SAFETY PERFORMANCE INDICATORS IN THE EXPLOSIVES SECTOR†

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Safety Performance Indicators (SPIs) are a method of analysing 'leading' and 'lagging' safety measures, encouraging a positive safety culture whilst allowing ongoing assurance that risks are being adequately controlled. They are typically used by Major Accident Hazard (COMAH) sites. The Health and Safety Executive (HSE) commissioned a project with the Health and Safety Laboratory to work with industry partners to look at how SPIs can be applied in the explosives sector. This industry was selected as low frequency high consequence events mean that measures that monitor accident and incident rates do not give a true reflection of how well safety is being managed.

'Leading' or "outcome" indicators report on the effectiveness of risk control systems. Examples include: percentage of safety critical equipment that reaches the necessary standard; and percentage of maintenance actions identified that are completed to timetable. Whilst 'lagging' indicators report on events that have occurred and would include incidents or events. The process from HSE guidance 'Developing Process Safety Indicators' (HSG254) was adopted and used by the industry partners to develop indicators. This paper looks at the steps that were taken with the explosives industry to introduce SPIs, examples of how they can be applied to the sector and how the industry is now adopting SPIs as part of good working practice.

KEYWORDS: safety performance indicators, case study, explosives industry

INTRODUCTION

Safety performance indicators (SPIs) are 'observable measures that provide insight into a concept – safety – that is difficult to measure directly' (OECD, 2008). They provide a method for monitoring and analysing 'leading' and 'lagging' safety measures, (i.e. performance) before or after an accident has occurred. SPIs are therefore increasingly used to assist in the identification and resolution of safety issues, whilst also encouraging a positive safety culture by providing ongoing assurance that risks are being adequately controlled (Ferguson and Birkbeck, 2006).

SPIs are typically used by Major Accident Hazard (COMAH) sites, and are currently utilised throughout a range of industries. A scoping study by Sugden et al (2006) found that safety performance indicators are used across a range of high hazard industries including rail, aviation, nuclear, military and process safety. This work highlighted that the nuclear sector was the most advanced in the use of performance indicators, whilst its success in other sectors was varied.

As stated in HSG 254 (HSE, 2006), SPIs are able to highlight deficiencies before catastrophic failure occurs, avoiding the discovery of weaknesses through costly incidents. The intent is to provide ongoing assurance that risks are being adequately controlled. Therefore SPIs can be used to focus attention on critical aspects of the process, enabling an organisation to prioritise and address deficiencies before those deficiencies lead to an accident or incident. The information generated through the definition, identification, collection and analysis of SPIs is valuable to a range of employees (from senior and middle management to operators) for a variety of purposes (e.g. auditing performance, operational control and emergency response).

There are two main types of indicators; lagging or outcome indicators and leading or activities indicators. The terms lagging and leading are used by HSE (2006), whilst outcome and activity are those coined by OECD (2008). The terms leading and lagging are used in this paper.

LAGGING OR OUTCOME INDICATORS

Lagging or outcome indicators are reactive, reflecting 'when a desired safety outcome has failed, or has not been achieved'. Therefore they are useful for assessing whether risk controls (e.g. equipment performing as expected) are effective, therefore resulting in a reduced likelihood of accidents/incidents occurring, by reflecting changes in safety performance over time, or failure of performance.

In general, the majority of lagging indicators are related to reported incidents/accidents (e.g. percentage of incidents due to failure of safety critical equipment).

LEADING OR ACTIVITIES INDICATORS

Leading indicators report on the effectiveness of risk control systems. They are proactive, measuring safety performance against desired levels, and highlighting deviations from safety expectations at a specific point in time.

As such, leading indicators provide organisations with a means of systematically checking the efficacy of the controls implemented. In addition they can help explain why a result (measured by a lagging/outcome indicator) has been achieved or not.

Leading indicators are measures of how well the systems ensuring safety are operating. Examples might include measures of safety critical equipment reaching the required standard, or maintenance activities being completed on time to plan.

Overall, SPIs provide a system for capturing and monitoring performance-related information, and provide an efficient method for identifying potential problems, through early warning that critical risk controls are not operating as intended, or have deteriorated to unacceptable levels.

This provides organisations with the assurance that risk control systems are working as expected. The use of SPIs enables the organisation to demonstrate that they have implemented appropriate controls, whilst their ability to detect declines or weaknesses in risk control systems indicates the effectiveness of those controls. SPIs therefore enable continuous assessment and appraisal of overall safety performance.

However the efficacy of the SPI programme is dependent on the quality of the indicators selected, and therefore the programme may capture information to varying degrees of sophistication, depth and spread of cover, depending on the indicators selected and how they are used.

Therefore key considerations when designing SPIs include:

- Accessibility of the information underpinning the indicator; and
- The extent to which the indicator is useful (i.e. its relevance to the management of safety performance).

CURRENT USE OF SPIS

Despite a large volume of published material on performance indicators, it is recognised that the nuclear industry appears to have taken a strong lead in implementing SPIs, although many organisations in other industries are also utilizing SPIs to differing degrees. In most cases, where they are used, SPIs seem to be developed in the absence of any underlying rationale or model. A recent special issue of Safety Science (2009) included a wide range of papers on the issue of performance indicators, highlighting the ongoing debate and interest in this area.

However, it was observed that the diversity of industries where SPIs could be utilised meant that the development of a single SPI model would not be straightforward. There is a need to ensure that any cross-sector model that is developed is, where possible, consistent and compatible with any frameworks already being used.

Although SPIs are not widely used within the explosives industry, scope for their effective use has been recognised, and recent interest has led to consideration of appropriate guidance for developing and implementing SPIs.

CURRENT SAFETY MANAGEMENT SYSTEMS IN EXPLOSIVES INDUSTRY

Organisations within the explosives sector are regulated under the Manufacture and Storage of Explosives Regulations (MSER) 2005. In addition, larger sites are also subject to the Control of Major Accident Hazards regulations (COMAH, 1999) which has duties to prevent major accidents involving dangerous substances and limit the consequences should an incident occur.

The historical nature of the explosives industry has fostered a culture where procedural compliance and inherent safety are the main mechanisms of risk control/means it cannot/will not operate safely, solely through reliance on prescriptive regimes and compliance with rules and regulations (Marriott, 2008). The handling and use of unpredictable explosive materials means it is difficult (and impracticable) for the explosives industry to write rules and procedures to cover every possible event/eventuality.

Therefore current explosives industry safety cases focus on demonstrating a robust approach to managing safety (i.e. less dependent on calculations, and the inherent associated assumptions) with a focus on clearly and comprehensively identified risks, and appropriate risk controls. Within the explosives industry, safety culture is critical due to the reliance on procedures and inherent safety as the main mechanisms of risk control. To date, SPIs have not been widely used by the explosives industry.

The explosives industry, as a licensed industry, has well defined requirements and a reasonable level of regulatory attention. Considerable difficulty has been observed in the determination of targets for leading indicator elements, as for most of the activities undertaken, anything less than 100% is considered unacceptable, and is generally managed to resolution within very short timescales.

Overall, there are a limited number of failure scenarios within the explosive processes, and due to the nature of the explosive materials on site, lagging indicators may not give adequate forewarning to correct risk control deficiencies.

HOW SPIS CAN BE APPLIED TO THE EXPLOSIVES INDUSTRY

A pilot group was set up in May 2007, coordinated by HSE and HSL, and involving 4 explosives companies, which represent in excess of 20 licensed sites. The aim of the group was to share experience and practices, to explore how they could develop and extend the use of SPIs, and to develop a worked example to help encourage further take-up across the sector. A number of meetings have been held and the group has participated in a piece of research to encourage the uptake of SPIs within the explosives industry (Ferguson and Nash, 2008) and fed back the findings as the companies started using performance indicators.

BACKGROUND OF THE PILOT GROUP

Whilst the volunteer organisations are part of the explosives sector and operate under a licensing system, they each undertake a different range of activities. These activities broadly include:

- Transporting explosives to and from the site;
- Filling of explosives articles;
- Mixing of explosive substances;
- Research and development of explosives; and
- Storage of completed explosive products.

Most respondents reported explosive manipulation, storage and transportation as an aspect of their activity, whilst production of very limited amounts was reported for one organisation. All of these activities are regulated by HSE as part of a licensing regime. This result in a range of control measures that are mandated on the organisation including:

- Where explosives can be manufactured or stored;
- The operations that may be undertaken;
- Control of the amount stored in any specific location;
- The emergency arrangements; and
- The location of explosives buildings in relation to residential areas.

These control measures act to reduce the hazard and risk presented by the site and its activities.

The main hazard controlled for is explosion. One respondent suggested fire as an additional hazard although this would often form a precursor or consequential element to a major accident scenario at the site.

In the initial study (Ferguson and Nash, 2008) participants' responses suggested that the key areas meriting consideration in relation to the development of performance indicators in the explosives industry would be:

- Design, operational and other procedures (processes);
- Maintenance and inspection;
- Leadership;
- Employee attitude;
- Change control;
- Control of contractors; and
- Audit.

The principal areas for consideration in developing key performance indicators were identified as operational procedures and employee attitude as they were considered to be critical to sustained safety performance and offer the greatest potential for unidentified degradation over a period of time (i.e. are most vulnerable).

The initial work suggests that the competency of individuals is key, in terms of complying with operational and inspection/maintenance procedures, in relation to the development of improved controls and in the identification of scenarios where operational procedures had the potential to lead to undesirable consequences.

INITIAL STEPS

Following on from the initial work, the companies from within the working group all started to develop performance indicators. These initial efforts by the industry attempted to follow the process outlined in HSG254 (HSE, 2006) and some nuclear industry guidelines (IAEA, 2000) and led to the development of many performance indicators. The companies adopting safety performance indicators reported a number of problems, including:

- A large number of potential indicators were developed, which made the process hard to manage;
- Problems with multi-site organisations, and the difficulty of identifying meaningful indicators that could be used across all sites, for the range and complexity of sites;
- The challenges of aggregating scores up through the organisational hierarchy such that it provides meaningful information at all levels;
- Concerns about identifying benchmarks, and how to decide when an indicator no longer adds value.

Two findings were consistent across the group, these were comments about the time-consuming nature and that engagement across a whole organisation is required; and the challenges of identifying an appropriate measure to demonstrate the competence of staff. Competence is recognised as an essential risk control, however none of the companies have yet been able to identify an appropriate measure, due to the complexity of the issue.

Overall there was little consistency or commonality between the groups in terms of the leading and lagging indicators developed. It was felt that to engage the rest of industry that a worked example and a case study should be developed. A disposal scenario was selected, as it was the belief that the majority of the sector has to dispose explosive materials.

WORKED EXAMPLE FROM HSL

HSL and HSE are currently involved in work with explosives sector companies to develop a sector specific worked example to demonstrate the application of SPIs in an explosives waste disposal scenario. This work builds on the examples and indicators identified in a previous study (Ferguson and Nash, 2008), and aims to encapsulate the types of activities common to a large number of organisations.

METHOD

HSL followed HSE guidance on developing performance indicators, which recommends the steps shown in Table 1.

SCENARIO

The worked example represents a safe explosives waste disposal operation at a production site. In the example, manufacturing has resulted in waste explosives products. These waste products are desensitised, and then transported from the production shops to the burning ground (i.e. the designated disposal area) where the waste products are destroyed using the most appropriate method, based on the nature of the waste material and the location of the disposal site.

Table 1. Process for developing performance indicators

Decide the scope of the measurement system. Consider what can go wrong and where	Select the organisational level Identify the scope of the measurement system: • Identify incident scenarios – what can go wrong? • Identify the immediate causes of hazard scenarios • Review performance and non-conformances
Identify the risk control systems in place to prevent a major accident. Decide on the outcomes for each and **set a lagging indicator**	What risk control systems are in place? Describe the outcome Set a lagging indicator Follow up derivations from the outcome
Identify the critical elements of each risk control system (i.e. those actions or processes which must function correctly to deliver the outcomes) and **set leading indicators**	What are the most important parts of the risk control system? Set leading indicators Set tolerances Follow up derivations from tolerances
Establish the data collection and reporting system	Collect information – ensure information/unit of measurement is available or can be established Decide on presentation format
Review	Review performance of the process management system Review the scope of the indicators Review the tolerances

Adapted from table 1, p5 HSG 254.

RISK CONTROLS

Figure 1 shows the key risk controls identified in the development of the worked example. These were mapped onto the activities of a production site, namely: production of waste, transport of waste and disposal site, e.g. burning ground.

The risk controls required from the production facility, with respect to its contribution to disposal, were 'match production rate to disposal rate', the availability of 'sufficient containers', and correct labelling of materials. The necessity of matching production to waste production is essential to avoid the build-up and backlog of material. This can present risks by increasing the waste inventory, and good practice controls the size of the waste backlog.

Insufficient containers could cause problems in that using incorrect containers could lead to confusion, contaminants and potentially problems with escalated or retarded events. Similarly it is important that the material is correctly labelled, in terms of its composition and weight. Transport was not viewed as a significant contributor to the waste disposal risk, however the timely delivery of waste and return of containers to production is a risk control measure.

The majority of risk controls were linked to operation of the burning ground, and include:

- A culture of safety, such that all involved understand the risks and behave safely, as well as have expectations about the physical working conditions (e.g. housekeeping) and compliance with procedures;
- Systems for ensuring that the 'right people are doing the right things at the right time', including clearly defined roles and responsibilities, competent and trained operators, and up-to-date procedures;
- Equipment factors, including equipment performing as expected and adequate and appropriate physical separation, e.g. barriers and interlocks.

Following the definition of the risk controls, the various stages in the life cycle were again considered and the various indicators proposed following the process outlined in Table 1.

LAGGING INDICATORS

Figure 2 displays the lagging indicators that show 'when a desired safety outcome has failed, or has not been achieved'. The majority of these lagging indicators are linked to reported incidents/accidents during disposal activities; the exception is the indicator linked to a failure during an emergency exercise.

The ability to use these as more sophisticated performance measures relies on the extent of use of the reporting system and the quality of their investigation. For example if the investigation does not get to the root causes of the incident and uncover the systematic and cultural issues lying behind the active fault then the performance indicators will be unsophisticated and will probably identify human error as the main cause.

As can be seen there are very few lagging indicators compared to the number of risk control systems in place. This is a common finding, and is one of the reasons leading indicators were suggested (HSE, 2006) to provide assurance before incidents occur.

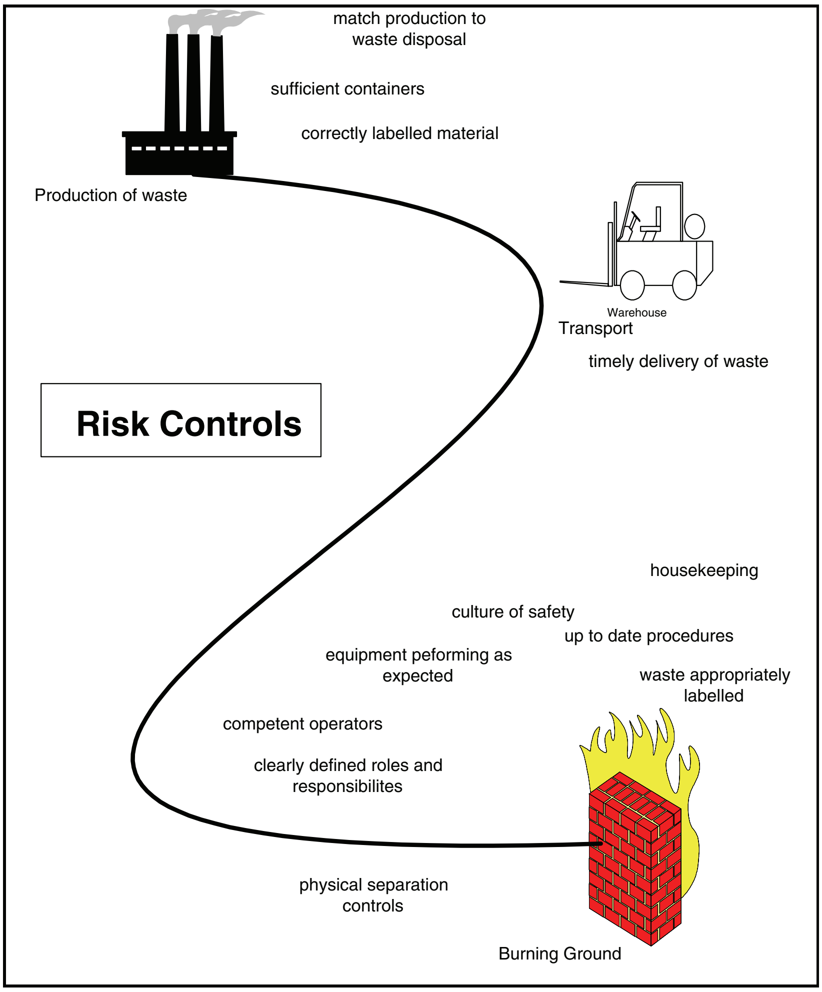

Figure 1. Explosives risk control systems

LEADING INDICATORS

Figure 3 was developed by considering all the risk control systems outlined in Figure 1 and using these as prompts to identify those indicators that would demonstrate whether a particular risk control system was working effectively. The leading indicators are a mix of generic safety management indicators, and more specific indicators referring to specific risk controls at the worksite.

The indicators were developed around the following headings:

- Staff competence;
- Operating procedures;
- Inspection and Maintenance;
- Management of change;
- Definition of safe work methods;
- Communication;
- Supervision;
- Matching disposal to waste generation rate;
- Safety culture;
- Emergency arrangements;
- Housekeeping.

NEXT STEPS

The worked example will be piloted across industry and evaluated by up to five parties, representative of the explosives industry. In consultation with HSL, the industry representatives will evaluate the usability and effectiveness of the worked example, with consideration and discussion of the information available/already collected, to ensure the worked example is appropriate for use within the industry.

The worked example would then be refined to reflect the discussions and feedback received. HSL's experiences in developing appropriate indicators will influence further guidance to the explosives industry regarding how companies can develop their own specific indicators. In particular companies will need guidance to help them identify the

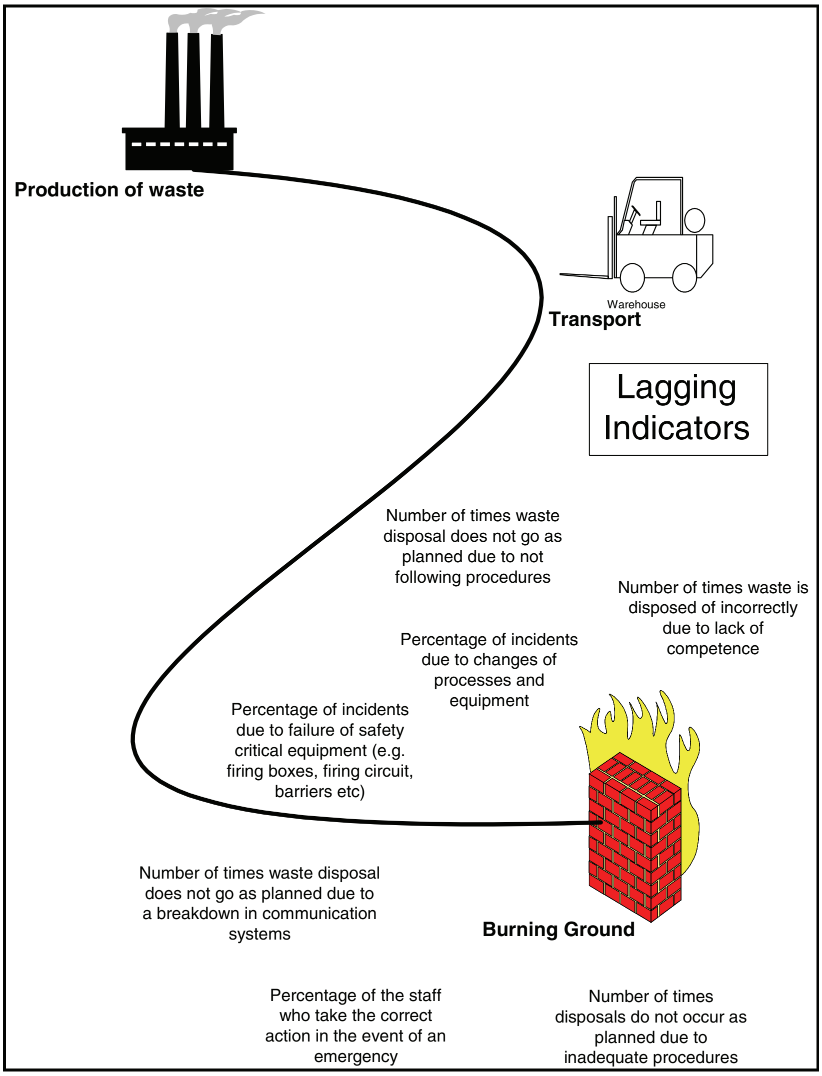

Figure 2. Lagging indicators

upper and lower limits of acceptability for their safety performance indicators, as well as determining indicators for other operational scenarios.

LESSONS LEARNED FROM INDUSTRY TRYING TO IMPLEMENT SPIS

Development of the worked example has highlighted a number of interesting challenges. A key area for consideration in the development of SPIs are operational procedures and employee attitudes, which are critical to safety due to the industry's reliance on procedural compliance as a mechanism of risk control.

Initial efforts by the explosives industry to develop SPIs identified the large number of potential indicators and the relevance of SPIs across multi-site organisations. There are also challenges associated with aggregating SPIs meaningfully, without losing the richness and detail of a specific site's performance.

In addition, the competency of operators is also considered a key risk control, however identifying appropriate SPIs to demonstrate staff competence proved complicated, and although considered essential, an appropriate indicator has not yet been identified.

HSL also observed a tendency for the explosives industry (unlike other industries) to favour leading indicators, reflecting the potential outcome of failure of a risk control during the disposal process. HSL found the process of identifying appropriate SPIs time consuming and complicated, and observed the potential to identify a number of SPIs which reflect similar underpinning information. Here the challenge is to review the information generated from the SPIs regularly, to ensure utilisation of an effective selection of SPIs.

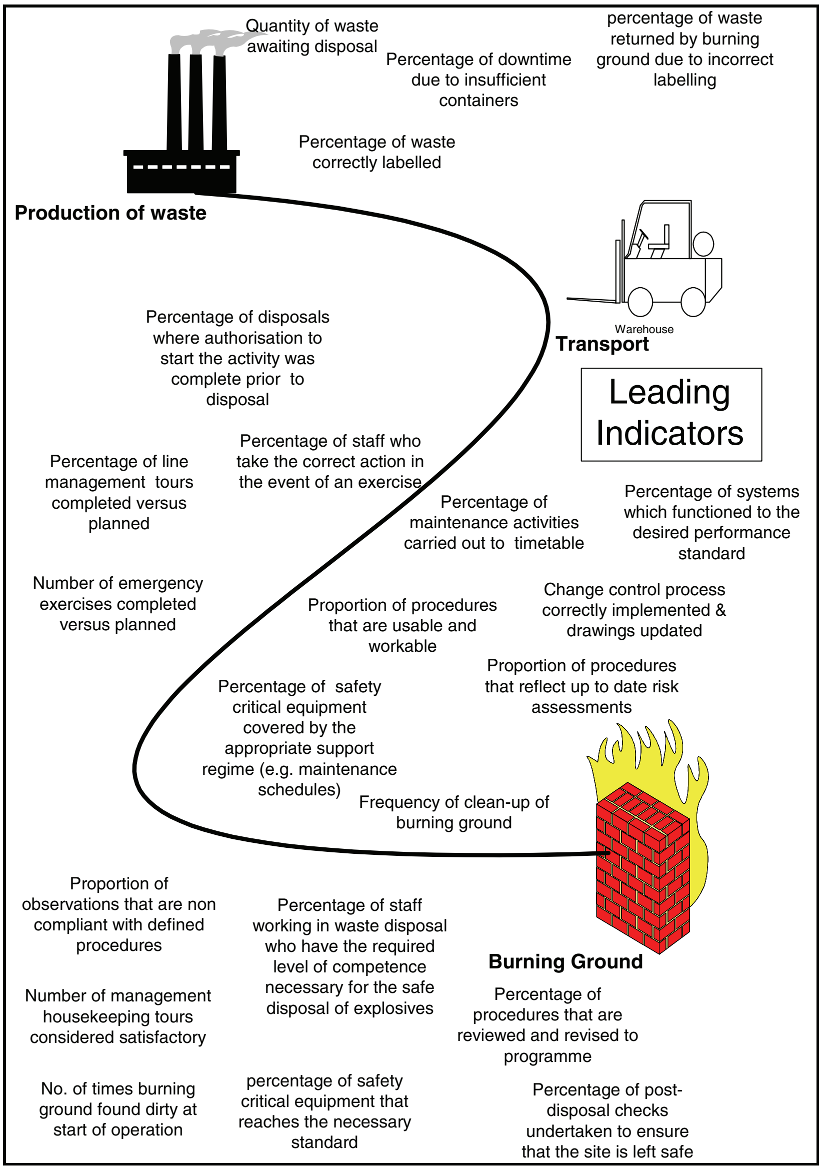

Figure 3. Leading indicators

CONCLUSIONS

Overall the utility of SPIs is widely recognised, and demonstrated through their use in a variety of industries. Despite only limited but growing use within the explosives industry, the potential value of utilising SPIs is becoming increasingly recognised.

HSL's development of a worked example has highlighted the need to consider some of the challenges when defining and developing a system of SPIs. However the worked example developed provides a useful tool for engaging the explosives industry in an evaluation of the suggested SPIs, encouraging industry to consider the potential utility and relevance of specific SPIs to their organisations.

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