Towards a new tool for measuring Safety Management Systems performance

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Abstract. This paper deals with the assessment of Safety Management Systems performance and presents a new tool developed for that purpose. It recognizes two dimensions in a SMS: a structural facet corresponding to the formal description of the system and an operational one focused on the system's influence on the working environment and practices of people. Building up the operational performance of a SMS actually strengthens the overall resilience of the organization. Authors of the paper believes that the operational performance of SMS can be measured using Tripod Delta. This method is actually designed to detect weak areas in the environment in which people are working and the level of control that the organization has on it. The method and its interesting model of organizational resilience are presented in the paper. In the framework of this paper, Tripod is used as an input to measure the SMS operational performance. Both of the tools designed to measure the structural and operational performances of Safety Management Systems are then described.

1 PERFORMANCE OF SAFETY MANAGEMENT SYSTEMS

Many companies are implementing a Safety Management System in order to manage health and safety in the workplace in a more coherent and more effective way. This "emerging" mode of managing safety mainly comes from the growing need for a global and structured approach of risk management. Despite the several benefits of its implementation, experience show that companies sometimes fail to implement an effective SMS. As shown by Favaro (Favaro, 2005) and Drais (Drais, 2005), if special care is not taken when SMS is designed and formalized, the system can end up being quite superficial, disconnected from real work situations, be poorly dynamic and can also introduce additional constraints for workers or rigidity in the way the safety is managed in the company. In other words, the system is more likely to go against workers if the inherent prescriptive and normative tendencies of the SMS are not well managed when the system is designed and implemented.

Avoiding such shortcomings in the system inevitably includes the acknowledgement of two dimensions in the Safety Management System: a 'structural' dimension and an 'operational' dimension.

1.1 The 'structural' and 'operational' dimensions of a SMS

The 'structural' facet of the SMS can be defined as the formal description of all the efforts that are made by the company into managing health and safety at the workplace. These efforts can be categorized into several Safety Management Processes (i.e. sec-

tions or chapters in safety management standards) such as the definition of an Occupational Health and Safety (OH&S) policy, an OH&S program, implementation of a communication or documentation system, hazard identification, etc. Each of these Safety Management Processes (SMPs) implies policies, rules, procedures, guidelines, working instructions, techniques or methods, etc. that the company has internally established to manage safety. These rules, procedures, techniques, etc. are the formal answers to the good practices (and legal requirements) emanating from safety management standards, from the company standards, from the branch specifications, etc. This prescribed system gives an image of how the safety management system works on "paper".

However, things can be perfectly organized on paper, but can not work in "real life". It seems then necessary to analyze how things are done in addition to how things are formalized. This aspect refers to the 'operational' facet of Safety Management Systems. Alongside their formal description, the efforts made by the company in the safety management need to be implemented and integrated throughout the company until the 'sharp end'. The way these efforts or actions are integrated within the practices of the company and its members is of concern here. This time, the scope of analysis concerns the influence of the efforts that the company has put into managing safety of peoples' activities at the workplace. It is considered that a SMS is actually 'operationally' working if the different SMPs are integrated within the practices and if they positively influence the working conditions of people. The operational facet of a SMS is of course the most important one in terms of safety. One can agree that safety practices shared by everybody in the company, well integrated within the practices and influencing positively the working environment have a higher impact on the overall safety state of a company than a well-formalized, well-structured or well-described management system.

With respect to these two dimensions, the global performance of a Safety Management System can be assessed according to its structural and an operational performance (Figure 1). Structural performance can be defined as the level of compliance of the internal processes (SMPs) as established by the company (under the forms of procedures, instructions, policies, techniques, tools, etc.) with the existing safety management standards. This performance, generally aimed at the accreditation of the SMS put into place by the company, is measured with structural indicators (e.g. has the company established a procedure regarding its training program? is the procedure updated? validated?). Operational performance can be described as the level of integration and of influence of these formal processes on the practices and the working environment of people. Examples of operational performance indicators could be: Do the personnel feel that they are correctly trained? Are trainings adapted to the level or the job of people? Are the personnel able to put in practice the theoretical courses? Are there sufficiently trained and qualified people in each team? Etc.

Operational performance is then more focused on what the management system does rather than on what it has (this matter is tackled in the structural performance) and is clearly considered as the intrinsic value of a safety management system. Building up the operational performance of a management system strengthens the overall resilience of the organization.

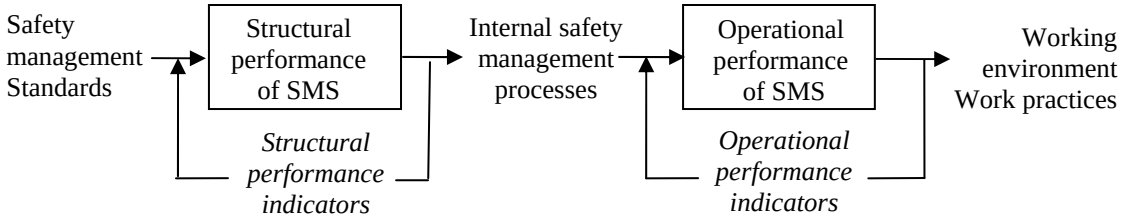

Fig.1. Global performance of safety management systems

1.2 Main approaches currently available for measuring SMS performance and the proposed approach to measure SMS performance

Three main approaches are currently available to measure performance of safety management systems: (i) the results-based approach, (ii) the compliance-based approach and (iii) the process-based approach.

The results-based approach consists of looking at safety results obtained by the company over the past years to assess if the safety management system put into place is effective or not (accident frequency rate, injuries, incidents, near-misses, occupational diseases, etc). This approach is widely used because it is easy to implement, not too time- or cost-consuming for managers and finally because it is requested by regulation. However, it does not assess the operational nor structural aspects of the SMS whatsoever. Discussing the many other issues involved in such a safety approach falls outside the scope of this paper but examples of such limits can be found in Booth (Booth, 1993), O'Brien (O'Brien, 2000), Roy *et al*. (Roy *et al.*, 2004); Stricoff, (Stricoff, 2000), Shaw & Blewett, (Shaw & Blewett, 1995).

The compliance-based approach is the classical way of measuring effectiveness of SMS put into place. It consists in auditing the degree of compliance of the SMS with the existing safety management standards (e.g. OHSAS 18001, ILO-OSH 2001, etc). This approach is often appealing for many managers as it can easily give a "facade" of performance as well as a "recognized" performance (e.g. OHSAS accreditation). However SMS audits focus on the "structural" side of SMS, on the formal description of all the efforts that the company has put into managing safety. Despite some visits and inspections in the different work areas, the SMS audits do not fully address the way the system influences the working environment of people and the organizational conditions of work.

The process-based approach measures the performance of each management processes (SMP) that constitutes the SMS independently (policy, communication, safety program, hazard identification, legal requirements, etc) and gives the overall level of organization's effectiveness in safety management (e.g. International Safety Rating System (ISRS)). Through interviews with management or operational staff from the company, this approach intends to assess if the safety management system put into place is actually resilient, if this system is embraced within the organizational practices. The priority of the process-based approach is the "operational" performance of the SMS while documentary compliance as required by standards is put aside.

This short review emphasizes the fact that the current approaches seem quite limited to measure both the structural and operational performance of SMS in a combined way. With regard to the limits of the current approaches, a double approach is proposed to assess the global performance of safety management systems. The prescribed system (i.e. the structural performance) is proposed to be measured according to a documentary review of the system as it is carried out in the traditional compliance-based approach via safety management audits.

Measuring the operational performance of management systems is a bit more problematic and constitutes the central idea of this paper. Authors of this paper believe that this aspect of the SMS performance can be measured using the organizational factors engineering.

Indeed, many works and models have been developed over the past decades and have helped to enrich our capacity to analyse the influence of organization on the safety in the workplace. These models have led to the formalisation of several methods aimed at assessing organizational weaknesses of sociotechnical systems. In the context of assessing the gaps in between SMS rules and their operational implementation, it seems more than relevant to refer to these methods.

2 TRIPOD AS A META-INSTRUMENT TO ASSESS OPERATIONAL PERFORMANCE OF SMS

In order to choose the most relevant method for measuring the operational performance of SMS, different tools identified in the literature were compared with each other. A set of 21 methods dealing with organisational factors was initially identified. The next - and more challenging - step was to assess the relevance of each method with regard to measuring operational performance of SMS.

The comparison of each method was made using different criteria such as the accuracy and coverage of the model, the model of resilience proposed, the coverage of the tool with regard to the different processes in SMS, the level of expertise required, the ability of the method to take into account the specificities of the plant, the time or cost-consuming requirements, the validation of the method, etc. From this review and taking into account the different criteria chosen, Tripod Delta has emerged as being the most appropriate method for measuring operational performance (Cambon *et al.*, 2006).

2.1 Tripod theory

The Tripod theory and methodology was developed at Leiden and Manchester Universities. It originated from a research program investigating ways of preventing human error initiated by the Dutch Royal/Shell Group in 1986. The project resulted in an instrument that is now widely applied (Groeneweg, 1998).

Tripod is based upon the principle that the most effective way to prevent human error is to control the working environment. It aims at analyzing and controlling the environ-

mental conditions, the 'latent failures' (Reason, 1990) that cause human error. Latent, because they are present a long time before a specific substandard act or an accident occurs and remain hidden without a specific local trigger. According to the Tripod philosophy, these latent failures can be categorized in a limited number of ways, the Basic Risk Factors (Table 1). The BRFs are the result of brainstorming, audit report studies, accident scenario inquiries and have shown through extensive field studies to be valid for all industrial applications (Groeneweg, 2002).

All of these BRFs can contribute to accidents in subtle ways, by allowing the development of undesirable combinations of situations and acts together (psychological precursors leading to one (or more) substandard act(s) and operational disturbance in the working environment), by increasing the chance that 'sharp end' individuals will commit substandard acts and by failing to provide the means to protect from accidents already in progress. Ten of these BRFs influence the process leading to the operational disturbances ('Prevention' BRFs) and one BRF is aimed at controlling the consequences once the operational disturbance has occurred (The BRF 'Defences'). This BRF is related to all the protective barriers put in place in the system. A more complete description of the propagation of the BRFs influences through the organizational system is given in Groeneweg (Groeneweg, 2002).

Table 1. The eleven Basic Risk Factors in Tripod theory

10 Prevention BRFs
- *Design (DE)*: ergonomically poor design of tools or equipment
- *Hardware (HW):* poor quality, condition, suitability or availability of materials, tools and equipments
- *Maintenance (MM)*: no or inadequate performance of maintenance tasks and repairs, bad planning
- *Housekeeping (HK*): no or insufficient attention given to keeping the work floor clean and tidied up
- *Error Enforcing Conditions (EC)*: unsuitable physical conditions (cold, heat, noise, darkness, etc) or personal factors (motivation, boredom, stress, complacency, etc) influencing human functioning
- *Procedures (PR)*: insufficient quality or availability of procedures, manuals and written instructions
- *Training (TR)*: inadequate planning, ineffectiveness of trainings, insufficient competence or experience of personnel
- *Communication (CO)*: ineffective communication between sites, departments, individuals
- *Incompatible Goals (IG)*: unsuitable situations in which people must choose between optimal working methods on one hand and the pursuit of production, financial, social or individual goals on the other one
- *Organization (OR)*: shortcomings in the organizational structure, organization's philosophy, management strategies
1 Mitigation BRF
- *Defences (DF)*: insufficient protection of people, material and environment against the consequences of operational disturbance

2.2 The concept of organizational resilience in Tripod theory

In Tripod theory, safety is defined as an equilibrium between substandard acts and compensating factors so that unwanted operational disturbances cannot occur. The metaphore of a marble on a rough plateau illustrates this equilibrium (Figure 2). When the marble stays on the plateau the situation is safe: this situation happens when there is no operational disturbance. If the marble starts to move and gets pushed either way over the edge of the plateau, an event will happen (an accident or an incident). The chance of

having an incident is much higher than having an accident, but is not part of the present discussion.

This model, first introduced by Kletz (Kletz, 1989) and further developed by Groeneweg (Groeneweg, 2002) has a few axioms, such as (i) it is impossible to predict the direction of the marble (nobody can predict if something will become an accident or an incident), (ii) external forces influence the way the marble rolls (the model recognizes that the marble rolls according to operational disturbances coming from the working environment),(iii) the surface of the plateau is rough and allows small resistance against the movement of the marble, (iv) obstacles (ie. safety barriers) can be placed on the plateau to prevent the marble from dropping off (v) however these obstacles are not effective all the time, can be sometimes too weak or even missing, etc.

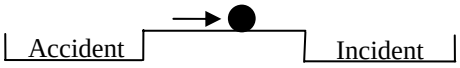

Fig. 2. A marble on a rough plateau

In this theory, the mechanism of a BRF is twofold: it generates substandard acts or situations (ie. it makes the marble roll) and it influences the resilience of the organization (i.e. it makes the plateau easier to drop from, the marble slides more easily). Influences of BRFs are shown in figure 3. According to Tripod theory, preventing individual substandard acts themselves, setting the right barriers at the right place are of course essential but hardly controllable. What is controllable on the other hand is the overall state of the organization, the shape of the plateau. The shape of the plateau symbolizes how resilient the organization is against operational disturbances.

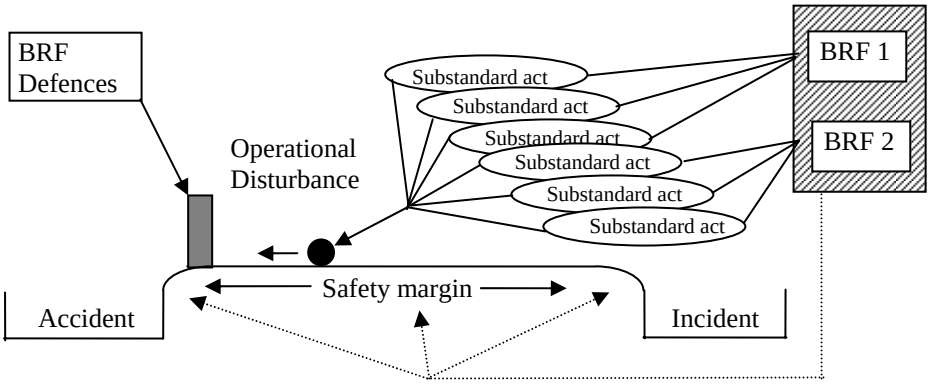

Fig. 3. Influences of the Basic Risk Factors

In this model, resilient organizations are organizations able to self-recover after disturbances occur. Resilience is represented by a stable equilibrium (Figure 4a). After an operational disturbance, the marble has been put in motion but returns automatically to the initial, safe state. It does not mean that the situation is inherently absolutely safe as it is still possible for the marble to leave the plateau (in cases of extremely large external influences) as well as it is possible for 'good' companies to produce accidents. However, in this stable equilibrium, organizations can return to the initial and safe state. On the other hand, in non-resilient organizations, the initial safe state cannot be reached anymore. This equilibrium is this time unstable (Figure 4b). Here, the possibility of

dropping the marble in one of the baskets is much greater after the marble was set in motion. The marble gains momentum after leaving the safe area and will not return to the initial state.

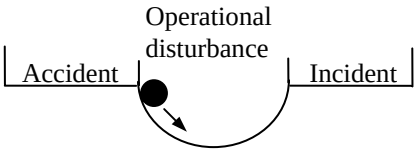

Fig. 4a. The stable equilibrium of resilient organizations

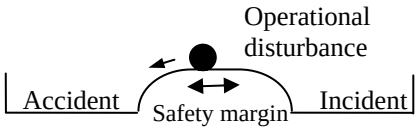

Fig. 4b. The unstable equilibrium of non-resilient organizations

2.3. From the theory to the practice: mains principles of Tripod Delta Survey

Tripod theory and the safety equilibrium model have served as basic concepts for a methodological tool to measure the soundness of organizations in terms of safety. This tool is called the Tripod Delta Survey and is designed to detect weak areas in the environment in which people are working and the level of control that this organization has on processes. The survey uses questions to anonymously collect data relating to factual verifiable operational experiences. The questions are designed in such a way that they make it possible for the participants to establish a direct link between the question and their own knowledge or observation of the system and their actual practices within it (e.g. for BRF 'Procedures': During the past four weeks, did you have to work with procedures with conflicting information?). The questions have been gathered in a central question database (the "Delta Base") enclosing around 1,500 validated questions.

2.4 Tripod as an input for the measurement of operational performance of SMS

The capacity of Tripod to detect the consequences of Basic Risk Factors, i.e. weak areas in the working environment of people appears very relevant when measuring the operational performance of the SMS put in place by the company. As a matter of fact, the organizational weaknesses (or strengths) as observed and stressed by all the members of a company give a good picture of where the main *operational weaknesses* (or strengths) of its safety management system are. For instance, the Tripod question "Are the management's statements in line with their actions?" is a good indicator for measuring if the management is really involved and committed in its OH&S policy.

A tool was then designed on the basis of the assumption that the findings from a Tripod Delta Survey can be used as indicators of the operational performance of the company's SMS (Figure 5). The tool integrates 14 SMPs as the main components of the Safety Management System and interconnects them with the Tripod questions (categorized in 11 BRFs). For each of these SMPs, the Tripod questions considered as quite good, good or very good indicators were identified and selected from the Tripod Delta Base. All together the Tripod Delta Base includes around 1,500 questions. Approximately 70% of them (i.e. 900 Tripod questions) are assessed as good or very good indicators for measuring the SMS operational performance. Some BRFs (such as BRF Training or Com-

munication) have a direct corresponding SMP (3.1 Training, competence and specific trainings, 3.2 Consultation, communication, information of employees). Most of the BRFs cover several SMPs. For instance, the BRF 'Organization' provides good indicators for the SMP 'OH&S policy and commitment of management', 'OH&S objectives and management program', 'Role and responsibilities of employees', or 'Consultation, communication, information of employees'. The SMP 'Management of safety in activities', qualified by SMS auditors as being the most time-consuming and most difficult section to evaluate, is covered by more than 300 Tripod questions.

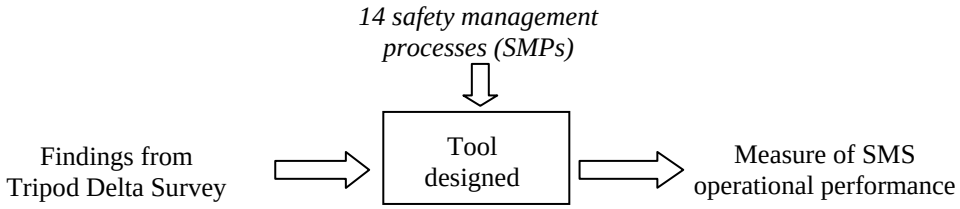

Fig. 5. Tripod as an input for the measurement of SMS operational performance

3 PRESENTATION OF THE TOOLS DEVELOPPED FOR MEASURING SAFETY MANAGEMENT SYSTEM PERFORMANCE

According to the two dimensions involved in the Safety Management System, two tools have been designed in order to measure its 'structural' and 'operational' performance.

3.1 Principles of the tools designed

The tool designed for measuring the 'structural' performance is based upon existing Safety Management standards (OHSAS 18001, ILO-OSH 2001 and MASE). It involves a checklist to help the auditor to assess through a documentary review and interviews if the structure of the SMS (procedures, policies, programs, etc) has been efficiently formalized by the company and if it complies with the standards requirements. The tool developed is based upon 230 'structural' indicators (Table 2 presents five of them). It can be used as an *inventory* assessment when the company is willing to build its own SMS (the tool gives an indication of what is done and what needs to be done in terms of structure) and can be used also as a *diagnostic* of the SMS before an audit of accreditation. This tool is currently being experimented on two French pilot plants.

Table 2. Example of structural indicators for the OH&S policy (§4.2 in OHSAS 18001, §3.1 in ILO-OSH2001

OH&S Policy and commitment of management	
1	Has the management established an OH&S policy?
2	Is the OH&S policy appropriate and adapted to the organization?
3	Is the OH&S policy dated and regularly updated?
4	Is the OH&S policy signed by the organization's corporate management?
5	Is this policy text enclosing a commitment for continual improvement?
…	….

The tool designed for measuring the 'operational' performance uses Tripod as an input. A Tripod Delta survey needs to be carried out in the company before its complete implementation (Figure 5). The tool assesses the influence of the SMS on the working environment and practices through the experience and observation of people. The tool developed is based upon 90 'operational' indicators. Each of these indicators refers to several Tripod questions. For example, in Table 3, the first 'operational indicator' related to the real involvement and commitment of the management in its OH&S policy can be assessed with 10 Tripod questions. This tool is currently in the experimentation stage in one French pilot plant (also pilot plant for Tripod Delta and for the implementation of the tool measuring the SMS structural performance).

Table 3. Example of operational indicators for the OH&S policy (§4.2 in OHSAS 18001, §3.1 in ILO-OSH2001

OH&S Policy and commitment of management	
1	In practice, is the management really involved and committed into its OH&S policy?
2	Does the management give sufficient resources (financial, human and time) for the implementation and application of its OH&S policy?
3	Is this OH&S policy really known and understood by employees?
…	

3.2 Next stage: integrating the results

The two tools developed provide an assessment of the level of compliance of the company's SMS with the existing safety management standards as well as an assessment of its influence on the working environment and peoples' working practices. The results of these two assessments can be represented on the same graph as shown in Figure 6. The integration of results is possible as the same measurement criteria have been chosen for the two assessments (the overall SMS has been divided into 14 safety management processes (or sections)).

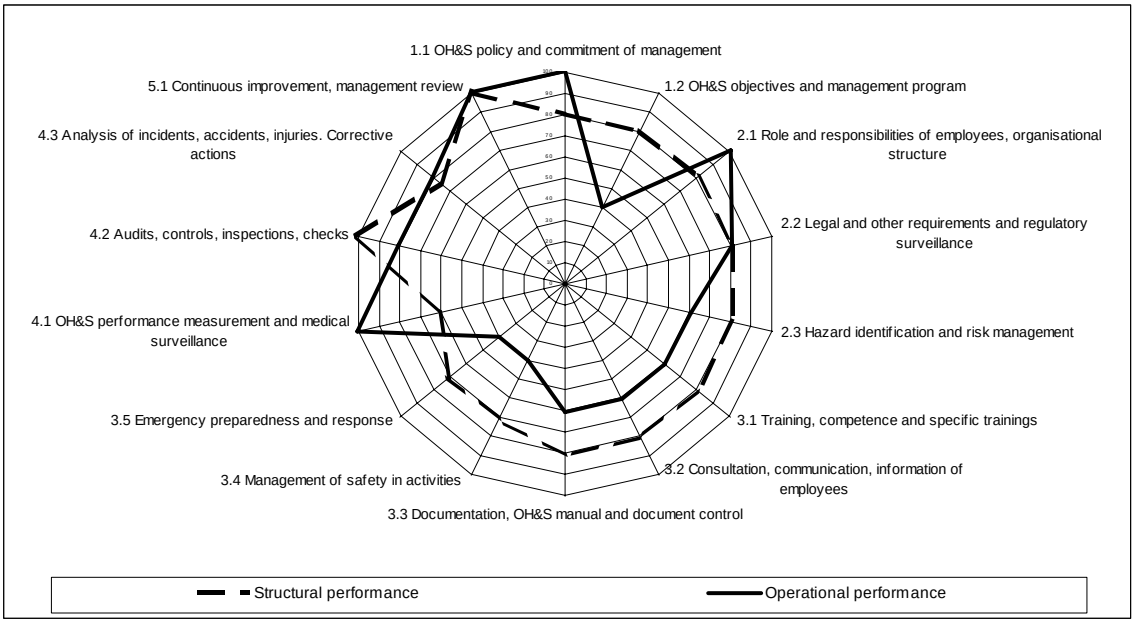

Fig 6. Example of structural and operational performances of a Safety Management System

Figure 6 is an example of results obtained for a virtual SMS. The integration stage of the two assessments has not been reached yet as the two different tools are currently in the experimentation stage. The discontinuous line represents the structural performance of the virtual SMS put into place and the continuous line its operational performance. The graph can be used as a support to analyze (i) the safety processes poorly formalized (e.g. processes n° 2.2 and 3.5), (ii) the safety processes with low effectiveness on people's working environment (e.g. processes n°1.1, 1.2 and 3.5) as well as (iii) the significant gaps between the system on 'paper' and the system's real influence on people's working environment (e.g. processes 5.1, 4.1, 3.4, 1.2).

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