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Empirical validation of operating discipline as a leading indicator of safety outputs and plant performance

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ABSTRACT

Historically, companies have tended to rely on injury/incident frequency measures to gauge their safety performance. There are several standardised ways to calculate lost time or total recordable injury rates. However, there are limitations to using incident frequency as a measure of safety performance, for example due to incomplete incident records and classification errors, or frequency of accidents being statistically unreliable.

This paper introduces Operating Discipline (OD) and trust towards management as potential leading indicators and explores the relationship between OD and a range of safety outputs including personal safety, process safety and plant reliability.

The study was conducted in one of the world's leading integrated oil and gas companies in the “Upstream operations” part of the business which is responsible for oil and gas production and processing.

The OD data was collected through a survey administered to the workforce throughout September to November 2015 and safety/reliability data was taken from the company’s internal databases.

The results demonstrate that OD predicted process safety performance and plant availability but not personal safety. Trust towards management predicted both personal and process safety performance.

1. Literature review

1.1. Limitations of using injury rates as an indicator of safety performance

Traditionally, companies have tended to rely on injury/incident frequency measures to gauge their safety performance. There are a number of standardised ways to calculate lost time or total recordable injury rates. These measures are relatively easy to collect and trend over time. They can also be used to compare performance between different companies.

However, there are limitations to using incident frequency as a measure of safety performance. Commonly cited reasons for which the accident rate is not a good measure of a company’s safety include:

- Incidents are usually rare events with low probability of occurrence, so the frequency of accidents can be statistically unreliable due to the restriction of variance (Fullarton and Stokes, 2007; Hopkins, 2009). Even in large projects and operations the incident frequency is insufficient to statistically validate (Stricoff, 2000);
- Lack of incidents does not indicate that a site is safer than another site which did have incidents in the same period of time (Cadieux et al., 2006). This is due to the non-linear relationship between risk and accidents.
- Frequency rates measure the absence of safety, not the presence of safety (Arezes and Sérgio Miguel, 2003).
  - o If safety is defined as a “dynamic non-event” (Weick, 1987), then it cannot be simply counted and incident rates can NOT be considered a direct measure of safety (Lofquist, 2010) as otherwise it may lead to pre-occupation with measuring the absence of undesired events (Dekker and Pitzer, 2016).
  - o If safety is defined as “the organisational potential to deal with expected and unexpected circumstances”, then the incident rates will NOT be able to accurately describe safety performance (Reiman and Pietikäinen, 2012).
  - o Also, time delays between input (risk management/control) and impact render them a poor indicator of the effectives of hazard management, at least in the short to medium term, i.e. they are of limited value in providing feedback on the effectiveness of risk management systems and interventions (Leveson, 2004).
- Frequency rates ignore the different exposures to risk inherent in occupations (Cooper, 2000; Thompson et al., 1998)
- The definition of an injury may well be broad, including minor cases

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such as insect bites, as in the case of the definition used by the US Department of Labour Occupational Safety and Health Administration.

- Incident rates indicate IF a result was achieved but NOT WHY it was achieved (OECD, 2008)
- Also, due to happenstance, the absence of incidents is not necessarily a good indicator of effective hazard/risk management performance and can sponsor unrealistic optimism and over-confidence (Dekker and Pitzer, 2016).
- Incidents are not always consistently recorded:
  - o Probst & Estrada, (2010) found that for every reported accident there were on average 2.48 unreported accidents.
  - o The UK Health and Safety Executive estimated that in the construction industry over 50% of non-fatal incidents are not reported (Daniels and Marlow, 2005)
  - o Low levels of job security may drive under-reporting (Probst and Graso, 2013)
  - o Rewards and bonuses for periods of time with no incidents may drive reporting down (Pedersen et al., 2012)

1.2. Move towards leading indicators of safety performance

As a result of growing dissatisfaction with placing too much emphasis on the use of frequency rates, industries and academic communities focused on developing alternative measures of safety performance. There was increasing recognition of the partial picture provided by lagging indicators and the poor fit with the need for feedback on risk management performance e.g. interventions aimed at reducing risk need measures (e.g. audits) and KPI's that relate to how well risk is being managed – in order to compare like with like.

The very first attempt to develop predictors of safety performance were based on the Heinrich's triangle (Heinrich and Granniss, 1959) which indicated that the frequency of low severity incidents (near misses, first aids) can predict a high severity incident (fatality). Despite the fact that this model has been seriously questioned (Gallivan et al., 2008; Manuele, 2014; Taxis et al., 2005) it is still a very popular framework used for justifying the development of leading indicators. It benefits from strong intuitive appeal.

Based on a linear model of incident causation and an assumption that incidents are caused by a chain of events, a number of institutions published their guides to developing safety performance indicators (CCPS, 2007; HSE, 2006; OECD, 2008; Step Change in Safety, 2001). However, as per the underlying model, they do not address complex interactions between system components (Leveson, 2015).

Although different studies identified a range of variables that correlate with injuries, very few managed to demonstrate a causal link between leading indicators and injuries (Salas and Hallowell, 2016). Attempts to develop a finite set of indicators that would help to predict an incident in the future has been futile so far (Khawaji, 2012). One possibility is that, more time and research is needed, another, that there is no a universal set of indicators, and they have to be developed separately for each system being monitored. Yet another explanation may be that the linear models of incident causality are not sufficiently accurate or sophisticated to identify such predictors.

There are different starting points and frameworks to develop leading indicators. Some of them focus on addressing gaps in safety performance, others look at barriers and there is a growing field of organisational resilience and resilience engineering that can also be utilised (Costella et al., 2009; Gibson and Tarrant, 2010; Madni and Jackson, 2009; Paltrinieri et al., 2012; Seville et al., 2006). This study is based on a barrier approach, where procedures are seen as one type of a barrier and OD functions as a way to measure barrier effectiveness (Duijm and Markert, 2009; Sklet, 2006). This approach was chosen to match the framework to which the sponsor organisation manages risk.

Different authors define Leading Indicators differently. For example:

- Hopkins (2009)- "*…those that directly measure aspects of the safety management system, such as the frequency or timeliness of audits*" (p.460)
- Shea et al. (2016)- "*…precursors to harm that provide early warning signs of potential failure*"(p.293)
- Hinze, Thurman, & Wehle (2013)- predictors of future levels of performance
- Jablonowski (2011)- variables that correlate with lagging indicators.

1.2.1. Role of procedural conformance in safety management

The safety performance indicators demonstrated in the literature to predict Total Recordable Injury Rate (TRIR) (Salas and Hallowell, 2016) include a combination of near-miss reporting, Job Safety Analysis (JSA), safety audits, stop work authority or corrective action items. None of the identified leading indicators related to following procedures or employee engagement. Furthermore, no study was identified that would demonstrate a link between leading indicators and process safety outputs.

Operating procedures and policies can be thought of as representing the organisational ability to preserve and transfer the know-how allowing continuous improvement, as well as providing on-site workers with the knowledge of the steps to take to perform an industrial process according to the organisation's expectations.

Compliance with procedures is critical because in large, high-hazard organisations jobs may be too complex to perform them from memory or to improvise. Documenting in a procedure the steps to take also enables the procedure to be auditable, as well as enabling procedures to be standardised. This has been recognised by the international Safety Management System Standards, which require operating procedures to be in place, e.g. OHSAS 18,001 (Kausek, 2007). These factors suggest that procedural compliance is at the heart of operating discipline, provided that the procedures are appropriate, practicable, workable, and are appropriately aligned with the principles of the hierarchy of controls.

1.3. Operating discipline (OD) as a potential leading indicator

1.3.1. Beginnings of operating discipline in high hazard industries

Most companies recognise that reliability of human performance enables organisational success. High-hazard industries developed different approaches to improve human reliability, e.g. behaviour-based safety (BBS) in the 50 s (Daniels, 2014) human reliability analysis in the 70 s (Spurgin, 2009), operational discipline (OD) in the 80 s or, building on the developments in BBS, behavioural systems in the 90 s (Malott, 2003). Most recent developments focus on the application of systems thinking (Leveson, 2012).

Although the first mention of the term operational discipline (OD) can be tracked to 1979 (Oaes et al., 1979), the American Institute of Chemical Engineers in 1986 (Rausch, 1986) first identified it as a key component of safety. This OD concept was used by different industries including military or aviation (CCPS, 2011)

In the late 80 s Dow Chemical Canada (DCC) and DuPont were developing their OD programmes and DCC published the description of their operating discipline program associated with implementing plant computerisation (Trask, 1990). They defined OD for the very first time as "*the knowledge and understanding of the thousands of details required to operate efficiently, reliably and safely and the dedicated attention needed to ensure their use all of the time*" (p.158). But Dow Chemical recognised that OD should not be limited to the front-line operators but also include the supporting systems. For instance, if people are expected to follow procedures, they need high-quality procedures available and easily accessible as well as knowledge and training, with the role of the leaders being to allocate resources to establish and maintain these supporting systems.