Therefore it is important to pay attention to these potential incidents, especially because of the difference in impact. While the maximum consequence of a reported accident can be a severe injury of even a fatality, high impact incidents can lead to a disaster with multiple fatalities.
This means that certain categories of risks are underestimated in safety statistics.

Basic Risk Factors of PSE

For several years PSE have been measured as a key performance indicator (KPI) for safety. Other safety KPI's included lost time accidents, reportable accidents, pipeline damage. Information on the Gasunie safety KPI's can be found in the 2013 annual corporate sustainability report.

Not only the number and the types of the PSE's are collected. Every PSE is analysed in more depth than other incidents. In fact, a PSE could have led to serious consequences, but one or more Lines of Defenses (LoD) was maintained. So it is therefore a "cheap" way to learn from accidents because the final top event (fortunately!) did not take place. Analysing the individual PSE reveals direct and indirect causes. Indirect causes (also called latent failures) are of most interest. Latent failures are hidden within the organisation for a long time (like a virus) and the negative impact (illness) can become visible, in the form of failure of safety barriers.

To improve total safety performance, it is more effective to detect and correct latent failures than just to react to direct causes (also called active failures), which are the perceptible symptoms.
It is therefore important to find out which type of latent failures lie behind a PSE and whether these latent failures differ from those that lie behind actual accidents and incidents.

In the TRIPOD investigation methodology, latent failures are categorised in 11 types of Basic Risk Factors (BRF). Adding up all the BRF of a single accident or of a number of accidents produces a kind of "fingerprint" of that single accident or number of accidents. Figure 5 compares the fingerprint of all actual accidents/incidents and the fingerprint of the PSE in the same period.

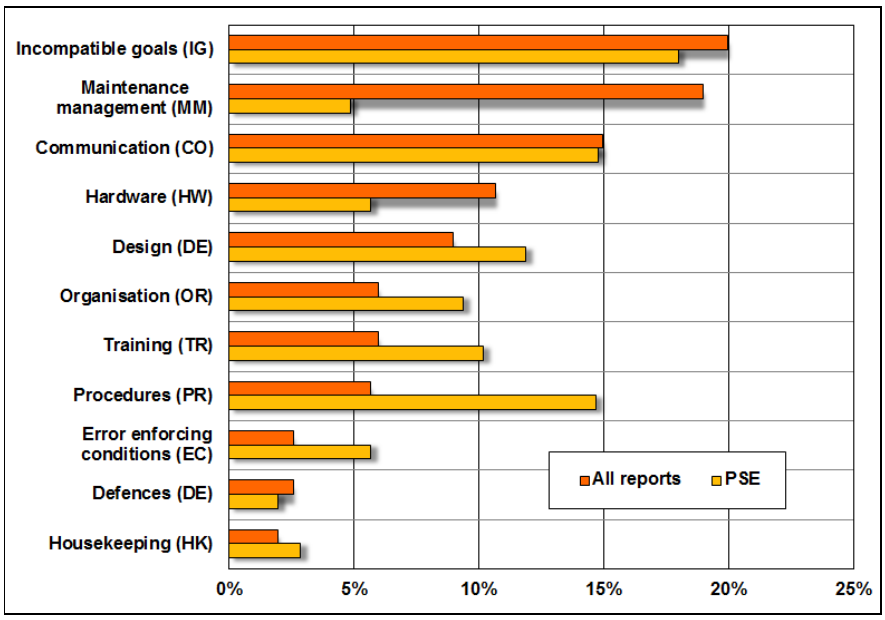

Fig. 5 BRF of PSE versus all reports

This figure shows that the dominant BRF for both categories are "Incompatible Goals" and "Communication".
Besides that, for PSE the dominant BRF are "Procedures", "Design", "Training" and "Organisation". For the average of all reports the dominant BRF are "Maintenance Management" and "Hardware".

Based on the theory of TRIPOD this means that in order to prevent the occurrence of serious or high impact events, the dominant BRF "Procedures", "Design", "Training" and "Organisation" should be minimised or at least reduced.

If no adequate measures are taken regarding the relevant BRF's, one can predict that, as long as latent failures exist, not only PSE will happen, but there is also still a real risk of an high impact incident. Even so can be predicted that the PSE regarding high pressure is most likely to happen based on the statistics in the past

6. Conclusions

General

From the results in paragraph 5 it can be concluded that:
1. In the period 2007 - 2013 a total of 111 accidents involving Gasunie's own staff took place, including 10 with lost time. In the same period 61 PSE were registered. Because of the PSE category, there are more relevant reports for analysis, especially when compared to just a few failure accidents.
2. A more qualitative analysis of the actual accidents delivers special information about safety at work and working conditions. Since the PSE relate especially to potentially higher risks, particularly including risks associated with process safety, an analysis of this type of events clearly provides other information. In other words, there is now a better understanding of process safety (potential incidents with high pressure, outflow of gas, etc.) and not just trips, slips and falls.
3. As a result, PSE analysis complements accident analysis. This means that other and more specific curative and preventative action can be derived from these analyses.

Question under examination

How can safety (or the absence of it) be predicted and what is the answer to the question posed in the Introduction: Can we get useful results from quantitative and qualitative information from this type of potentially serious events and can this information be used for preventive action and for generating performance indicators?

Looking at the results and the conclusion the following answer can be given:
Potentially serious events deliver more and other information than accident analysis alone. In addition, it turns out that the results are more in the field of process safety. This is in contrast to accident analysis that generates more results in the field of occupational safety. Keeping records of the number of potentially serious events as a (key) performance indicator is therefore meaningful to determine not only whether the number is increasing or decreasing, but also the occurrence of the type of PSE.
In addition, keeping records of the Basic Risk Factors is also useful when improvement action must be taken to address the relevant latent failures, which are after all the basic causes of incidents and accidents.