DEVELOPING KPIS THAT DRIVE PROCESS SAFETY IMPROVEMENT

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A case study is provided describing Lloyd's Register's development of a set of Key Performance Indicators (KPIs) for Process Safety Management (PSM) for an oil and gas client.

The development process is described in this paper along with discussion of how the KPIs were developed and designed to support the client in gaining a clearer picture of their current Process Safety performance and to drive the improvement of that performance.

This paper includes discussion of the number of KPIs that are introduced, the sequencing of introduction of KPIs, the associated implementation requirements, the reporting of the metrics to management at all levels in the organisation, and the value provided by both the measurement and reporting of the KPIs.

INTRODUCTION

The Baker Report (Baker 2007) will have provided uncomfortable reading for many senior oil and gas managers when first published. The Technical Director of a client of Lloyd's Register's read his copy on the plane home from a business trip. The findings left him feeling distinctly uneasy that some of the same conditions that existed at Texas City before the incident in 2005 may also exist in his own company. His concern motivated the company to rise to the Baker Report's challenge to all process-related companies to review their own Process Safety Management practices. During 2007 and 2008 Lloyd's Register worked with them to establish a realistic understanding of the PSM performance across the company.

'Process safety' is defined in the Baker Report (Baker 2007) as "... hazards [that] can give rise to major accidents involving the release of potentially dangerous materials, the release of energy (such as fires and explosions), or both. Process safety incidents can have catastrophic effects and can result in multiple injuries and fatalities, as well as substantial economic, property, and environmental damage."

Based on Bill Hewlitt's truism that "you cannot manage what you cannot measure", one element of the work carried out with our client was to review their current mechanisms for measuring PSM performance and to work with them to establish a comprehensive set of Process Safety KPIs that would provide both leading and lagging measures. This set of Process Safety KPIs needed to establish both a baseline of realistic current process safety performance, and also enable all levels of the organisation to understand and drive improvements in process safety performance in the short to medium term.

WHY DEVELOP KPIS?

KPIs give an indication of how well a process or practice is working. In relation to process safety this provides a measure of how well the barriers or hazard controls related to preventing process safety incidents and the mitigation measures preventing escalation are working. For example, measuring compliance with Permit to Work requirements, where the Permit to Work system is designed to control hazards such as ignition sources, provides an indication of how well the PTW controls those hazards.

KPIs form the primary means of management feedback on the control of process safety risk and form part of the business assurance model for safe operation. Reporting on KPIs provides an opportunity for management intervention and corrective action, through the establishment of performance goals or targets on each KPI.

Additionally, in our experience many companies have a KPI-driven culture, where those activities that are accompanied by targets in individual performance contracts are those that receive the majority, and in some cases, all of the individual's attention. Therefore, in such companies, KPIs can be a useful means to focus attention on areas that require prioritised improvement. However, as Hopkins (Hopkins 2007) also points out, caution is needed in determining the right indicators and targets for companies with this type of culture as the individuals may see their role as managing the indicator rather than managing the process that it is indicative of.

KPI DEVELOPMENT PROCESS

The development of the Process Safety KPIs for our client was undertaken in four stages, as depicted in Figure 1. As set out earlier, this KPI development activity was part of a much larger assessment of how the company managed process safety at the time. The assessment included activities such as: PSM systems implementation assessment; brownfield Hazard and Operability (HAZOP) and Layers of Protection Analysis (LOPA) studies; alarm rationalisation; control room operator competency review; leadership coaching; business risk segmentation assessment; and a pan-company process safety culture assessment. The strength of developing Process Safety KPIs in this context was the ability to utilise the objective findings of the assessment activities, which highlighted gaps in process safety management, to target the KPIs onto areas of known weakness.
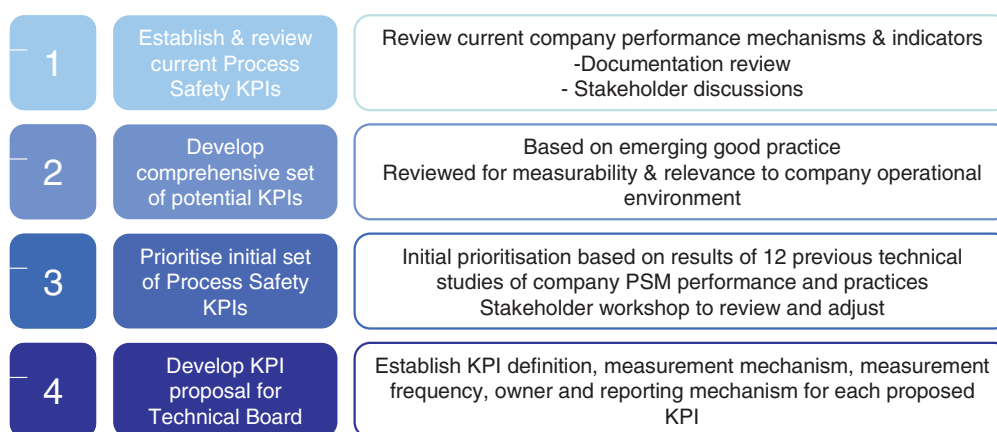
Figure 1. Process safety KPI development process

STAGE 1: ESTABLISH AND REVIEW CURRENT PROCESS SAFETY KPIS

The initial stage of the Process Safety KPI development process consisted of reviewing the performance mechanisms and indicators that the company already had in place. This stage was conducted through documentation review and iterative discussions with relevant staff members, including their cross-discipline Process Safety Working Group.

The types of documents/mechanisms reviewed included:

● Corporate Scorecard
● Health, Safety and Environment (HSE) Scorecard
● Maintenance Dashboard
● Operations Dashboard

The disciplines covered by these discussions included:

● HSE, including Technical Safety
● Concept and Design Engineering
● Production Operations
● Maintenance Engineering
● Well Engineering
● Well Services
● Human Resources and Training
● Document Management
● Security

This review established the type and number of existing Process Safety KPIs already being measured within the company, some of which were leading indicators (e.g., compliance with preventative maintenance plan), and some which were lagging (e.g., number and volume of oil spills). The main finding of this stage of the review was that the company had few indicators, particularly outside the maintenance arena, which could truly be considered to measure process safety performance.

As highlighted by the Baker Report (Baker 2007) and like many oil and gas companies over the past decade or so,

the company had focused on measuring production, personal safety and environmental performance.

STAGE 2: DEVELOP COMPREHENSIVE SET OF POTENTIAL PROCESS SAFETY KPIS

The second stage of this review was to develop a comprehensive set of Process Safety KPIs based on emerging good practice that could then be considered for use within the company. This was achieved through review of many of the recent publications related to process safety indicators (including CCPS 2007, CCPS 2008, HSE 2006, Hopkins 2008, OECD 2003 and PACIA 2008 publications). This activity produced an initial set of over 70 possible Process Safety KPIs.

There are considerably more Process Safety KPIs that could have made it onto the initial list, however, we were cognisant of the need for the KPIs to be both measurable and relevant in the context our client's organisation. Some of the KPIs that we felt would have been useful we knew would have proved currently immeasurable in our client's operation (for example, the percentage of deviations from design engineering standards without approvals per engineering project) and other KPIs which, although valuable to other organisations, were not useful in their operational environment.

Along with the process safety KPI description for each of the 70+ KPIs on the initial list, some thought was given to who would be the owner of the KPI, who would collate the metrics and where in the organisational hierarchy would the KPI be measured and then reported.

This initial list was mapped against the company's model for PSM and against the CCPS PSM elements list (CCPS 2007) to ensure comprehensive coverage of all PSM areas and PSM barriers and mitigation controls.

STAGE 3: PRIORITISE INITIAL SET OF KPIS

The third stage of the review was to prioritise the initial list of 70+ KPIs. A preliminary prioritisation was made by

Lloyd's Register, based on our knowledge of the company gained through 12 previously undertaken technical studies of the company's PSM performance and practices over the past 12 months. The KPIs were prioritised into three categories:

- Category One – KPIs that were considered to have the greatest potential to drive performance improvement in those PSM controls that required immediate attention.
- Category Two – KPIs that were considered to have potential to drive performance improvement in those PSM controls requiring attention in the medium term.
- Category Three – KPIs that would drive improvement in PSM controls requiring attention in the longer term.

Table 1 shows the breakdown of the 73 Process Safety KPIs into our initial prioritisation categories.

Having undergone a provisional prioritisation, the initial set of Process Safety KPIs were then reviewed with the relevant stakeholders in a workshop to test the measurability, relevance and prioritisation given to each KPI in priority order. Table 2 compares the numbers of Process Safety KPIs in each priority category for the initial prioritisation and final prioritisation exercises. It can be seen that the stakeholder review reduced the Category 1 KPIs from 31 to 29, the Category 2 from 27 to 16, and the Category 3 KPIs increased from 15 to 23.

5 of the KPIs were 'put on hold' as their definition needed to be further reviewed and, dependent on the definition provided, a decision would be made regarding their

Table 1. Breakdown of provisional prioritisation of initial set of Process Safety KPIs

Provisional prioritisation category	Number of KPIs	Percentage of total
Category 1	31	42%
Category 2	27	37%
Category 3	15	21%
Total	**73**	**100%**

Table 2. Breakdown of reviewed prioritisation of initial set of Process Safety KPIs

Priority category	Number of KPIs	
	Initial prioritisation	Reviewed prioritisation
Category 1	31	29
Category 2	27	16
Category 3	15	23
Hold (definition and decision pending)	–	5
Total	**73**	**73**

priority. Those KPIs put on hold were mainly related to ensuring process safety consideration in the design process.

STAGE 4: DEVELOP PROCESS SAFETY KPI PROPOSAL FOR TECHNICAL BOARD

In discussion with the company Process Safety Working Group and Engineering Director it was determined that it would not be practical to attempt to implement the 29 Category 1 Process Safety KPIs in the following 12 months. Therefore, the Category 1 KPIs from the stakeholder review were further examined and the number of KPIs further reduced to 18.

The culling process removed some duplication of KPIs related to the same PSM control/system. It also focused on those KPIs that would provide the greatest contribution to reducing the current corporate process safety risk. The intent of the majority of the KPIs is to drive improvements in leadership and infield behaviours and therefore in operational compliance and control. They centre around the need for establishing a strong PSM culture in the company and strengthening known weakness, rather than examining the health of every PSM control measure that exists.

Those KPIs that fell into Category 2 are intended to be implemented at a later stage.

The final list of KPIs that were put forward to the company's Technical Board for approval is shown in Table 3.

Considering that is normal for this company to measure only 3 or 4 KPIs in relation to significant improvement programmes implemented in the past, taking on 18 KPIs in relation to process safety showed significant commitment to driving improvement in this area.

Included in the proposal was a thorough breakdown of each proposed Process Safety KPI, providing details of the following:

- KPI title
- KPI definition – the measurement equation
- Assurance mechanism – how the KPI measurement would be audited to ensure it's accuracy
- Accountable party – the accountable party defines the position in the management hierarchy that will be accountable for ensuring that the KPI is measured and reported. The accountable party may delegate the responsibility of measurement and reporting, however, they will remain answerable for the establishment of the KPI measurement and reporting
- Target – where applicable or already existing, targets for the KPI were set. However, it was advised that for the purposes of gaining a clear and accurate understanding of the PSM status of the business in the first year, targets should not be set on new KPIs
- Value to the business – a description of how the KPI would add value to the business
- Implementation guidance – a description of how best to establish the KPI measurement and reporting mechanisms

Table 3. Final list of PSM KPIs

No.	Proposed Process Safety KPIs	Related PSM control
1	Percentage of senior management asset visits addressing process safety completed	PSM Leadership
2	Number of visits per week to work site by production & maintenance supervisors, co-ordinators & asset managers	PSM Leadership
3	Percentage staff turnover in HSE Critical roles	PSM Competence
4	ON HOLD [Project delivery of process safety requirements KPI – to be determined]	PSM in Design
5	Percentage of pre-start up audits containing significant process safety findings	PSM in Design
6	Number of permit violations observed during local PTW Audits	Permit to Work
7	Number of PTW reviews per week by asset managers/asset	Permit to Work
8	Percentage compliance with Corrective Maintenance plan	Maintenance
9	Percentage compliance with Preventative Maintenance plan	Maintenance
10	Number of approved waivers & safeguarding overrides/asset	Operational control
11	Number of approved waivers & safeguarding overrides reissued/re-approved per asset	Operational control
12	Number of excursions outside asset operating envelop/asset	Operational control
13	Total alarm rate/asset	Operational control
14	Percentage of assets having undertaken & actioned an alarm rationalisation review	Operational control
15	Percentage compliance with local asset audit schedule	Audit of PSM systems
16	Percentage compliance with Emergency Response Exercise plan	Emergency response
17	Number of PSM incidents reported per month	–
18	Percentage completion against PSM Improvement Plan	PSM Improvement Plan

- Performance contract inclusion – guidance on whether the KPI should be included in senior management performance contracts

Also included in the proposal was a draft RACI chart for the KPIs. The RACI chart describes the positions in the company who are Responsible, Accountable, Consulted and Informed about each KPI, and therefore sets out the reporting hierarchy for the KPIs.

KPI REPORTING FORMAT
During the KPI development process some thought was given to the format in which the KPIs might be reported. Three different reporting formats were developed and presented to our client for consideration.

TRAFFIC LIGHTS
A familiar way of reporting on KPIs is to use a 'traffic light' format that shows whether the KPI is on or above target (green), slightly below target (yellow) or significantly below target (red). This format can also show whether there has been a change in status for the KPI from the previous reporting period using a faded traffic light (see Figure 2).

HEAT MAPS
A heat map uses a similar principle to the traffic lights above, in that the status of each KPI can be shown using

colour coding. It is a useful way of presenting information related to the KPI scores for several different assets or facilities in one table (see Figure 3). Actual KPI scores can be inserted into the table to provide more detail if
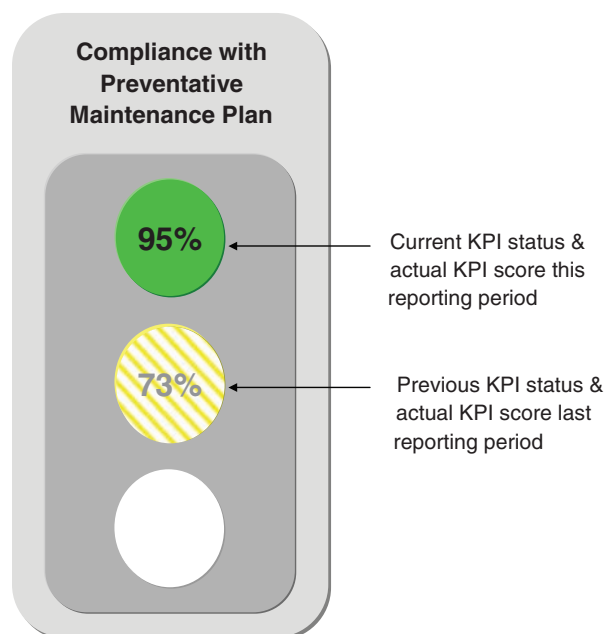

Figure 2. Example Process Safety KPI traffic light reporting format

Process Safety KPI	Facility 1	Facility 2	Facility 3	Facility 4	Facility 5	Overall
1	green	red	green	green	green	green
2	red	red	red	red	red	red
3	green	green	green	green	yellow	green
4	yellow	green	yellow	yellow	yellow	yellow
5	yellow	red	yellow	yellow	green	yellow
6	yellow	red	green	green	green	yellow
7	yellow	green	green	green	green	green
Overall	yellow	red	yellow	yellow	yellow	yellow

Figure 3. Example Process Safety KPI heat map reporting format

required, however, this can be cluttered. Changes in KPI status can be shown by splitting the columns and using a faded colour code for the KPI status from the previous reporting period.

PROGRESS GRAPHS

Progress graphs show whether a KPI is meeting its target (see Figure 4). For example, the target for the alarm rate/asset or facility might be 10 alarms per minute. If the facility alarm rate meets this target it is shown to have 100% progress against the target. If the facility alarm rate is less than 10 alarms per minute it would be shown to have over 100% progress against the target. This type of presentation format can be adjusted to show changes in KPI status over reporting periods, and actual KPI scores can be added to the graph bars for extra detail. It is a useful way of showing how far away from (or how close to) the target the KPI score is.
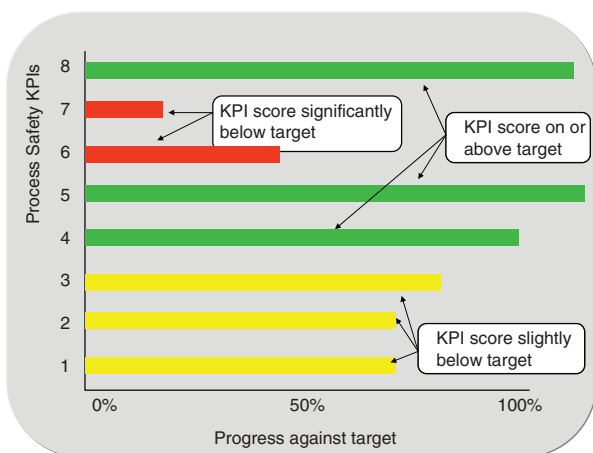
Figure 4. Example Process Safety KPI progress graph reporting format

KPI IMPLEMENTATION

The Process Safety KPI Proposal was presented to the company's Technical Board in early 2009 and duly approved. The company are now working on implementing the KPIs by establishing measurement and reporting mechanisms.

The challenges that they have faced in implementing the KPIs have included resistance from the differing business sectors to certain KPIs being measured and reported. The culture in this company in the past has been to only pass positive news up the chain of command, unless bad news can not be avoided. Therefore, significant effort has gone into coaching the various levels of management on the need for open and transparent reporting.

In order to encourage openness in reporting the majority of the KPIs have had no targets set for the first one to two years. The intent is to establish a more accurate picture of their PSM status, before using targets to drive performance improvement.

The coaching regarding openess has extended into discussions with the company's shareholders, who, like the rest of the company have been more used to hearing that plans are on target rather than being provided with a realistic picture of existing weaknesses. The shareholders have now been presented with the companies PSM KPIs report on two occasions, and their feedback on receiving this information has been extremely positive, including asking the company to ensure that they have set aside enough budget to cover the PSM improvement plan that has been developed to address the weaknesses identified.

It would have been unthinkable a year ago that this company would accept internally the messages that the PSM KPIs reporting is providing to them now, and even more unthinkable that they would publicise this data externally to their shareholders. That they are willing to do so now is testament to the cultural change journey that they have been on, and that the reporting of PSM KPIs will help to support into the future.

DISCUSSION

There has been much discussion in recent publications related to the need for process safety indicators to represent both 'leading' or 'lagging' metrics. However, there are numerous (and conflicting) definitions of what is a leading and lagging indicator. In this paper, leading indicators are generally thought of as being those that indicate precursors to a process safety incident, and lagging indicators are those that measure the frequency of process safety incidents.

Hopkins (Hopkins 2007) concludes that there is little or no consistency in the use of the terms 'leading' and 'lagging' and also that there is little point in trying to pin down a precise meaning. He believes that what is important is that process safety indicators are chosen to measure the effectiveness of the controls upon which the process safety control system relies. However, we believe that in addition to measuring the effectiveness of the controls, there must also be one or two KPIs that measure the frequency of any incidents that do occur.

Since developing our set of Process Safety KPIs with our client, the CCPS (CCPS 2008) have defined three 'lagging' indicators that they consider should be used industry-wide to measure process safety performance. These are the Total Count of Process Safety Incidents (PSIC), the Process Safety Total Incident Rate (PSTIR) and the Process Safety Incident Severity Rate (PSISR).

$$PSIC = \text{Total count of process safety}$$
$$\text{incidents (as defined by CCPS)}$$

$$PSTIR = \frac{\text{Total process safety incidents} \times 200,000}{\text{Total employee and contractor work hours}}$$

$$PSISR = \frac{\text{Total severity score for all process safety incidents} \times 200,000}{\text{Total employee and contractor work hours}}$$

The adoption of these indicators would provide a useful means to benchmark industry PSM performance, and reduce the reliance on using personal safety indicators as a measure of overall safety performance. These indicators will be recommended for inclusion in the PSM KPI Suite of our client in the near future.

There is also some discussion by groups such as the European Process Safety Centre (EPSC) of the need for each process safety control to be measured using a leading and lagging indicator, where the leading indicator measures the inputs to a process at stages before any adverse outcomes have occurred and the lagging indicator monitors the output from the process (EPSC, 2004). The scores from both types of indicator can then be plotted to show how effective the leading indicators are at predicting process safety performance. Whilst this aim is both sensible and desirable, considering the number of process safety controls that need to be monitored, the practicality of implementing two indicators for each control for many companies will be questionable. It may be more practical to either introduce one indicator for each control or to introduce lead and lag indicators for the most critical or vulnerable controls in the first phase, and as the company becomes used to measuring these KPIs and their process safety culture maturity increases, further measures can then be introduced in a second phase. This is the approach we have taken with our client.

The success of the KPI measurement will rely heavily on the transparency of reporting. This applies to all indicators. Senior management must stress the need for open and transparent reporting of PSM performance to the business. Consequently, senior management should prepare the business for an increase in PSM incidents being reported over the initial period of implementing the process safety KPI suite. This can be disconcerting for a company: to start implementing process safety improvements and measuring process safety performance only to see that performance drop. However, if this does occur it is likely that in the past process safety incidents have been underreported and PSM performance overrated. Gaining a true picture of company PSM performance provides the senior managers with accurate information to act upon.

It is the 'acting upon' that is crucial to the improvement in PSM performance. Measuring alone will not drive this improvement. The information the KPIs provide must be used by senior managers to change PSM policy, procedures, practices and beliefs, and it is these changes that will drive PSM improvement.

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