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Safety management systems under Seveso II: Implementation and assessment

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Abstract

The 'Seveso II Directive' (96/82/EC) requires certain establishments holding hazardous substances to implement a Safety Management System (SMS). The first part of the paper discusses the origin of this requirement, the guidance drawn up to help companies fulfil it, and the results of preliminary testing of this guidance. One important element in implementing and inspecting SMS is the identification of SMS weaknesses, the safety culture that effects SMS and finally the evaluation of safety performance. The second part of this paper examines some principles underlying industrial practice in evaluating SMS. Audit-related activities, involving proactive performance indicators for monitoring compliance with standards, are used nowadays to identify weaknesses of the SMS. Preventive actions to control risks and policy updating within the company through strategic plans are found to be sensitive to the number and type of SMS elements taken into account as indicators. The value of quantifying performance using simple rating systems in audits may be limited to the single installation. The guidelines and evaluation methods could thus produce useful results only when safety aspects and system elements are identified and evaluated separately for each installation; the value of quantification is limited to the individual elements after considering their functional relation with the rest of the elements in the SMS environment and the local safety culture into which they are developed.

Keywords: Safety management systems; Safety performance; Audit

1. Structure of this paper

This paper draws from conference papers presented by the authors (Mitchison & Clementé, 1998; Papadakis & Loupasis, 1998).

Section 2 discusses the background of modern approaches to safety management, both from the point of view of companies and in the changing legislative requirements, in particular those embodied in the new 'Seveso II Directive' (96/82/EC). Section 3 discusses the guidance currently being drawn up to help companies fulfil the Directive's requirement to implement a Safety Management System (SMS) and the results of preliminary testing of this guidance carried out in several EU countries. In Section 4, a summary of some industrial approaches to performance indicators and safety performance measurement is presented, while Section 5 discusses the quantification of the results of a safety audit as a means of evaluating safety performance. Section 6 presents an example of such an approach, and discusses the results and the limitations and uncertainties involved. Finally, Section 7, contains an overall discussion and conclusions on the usefulness of generic guidance and the applicability of a simplified audit rating for the assessment of an establishment's SMS.

2. Introduction

Among the new provisions of the 'Seveso II' Directive (96/82/EC) (see another paper in this special issue: Wettig, J., Porter, S., Kirchsteiger, C. Major Industrial Accidents Regulation in the European Union), is one which requires operators of certain establishments holding substantial quantities of hazardous substances to put into effect a Safety Management System. A Safety Management System (SMS) is defined in the Directive as including 'the organisational structure, responsibilities, practices, procedures, processes and resources for

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determining and implementing the major-accident prevention policy', in other words the system for implementing safety management. The Directive recognises that the requirements laid down in the major-accident prevention policy should be proportionate to the major accident hazards presented by the establishment.

The simplest reason why an SMS is required under the new Directive is the large proportion of accidents reported in the European Commission's Major Accident Reporting System (MARS) since 1984 for which management failings are an underlying cause. While the exact figure depends on which causes are categorised as management failings, Rasmussen (1995) gives the proportion as 67% for the accidents notified to MARS up to 1993. This figure practically corresponds to the one for the accidents notified by the end of January 1998 (~66%; see another paper in this special issue: Kawka, N., Kirchsteiger, C. Technical Note on the Contribution of Sociotechnical Factors to Accidents Notified to MARS). A further inspiration for the emphasis on SMS has been the management approach developed in the area of quality management and assurance (Amendola, 1998). While this approach was initially adopted for projects which had large investment costs and very high reliability and safety targets, nowadays many services and projects request conformance with quality management standards.

It is more and more recognised that the management of safety plays an important part in achieving and maintaining a high level of safety, on top of a more technology-oriented approach in the past. Many of the larger chemical and petrochemical companies have adopted integrated health, safety and environment (HSE) management systems (Cacciabue et al., 1994), which are in some cases further integrated with total quality management (TQM). It is important, however, that an SMS intended to control major hazard be implemented in a way which is consistent with the larger management system within which it functions. Appropriate safety management starts with the safety policy: the overall safety intentions and direction of an organisation regarding safety, as formally expressed by senior management. Safety management is that aspect of the overall management function that determines and implements the safety policy. This will involve a whole range of activities, initiatives, programmes, etc., focused on technical, human and organisational aspects and referring to all the individual activities within the organisation. All this effort is associated with the concept of continuous improvement through 'control loops': planning, organising the work, implementing, evaluating, checking the outcome against the plan, and adjusting/taking corrective action. In order to assist managers with these tasks, SMS have been developed, thereby converting the management of safety into a formal system.

There are many companies in the European Union with a long tradition in SMS. Approaches of different companies and different establishments to safety management frequently vary substantially, because safety culture, history and company size differ from company to company and local culture from country to country. However, several studies have shown the importance of safety culture, which is the assembly of characteristics and attitudes in organisations and individuals that ensure that plant safety issues receive the attention warranted by their significance (Morici & Battistella, 1993).

The need to measure safety performance by the use of performance indicators—output measurements and indirect indicators—and thereby to evaluate the effectiveness of the SMS on-site is well established in the process industry. However, one of the characteristics of the area of process safety is that real accidents (as opposed to 'might-have-been' accidents, near misses and incidents) are rare but serious events. It is therefore insufficient to judge the success of the process safety part of a SMS by counting the number of major accidents; some more pro-active performance indicators are needed. Attempts have been made to identify key performance indicators or indicators of good safety culture (IAEA, 1991; CCPS Guidelines, 1994). Approaches based on pro-active indicators examine:

- weaknesses and malfunctioning of SMS;
- preventive actions which control the risks;
- the use of output measures to evaluate results and trends;
- accident causation factors;
- etc.

One means of applying performance assessment is through auditing. There are dangers in using an audit primarily to quantify the performance of an installation or a site: the quantified results are usually only comparable over time within the same unit. However, with that restriction, the results can indicate, with some degree of accuracy, the development of the system. The accuracy of those indications will strongly depend on how accurately the conditions of the SMS on site are depicted by the rating system in use.

3. Guidance on SMS: drafting and testing

Several national and international initiatives over the past few years have aimed at developing guidelines for SMS in various domains, e.g. OSHA (1992); BSI (1994); Cacciabue et al. (1994); E&P Forum (1994); IMI (1994); ISO (1995). Although the terms used may be different, these different guidelines often have many similarities in substance (Mitchison & Papadakis, 1996). After an initial workshop for national authorities on the subject of SMS (Cacciabue et al., 1994), the European Commission, in conjunction with the national authorities concerned, decided, particularly in the light of requests for help in this area from small and medium-sized enterprises (SMEs) and bodies representing them, to set up a technical working group (TWG) to develop guidelines to help operators and authorities interpret the requirements of the 'Seveso II Directive'.

Initial input to the TWG's work came from the conclusions of an earlier seminar on the subject (De Cort in Cacciabue et al. (1994)), and the work of the ACRONYM project (van Steen et al., 1994). After a series of meetings, a proposed guidance document was drawn up (Mitchison & Porter, 1998), which has just been finalised and is due to be published during summer 1998. The overall aim of the TWG was to identify and describe the current 'best practice' and to ensure that the resultant guidance was appropriate to a very wide range of situations and industries involving hazardous chemicals.

One unusual aspect of the preparation of the guidance was a series of tests carried out of the draft guidance over 1997. The ultimate test of the 'operationality' of the draft would of course have been to use it to build a SMS from scratch in several companies, and evaluate the results; but for several reasons, including the time and resources available, that was not possible. More limited tests were therefore carried out, with feedback on the guidance provided from authorities and industry in France, Austria and Finland. The test procedures were somewhat different in the three countries.

In the case of Austria, the guidance was sent to various companies, along with a questionnaire covering other aspects of SMS. Replies were received from seven companies, with a wide range of sizes of establishments (from 80 to 3000 employees on site). The main conclusions concerning the draft document were:

- there was a satisfactory coherence between the requirements for SMS systems and those involving quality management and the voluntary EMAS scheme, in which three of the companies took part;
- the guidance, being descriptive rather than prescriptive, was in places difficult to understand;
- there were certain specific gaps, including a failure to offer a complete feed-back structure for the whole SMS.

Points to be noted about the Austrian situation are that there is at present no requirement on companies to implement a SMS, nor is there much experience with SMS development tools. There are however numerous norms, standards, and ordinances governing different aspects of the prevention of accidents.

In Finland the guidance document was tested with a total of four establishments, ranging in size from 15 to 130 employees. Apart from specific points concerning particular items of the guidance, the overall points made were:

- it was not clear whether the objective of the guidance was to help operators to create or improve their SMS, or to help them define and describe their existing system to the Authorities;
- there was a need for more practical examples;
- the document was not fully consistent, going into more detail in some areas than in others.

The French initiative involved integrating the draft guidance into a more general document presenting key issues to be addressed by the operator, as well as the elements required for compliance with the recommendations in each section of the guidance. The resultant document was tested in co-operation with 12 companies, all with substantial experience in SMS. The establishments concerned varied widely in size (from 14 to 1800 employees) and in their activities, including refineries, gas storage and distribution depots, integrated chemical plant, and agrochemical distribution stores. The test required the inspectorate to study documentation provided by the operator on his SMS, and then to carry out a 1-day inspection of the safety management.

Several conclusions were drawn, some concerning the guidance document and some more general concerning SMS inspection:

- a very company-specific SMS can be very difficult to assess;
- the safety culture of the operator can make a great deal of difference to the inspector's task, making it more or less easy;
- the agrochemical distribution industry appears to have a particular need to concentrate on this area in order to fulfil the Directive's requirements;
- it is very important to confirm by interview what is stated in company documents;
- overall the guidance document was felt to be useful, despite criticisms of some parts of the 'organisation and personnel' section, felt to be too general.

It is worth noting that even this pilot experiment led some of the operators to identify areas of their safety management that could be improved.

The conclusion is that the proposed guidance is useful and meets a real need. Even with some further amendments agreed as a result of the testing, the document remains open to the criticism of not being sufficiently detailed, but it was felt that this is intrinsic to any document of its type, which attempts to cover the requirements of a wide variety of industries and activities: indeed there was a danger that introducing further detail could be misleading, as there would inevitably be some cases where the more detailed descriptions and suggestions would be inappropriate. There also remains a question of terminology. It was clear that some terms used had different meanings for different participants, and that even careful definition in the text of the guidance had only limited effect on the reader's initial assumptions.

4. Safety performance measurement: industrial practice

There remain major outstanding questions concerning safety performance and safety culture. Among them are:

- how should safety performance be evaluated? (van Steen, 1996; Ministerie van Tewerkstelling en Arbeid, 1997)
- is it possible to define 'safety culture' and what its effects on SMS effectiveness and performance are? (Papadakis et al., 1997)
- how best can the weaknesses of particular SMS be identified and addressed? (an interesting development here is the AVRIM2 approach (Bellamy et al., 1995; Bellamy & Brouwer, 1998)).

Safety performance is a measure of the completeness and adequacy of the SMS operating on-site. The system can fully operate only when a number of control loops integrate effectively all relevant system elements at all levels of operation. Such control loops will include some fundamental elements such as: policy setting and standards drawn by regulations and norms; implementation procedures and training; operator and equipment reliability; and monitoring, control and revision.

The performance indicators—output measurements and indirect indicators—needed to evaluate the effectiveness of the SMS on-site have come under discussion recently (van Steen, 1996). Reactive indicators such as fatal accident rate (FAR), lost time injury (LTI) rate and other output indicators have been used extensively in assessing process safety. Other indicators such as loss of containment rates (LOC) and positive indicators such as fraction of positive observations to the total number of observations are considered in some approaches (Bellamy et al., 1995; Bjerke, 1996).

Companies make use of a wide variety of indicators, subject to the availability of the relevant measurements and the quality of their results, in order to check the implementation of the SMS and identify strengths and weaknesses. Results are normally observed and compared with management goals. When information provided by the results of the several indicators and measurements is poor, it is common practice to conduct safety audits. It is interesting to note the different approaches in measuring safety performance in EU countries. Some characteristics of the various approaches in van Steen (1996) are summarised in Table 1, in which only a particular category of monitoring activities within the company's current practice in a specific area of safety management input is highlighted. Audit-related activities using appropriate tools appear to be the necessary procedure in most of the approaches for monitoring compliance with management, technical regulatory and statutory standards in specific safety areas.

5. Audit systems and rating

An audit of an SMS, as for any other management system, normally verifies the existence and implementation of objectives, standards and procedures. The results of such an audit are used to validate the efficiency, effectiveness and reliability of the SMS. While the individual SMS elements can normally be identified and evaluated, the interlinking of the procedures, rules and other management tools to form a functioning SMS is still under research (see Burgbacher in van Steen (1996)).

The assessment and measurement of the performance of an SMS can be carried out as part of an audit system. Such an assessment will aim to produce a 'snapshot' of the functioning of the SMS. The performance measurement should be treated with some care, both because of the extent of expert judgement required and because there are major difficulties in comparing one establishment and one set of procedures with another; however a sequence over time of such assessments can be of value both in confirming progress (or the lack thereof) and in identifying weaknesses and targeting intervention. Audit systems often include the rating of a certain number of SMS items and elements identified according to a standard programme. For this purpose the evaluation of independent variables representing those items and elements are related to relevant 'award' criteria and score scales. This is a simple and natural way to approach the quantification of performance. It is industrial practice to tailor available rating systems to encompass best company and site safety policies, management standards and practice based on operating experience. To this end, appropriate mathematical expressions (correlations) representing the involvement of all individual SMS elements may be used to deduce overall safety performance. Variables of several different types may be included in such a correlation, representing both the existence of provisions and procedures relevant to safety and the extent of their implementation as identified by the rating system in use. Often the variables used are grouped under such titles as leadership and administration, planned inspections, accident investigation, organisational rules, management and employee training etc. (International Safety Rating System, 1978).

When a number (n) of programmes are available in a rating system, a simple linear expression has been widely used in practice for the overall performance:

$$E_p = A_p \sum_{j=1}^{\mu} \sum_{i=1}^{\nu} \omega_{i,j} x_{i,j}$$

where p is the programme of the rating system ($p = 1,\ldots,n$); A_p the maximum score of the programme; x_{ij} the evaluation score of the ith item of the jth element at the

Table 1
Safety performance measurement approaches (Loupasis, 1997)

Company	Brief description
BASF	Behaviour is observed on the shop floor. After identifying and defining critical behaviour observers have been trained to recognise and measure the occurrence of the behaviours in the working place. A system of ongoing observations and feedback is established. The data gathered is used to identify corrective actions and plans for continuous improvement.
Bayer	The operator carries out a constant inspection of the plants and their components, independent experts are responsible for the initial and periodical inspection at set intervals and state authorities inspect initially as well as on unannounced occasions.
BP	The framework delivered a means of auditing, a tool to help managers set HSE plans and targets and a mechanism to facilitate sharing and comparing between business units. The framework (REALM) has two parts: a management systems component essentially common across all elements of HSE and, a technical/physical conditions framework subdivided according to the HSE disciplines (on the principles of ISRS).
Borealis	The minimum HSE requirements have been produced and the site performance is assessed using audits. The production sites are scheduled to be audited every 3 years. Separate HSE audits are carried out at the major production sites while combined audits are carried out at the minor sites.
Dow	The company is committed to responsible care and has developed a system of self audit against a range of environmental, health and safety standards and objectives to support it. The system covers 13 areas and each of these areas is given substance and complete descriptions which allow the people operating safety management system to see exactly where they are on a 1–6 scale.
Du Pont	Four steps to effective process safety management have been identified: establishing a safety culture, providing management leadership and commitment, implementing a comprehensive process safety measurement programme and achieving operating excellence. Safety performance measurements include both lagging and leading indicators.
Exxon	Annual self assessment of the system by reviewing system design, implementation status and effectiveness. The leader of the self assessment is a member of the site or unit management. The external assessment is carried out once every 3 years by an experienced multi-disciplinary team led by a senior manager. The entire team is external to the operations.
Hoechst	The idea is to incorporate as many different audit aspects as possible. A system with 18 modules was set up. The integrated aspect of the audit is achieved by the co-ordinated flow of information between the different modules.
ICI	Frequent audits check the activity against local procedures. Periodical audits check the adequacy of local procedures against standards, guidelines and good practice. An overall management audit every 1 to 3 years checks that the system covers all requirements and leads to improvements.
Shell	The Tripod incident analysis methodology distinguishes three 'feet' in incident causation: the incident itself, active failures and latent failures. The approach can be used reactively in incident analysis and proactively as a diagnostic tool for accident prevention.

time of assessment; ω_{ij}, the weighting factor (coefficient) of the item (i,j); ν the number of items in the element; and μ the number of elements considered in the programme.

The usual practice is to use constant coefficients ω_{ij}, defined according to the relative importance of the item in the overall evaluation. Therefore, the relative impact the individual item or the element has in the overall performance cannot surpass a predetermined upper limit. Although this approach ignores any interdependency between the variables (which could be captured, for example, by the introduction of higher-order terms in the linear relation defined above), it can be defended as a reasonable effort to produce a manageable formula without the need for a complex evaluation of the dependencies among the elements of the SMS—an operation which, even were it always possible to carry out in an objective manner, could prejudge exactly the questions which a safety performance measurement is intended to answer.

In such a rating system several programmes can be considered. For some sites, only a few programmes are relevant; the items and elements of those programmes can have coefficients (weighting factors) with different values because further elements and items are considered. The more advanced programmes include more items and elements. Fig. 1 presents the ratio of the individual elements to the overall maximum score of the programme for all elements of the 10 programmes (P1–P10; the higher numbers correspond to more 'advanced' programmes) considered in an early version of the International Safety Rating System (1978). It will be seen that the coefficients assumed for certain elements vary widely among programmes.

There does appear to be a difficulty with using a large number of elements and items (van Steen et al., 1994; Loupasis & Papadakis, 1997). On the one hand, it is difficult to justify substantial differences in the weightings attached to different items, when in some sense it is clear that all the items concerned make an important contribution to safety; on the other hand the importance of items clearly does differ from one to another, and assigning similar weights to them obscures this fact, and builds a distortion into the resultant rating system. In practice, it would appear that systems with a large number of elements end up assigning similar weightings to them (as exemplified by P8, P9 and P10 in Fig. 1): thus, for example, we can find the items 'planned inspections', 'protective equipment', and 'employee training' with similar weightings, despite their different impact on overall performance.

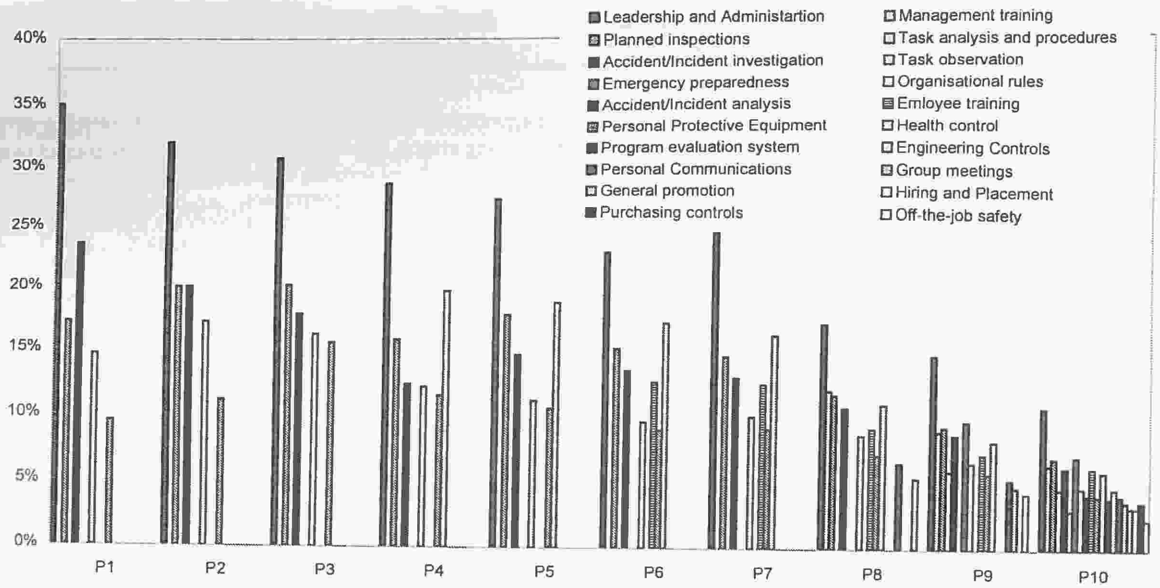

Fig. 1. Maximum weight of SMS elements vs. programmes of the rating system.

6. Application and validity check of a rating system

In order to study further the role of expert judgement in the selection and weighting of SMS elements and rating programmes, a rating system similar to the one discussed above was applied to a company which produces and stores a range of flammable substances. The major-accident prevention policy of the company has been implemented in all its sites using the same SMS. The SMS is periodically assessed and the safety performance evaluated using several performance indicators and a rating system. For each specific activity of the company, a rating programme is chosen, and tailored to meet the safety requirements associated with that activity. The selection of programmes and of individual elements within the programmes for the evaluation of SMS of the company is based on criteria developed from experience with operations and on independent expert judgement.

One such programme ('footprint') has been selected for this paper, as appropriate to the level of complexity of the operations concerned. In Fig. 2, the four elements of the footprint with the largest weights are compared with the relevant elements of the 10 programmes (P1–P10) available in the rating system. It can be seen that the footprint programme is among the most advanced in the rating system, similar to P9 and P10. It is also clear that these elements of the footprint do not differ much in their weightings (each contributes 5–10% of the maximum overall performance). Similar conclusions can be drawn from the examination of the variance of the weights of the elements within each programme (Fig. 3). None of the measures of deviation of element weights in the footprint exceeds 3%, whereas the less advanced

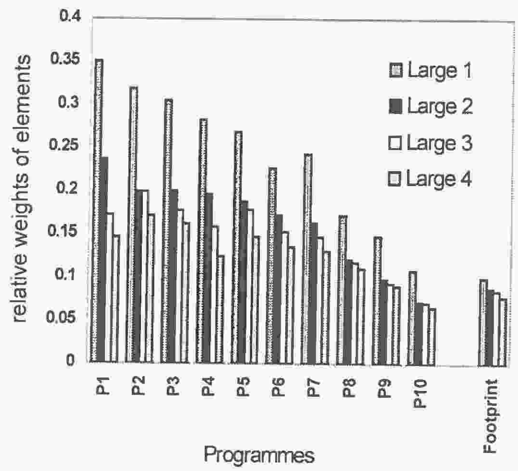

Fig. 2. Weights of the four largest elements.

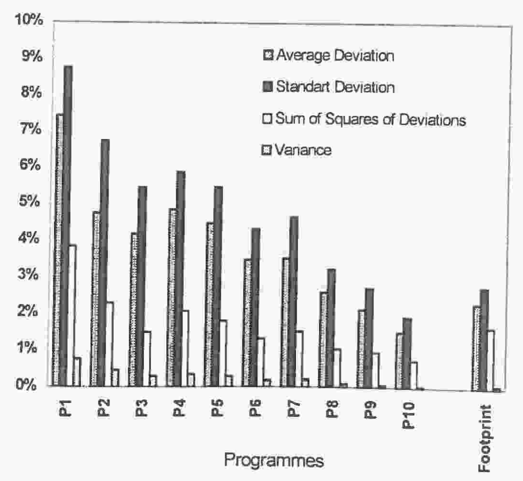

Fig. 3. Deviations of element weights.

programmes of the rating system show significantly higher deviations.

In order to examine further some functional characteristics of a rating system and to delineate uncertainties connected with its application, a simplified linear model was studied. It is postulated that all (μ) elements identified in the SMS under examination could be analysed into a number of items which are represented by appropriate variables in the rating system. The items thus identified can be evaluated and the quantified results can contribute to the overall performance according to the relative weighting of each item. The score for each item is a percentage of its maximum score controlled by its relative weighting. It is assumed that the same scores can be obtained when we reduce each item into a number of units that take values either zero or one and have equivalent weighting (ω_{ij}) in the overall performance. The number of such units in every item is thus equal to the maximum score of the item. The scores can then be obtained by summing up the number of the units with non zero values. The total number of units in such a model, for a specific programme, is assumed to be $\sum_{j=1}^{\mu} \nu_j$ and the weighting of each unit is the inverse of that. Such units are represented by variables (x_{ij}) that can take values either zero or one:

$$x = \begin{cases} 0 & \text{when the unit corresponds to the part of the item evaluated negatively} \\ 1 & \text{when the unit corresponds to the part of the item evaluated positively} \end{cases}$$

The number of elements (μ) in each programme and the number of units (ν) in each element are assumed to be linear functions of the programme (p), and are by default positive integers:

$$\mu_p = \mu_0 + p^*\Delta\mu_p$$

$$\nu_{p,j} = \nu_{0,j} + p^*\Delta\nu_{p,j}$$

The initial conditions μ_0 and ν_0 can arbitrarily take any non-negative values. The slopes $\Delta\mu_p$ and $\Delta\nu_p$ are positive integers and represent the number of extra elements ($\mu_{p+1} - \mu_p$) and units ($\nu_{p+1} - \nu_p$), respectively, added when passing from one programme (p) to a more advanced one ($p + k$), where (k) is a positive integer. A programme is considered to be advanced for a specific installation when the elements and items considered consist of an extensive inventory of safety related aspects.

The analytical solution for the relative weighting using the expressions above showed strong dependence of the weightings on the number of elements (μ) and on the number of items added to an element when passing from one programme to a more advanced one. The weighting of an element is reduced when passing from one programme to a more advanced one. A measure of such a reduction is given by $\nu_p/\nu_{p+k} - 1$.

In the case of $\nu_0 = 0$ and $\Delta\nu_p$ = const., the above formula for a given element is reduced to $\frac{-k}{p+k}$, where k can take values in the range (1,...,$p - 1$).

The minimum and maximum of the above expression will give an indication of the possible reduction of the element weighting when moving to more advanced programmes; for 10 successive programmes ($p = 1,\ldots,10$) these are − 10% and − 50%, respectively. For non-zero values of ν_0, the weights were found to reduce more than 20%. For programmes with large differences (i.e. $\mu_{p+k} \gg \mu_p$), taken from implemented rating systems, the impact of an item on the overall performance varies substantially. For example the element 'leadership and administration' of the International Safety Rating System can lose 50% of its weight when a programme with a large number of elements is considered instead of a less advanced one (Fig. 4). It is thus arguable that advanced programmes should assume satisfactory values for high-importance items as a prerequisite for their application, rather than attempting to take them into account explicitly within the evaluation process.

Often, the results of such evaluations are used to draw up strategic plans for the improvement of the SMS. In general, it is expected that comparable scores will be obtained when evaluations are performed by different groups of auditors using several programmes. Therefore, the scores obtained for each element as compared with the maximum scores of the selected programme should be independent of the programme itself. Using a simplified model like the one above, it can be argued that uncertainties in the process of quantification introduced by the modelling parameters could distort the strategic plans of the company and the perception which the company has of the improvements achieved in safety performance. It was found that a strategic plan can be assumed to be independent of the rating programme when the following condition is satisfied for each element and for the whole period of audit planning and execution:

$$\frac{\partial \sum_{i=1}^{\nu_{p+1}} x_{ij}\big|_{p+k}}{\partial \sum_{i=1}^{\nu_p} x_{ij}\big|_p} = \frac{A_j\big|_{p+k}}{A_j\big|_p}, \text{ for } j = 1,\ldots,\mu_p$$

This expression links the evaluations of the items (or units) with the maximum scores of element (A_j) addressed in two programmes (programme p and $p + k$) defined by the rating system. An example of this expression applied to a single element namely 'the leadership and administration' is presented in Fig. 4.

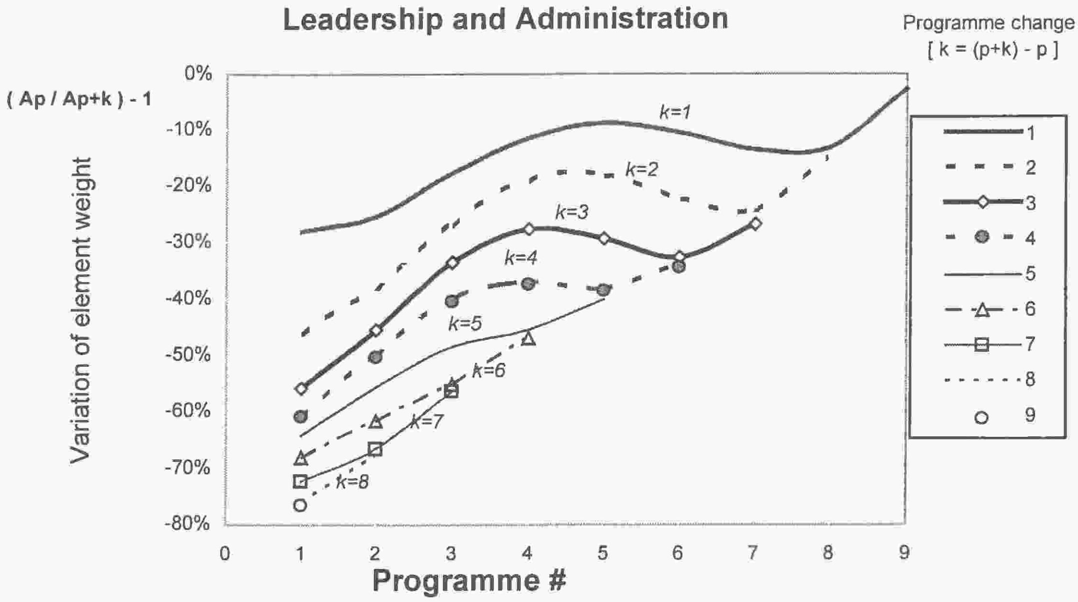

Fig. 4. Devaluation of element weight with different programmes.

The maximum scores of the element in the 10 programmes examined have been correlated with a polynomial. It appears that the evaluation of the items is sensitive to the weights assumed by the selected programme of the rating system. Since this effect may be strong in some cases it should always be taken into consideration by applying sensitivity analysis.

7. Discussion and conclusions

Most SMS guidance is intended to allow flexibility in the structure and details of a SMS, and the guidelines discussed here (Mitchison & Porter, 1998) are no exception. This flexibility is needed to allow adaptation to the company's practices, to local circumstances, and to the structure of other company management systems. The price paid, however, is that the guidance is not straightforward to apply. In particular, questions of overall priorities in safety management are not addressed by the guidance; they fall to be decided by the company itself, perhaps in discussion with the regulatory authorities.

Once these overall priorities have been decided, they can be used to establish performance measures and rating programmes. Such an operation is iterative, and should build on company and site experience. The correlation between different indicators, and therefore their value as performance measures, is a subject of some argument: e.g. what is the correlation between the rates of lost time injuries (LTI) and of loss of containment (LOC) accidents? (Bellamy et al., 1995). Often LOC rates are too low to be usable in such a correlation. It is also true that the trends of LTI rates do not usually represent the occasional sharp increase of the annual rates of serious accidents in a company (HYDRO Safety Report, 1997). It therefore seems reasonable to try and take as wide a base as possible in the establishment of performance measures. In particular this avoids the danger of ignoring a major part of the overall management system, a possibility with dedicated methods (Hurst et al., 1996).

If a safety audit is used to implement a safety performance rating system, caution is called for, both because the results will not in general be comparable across different establishments, and because the desire to perform well in the rating may prevail over the real objective, which is to improve overall safety. However, having made those cautionary remarks, it remains that the results over time of a series of audit-based ratings of the same site can be of use—provided the rating system is well adapted to the particular site conditions.

We have shown that the results of performance measurement can vary quite substantially according to the rating system and weighting factors used. Given the variability of companies, installations, and activities, it is difficult to see how a standardised rating system could be developed across one industry, let alone across all the industries handling hazardous substances. In particular, we remain sceptical as to the usefulness of rating systems based on simple and uniform formulae, adding up scores to give an overall value—although as we suggest above, such a system can be used in an incremental process to evaluate changes. On the other hand, other work (Papadakis et al., 1997) has shown that despite the considerable arithmetical variability which results from changing the element weights in a rating system, when an analysis looks at safety performance as a multi-dimensional variable, certain fundamental facts about safety culture and organisation remain salient. Still, some sort of sensitivity analysis should underlie the choice of weighting factors and programmes. Moreover, the analysis which goes into these choices can be of great value in its own right, as a means of focusing the attention of analysts and managers on the strengths and weaknesses of the company.

The other point to emphasise is that safety performance measurement should be seen as a means to an end. It is of use to know how you are doing; but it is even more useful to be able to improve your performance. To this end, monitoring the dependence of the performance of the various system elements against a wide variety of parameters enables the performance measurement system also to be used to identify weaknesses, and thereby to target interventions to improve safety.

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