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Safety Management as Problem - identification and Problem - solving

Carl Rollenhagen

Mälardalen University and SwedPower

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1 INTRODUCTION

Management of safety is sometimes described as basically a control problem (Rasmussen and Svedung, 2000). States are monitored, compared with norms/standards, and depending on outcome, actions are initiated (and the outcome monitored to close the loop). The control metaphor is common in the safety context and is, for example, also apparent in the quality domain (the "quality circle"). Such and similar theoretical accounts do indeed highlight important aspects of safety management and are of benefit for identification of various weaknesses in processes and structures. What is more seldom addressed in such models, however, concern organisational interfaces among the different steps (or activities) that together constitute the safety management process. These interface issues are intimately associated with "subcultures" surrounding various "parts" of the safety management process. For example, those activities (and associated subcultures) initiated to monitor current, past or possible future states are rather different from those activities aiming to find solutions to identified safety problems.

Safety management "interfaces" are used to support the transfer of data/information from one process to another, and can be implemented in terms of meeting arrangements, informational technology, procedures etc. The concept "interface" is here also used in a generalised and tentative meaning to discuss differences in cultures, mental models and arrangements among various (sub)processes of safety management. The concept "interface" is motivated because many of the issues addressed bellow can be understood as problems in creating suitable arrangements so that people in one tradition/culture can exchange, understand and appreciate information and experiences existing in another context/culture and then use these experiences to promote safety.

The present article addresses interfaces and subcultures in safety management processes with the ambition to generate a heuristic framework for analysis of why some problems arise and to suggest a method deal with those problems. The "System Group" concept is introduced as a tool for promoting exchange between different "parts" of the safety management process.

2 SAFETY MANAGEMENT AS PROBLEM FINDING AND PROBLEM SOLVING

For the purpose of elaborating about possible difficulties in the safety management process a simple theoretical conceptual framework is adopted, consisting of the following concepts: theory/model; method/praxis; problem finding; problem solving and the distinction between explicit and implicit (see figure 1). Problems may arise in safety management as a consequence of difficulties to find appropriate interfaces among; (1) problem-finding and problem-solving; (2) difficulties in finding bridges among problem finding methods; (3) differences in mapping theoretical models of safety with methods, and; (4) the difficulty to transfer implicit knowledge into an explicit form. Some of these potential obstacles will be discussed below.

2.1 Problem finding

An important class of activities in safety management is the identification of real (or possible) conditions that may increase the probability for accidents. Three *basic* classes of activities (methods) for problem finding can be distinguished: (1) Experience feedback (accident investigations, event statistics, indicators etc) (2) Auditing, inspection, and reviews, and (3) Risk analysis.

These three activity classes (and supporting methods) have emerged from partly different theoretical and practical frameworks/traditions and can therefore be assumed to also correlate with (at least partly) different ways of thinking about safety (i.e. differences in "cognitive orientations" regarding the approach taken to safety related problem finding). Differences in thinking about safety (including associated values) may relate to both interface problem(s) and priorities. For example, some issues could be neglected (by some actors/functions) because they are not judged as important (in contrast to what other actors/functions assume to be significant safety issues).

Auditing, safety analysis and experience feedback are sometimes implemented (organised) as different functions which also creates differences in subcultures (and related values) among actors and this may disturb effective and smooth transfer of information. Moreover, due to organisation of some problem finding activities in terms of "projects" rather than a constantly ongoing activity, safety issues may be perceived as partly detached from their everyday context. To organise problem finding as specific functions (such as safety departments) could support focus on safety but at the same time induce beliefs that "someone else is taking care of safety". On the other hand, many safety issues have to compete with other issues such as focus on production and costs, which can jeopardise safety values. Therefore special safety units constitute a safeguard for not losing attention to safety and are therefore highly recommended as a *complement* to "safety in the line". In any case, interface problems frequently occur regarding how safety related *problem finding* relates to other activities that are both part of the safety management process and also other *indirectly* safety related processes.

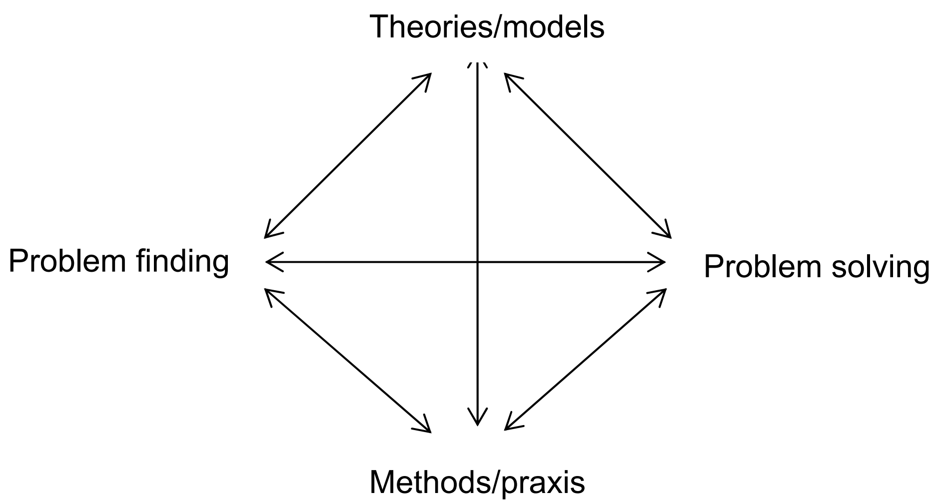

Figure 1. Relations among some aspects of safety management

2.2 Problem solving

Other classes of activities concern the process of "solving" (finding way to cope with) identified safety issues. Whereas problem identification is usually perceived of as an *analytical activity* (departing from an existing structure or process), design activities are more of a synthetical/constructive enterprise. Analytical activities assume, by definition, a strategy of decomposition in which something is decomposed into smaller elements/subsystems for a study of interrelations. Synthetical activities, on the other hand, are of a constructive nature in the sense that something is (or will be) constructed/designed or changed. As mentioned above there are many types of problem finding activities and a basic interface-issue concern how these relate to one another as well as how information from problem finding is *transferred to problem solving*. In problem solving a host of issues which are not necessarily evoked in problem finding tend to interact and influence the possible solutions.

2.3 Theories/models

Both problem finding and problem solving may find support by explicit theories/models (of many different kinds). For example: Probabilistic Safety Assessment is in need of (plant specific) technological models, safety statistics is often based on taxonomies of what is assumed as essential categories, and accident investigations may be supported by "generic accident models" etc. The *socio-technical scope* of those theories/models used to support problem finding and problem solving concern the extent to which models incorporate both technological, human factor issues (including culture), and "organisational" features.

Effective problem finding should succeed to identify problems in technological, human and organisational domains and, very importantly, the interaction among these. The transfer process from theory to method could be crucial of several reasons. Without an explicit theory for the supporting methods, there is obvious risk that findings obtained in the problem identification process become fragmented and unsystematic. For example, in the identification of human and organisational issues the lack of theoretical foundations may open for implicit values of what is judged as important dimensions.

2.3.1 Implicit and explicit

Models may be explicit but also remain as individually or collectively held beliefs about risks, causality etc. The explicit-implicit dimension is of crucial importance for safety management since it could affect communication practises. Assumptions and values may be "taken for granted" by some function but not by another, which, in turn, could effect both decisions and priorities related to safety. An important issue is thus to attempt to reduce the negative effects of interface problems by means of making the implicit explicit in communication and information management.

2.4 Methods/praxis

Methods may be developed from praxis without an explicit theoretical foundation but also as a direct consequence of theoretical explicit frameworks/models. Methods have many dimensions: they may be implicit (such as a taken for granted praxis) or explicit (such as a written description), methods may be general (such as a "how" to perform an organisational analysis) or highly specific (such as a method used for a special technical maintenance operation). Some methods rest on quantification and are highly formal, other are better perceived as general strategies (heuristics).

Depending how a given method mirrors the socio-technical scope of an underlying explicit or implicit theory, great consequences could emerge which influence the success of problem finding. For example, if there is an assumption that "threats" to a system rise from both technological, human and organisational sources, then the methods used for problem finding and problem solving should ideally reflect this assumption.

Methods supporting safety management should, of course, not only concentrate on problem finding but also focus attention of the problem solving process itself. For example, whereas methods for technological design have a long history, many human-interface design issues are surprisingly often still neglected (and this in spite of much research in the area and plenty of standards and guidelines). Also "organisational" design issues remains as a "problem" since safety aspects are not usually explicitly addressed by many organisations doing reorganisation design. Some regulator organisation have rather recently addressed possible safety implications of organisational (re)design but these issues remains controversial and methods are largely lacking to support problem finding and verification in this area.

Interface problem type	**Possible problems**	**Causes/influencing factors**
Transfer from problem finding to problem solving	Problems are detected but not transferred into effective solutions.	Problem finding fails to address more basic causes to problems since a too limited system model is applied. Unclear responsibilities. The problem solving process is not addressed as a process itself and given the same attention as problem identification, which could result in unsuccessful solutions. Problem solving is disturbed by other issues (economical factors, events etc) with reduced safety attention and failure of problem solving as a result.
Transfer from theory to practice Transfer from practice to theory	Methods used for problem finding or problem solving are not anchored in explicit theory, which could result in simplified or biased views of the identified problems. Experiences from application of methods do not reach those that may use these experiences to develop/modify theories.	Theories not developed that could match the methods used or vice versa. Cultural differences among academic research and pragmatically oriented contexts.
Transferring from implicit to explicit or vice versa.	Knowledge remains implicit, which could result in that important safety related issues are not addressed.	Ineffective mechanisms for knowledge transfer (meeting arrangements etc); deficient safety culture prevent open communication.

Interface problem type	Possible problems	Causes/influencing factors
Internal transfer among problem finding activities	Risk analysis, event investigations and auditing/inspection may in themselves identify problems but the results from each problem finding process are not integrated which results in a fragmented view of the threats/hazards. .	Functional organisations in which each problem finding process is organised without proper interfaces to other problem finding processes. Cultural factors and "traditions" associated to different problem finding processes prevent effective transfer.

Figure 2. Some hypothetical interface problem types and their possible causes.

3 INTERFACE PROBLEMS

3.1 Problem finding-problem solving interface(s)

Transfer from "identification" toward "solution" of safety related issues are far from easy. First, the identified negative state/situation should ideally be subject to further analysis for identification of more basic "causes" related to observed (negative) states/events. Secondly, identified problems have to be "solved" i.e. the process to find suitable arrangements that can cope with the problematic issues identified in the problem finding process. Third, there must be an implementation process that transfer solutions concepts to "installed solutions".

Principal solutions offered for safety problems usually fall into one or several of the following categories (Haddon, 1980). (1) The *threat/hazard is eliminated or reduced* by changing technological and/or organisational arrangements; (2) Changing/supporting the *control functions that control the hazards* (such as increasing training, better instructions, more effective technological control functions etc); (3) Introduction of *barrier systems* between the hazard and the valued object(s). (4) Finally, various sorts of arrangements may be implemented to cope with the accident situations *after* the critical impact (and thereby prevent further losses). These principal alternatives to cope with identified threats/hazards all have their pros and cons depending on circumstances, the nature of the threats, finical resources, and complexity issues and so on.

The choice of solutions, of the above types, critically depends on what *type of information* that is transferred from the problem-finding context to the problem-solving context. For example the scope (breath) and depth of the problem finding process may influence the solutions adopted. If, for example, the problem finding process only focuses on technological issues then one might first expect that the solutions also might favour technology as the principal solution. However, this intuition is presumably not necessarily correct since simplified "human factor" solutions in terms of "more training and more instructions" frequently appear in event analysis reports - reports that otherwise might have a strong technological biases in terms of identified causes. The problem appears to be that the technologically based problem identification process sometimes is complemented with *implicit human factor models* (or common sense models). Such models (depending who carries them) might, however, also reflect biases and unrealistic assumptions about human functioning. Consequently, if the problem identification process fails to explicitly address human and organisational issues, then the "problem solving" process is sometimes complemented with implicit models of human function - models that may overlook problematic human centred issues also in the selected solutions. This risk is further accentuated by the possible functional organisation of problem finding and problem solving as two organisationally separated processes. The decision-makers in the problem solving process might, for example, lack the implicit details carried by those performing the problem finding, which, in turn, could result in simplified "human factors" solutions to technological problems.

There are at least two principal strategies to the above problem. The first is to base the problem finding process on models and methods that have a wide explicit socio-technical scope i.e. that explicitly contains technological, human, and organisational issues in problem identification. The second solution principle is to create an overlapping context among problem finding and problem solving so that information is not lost in the transfer process.

3.2 Theory-method interface(s)

This interface has to some extent already been discussed above in terms of how problem-finding methods reflect and relate to underlying theoretical assumptions and knowledge domains. There are also other aspects of relevance in discussing this "type" interface. In particular the transfer processes from theory to practice (and vice versa) in the safety management process could be assumed as important. At least two basic problematic situations might occur that present obstacles in this transferring process. The first obstacle is related to theoretical weaknesses that influence the problem finding (or problem solving) processes with respect to methods used. For example, methods applied might only be diffusely (or not at all) related to an underlying explicit model. Above we have already described one version of this problem in the sense of using problem finding methods with implicit ideas about human functioning.

Another aspect of the theory-method interface (problem) is when organisational arrangements are selected on implicit assumptions. The "solutions" offered in such cases might be reflections of the latest fashions and organisational paradigms rather that based on a more sound theoretical and empirical foundations.

There is, however, also a possible problem in the other direction of transfer - implicit (but basically valid and well-grounded knowledge) remains in the "practical context" and is not transferred to the theoretical explicit context. An example of a situation which reflects this phenomenology is when good (and valid) practice based on years of experience does not reach the academic context (and thereby could delay theories and practice of safety management to reach a wider audience in research, education and training). In other cases disagreements arise among regulator organisation and operating organisation in terms of the "scientific" base for the methods used. Sometimes such discussion might be justified and promote insights, but other times misunderstanding among, for example, regulators and operating organisations appear to have a basis in differences in epistemological and ontological positions and values about safety. But also such disagreements might be fruitful provided that an effective and open communication is at hand.

By the same token, due to differences in cultures surrounding various activities for understanding safety management (such as the scientific culture on the one hand and pragmatic cultures on the other hand) information may reside isolated in respective context without a fruitful interchange (which is a waste of resources).

To seek the "basic-causes" to the above possible problems one presumably has to look both into the history of safety science as an academic discipline and also to understand history of specific organisations (and branches). With respect to the knowledge of safety, there has been a development from particularisation and focus on subject areas in isolation (technology, human factors etc) into complementing system-oriented models of safety. However, this development is highly diversified and depends on branch, countries, regulator systems etc and system-oriented safety models are still much academically oriented rather than they reflect a common explicit view about safety (at least this is the present writer's observation).

3.3 Implicit-explicit interface(s)

Being able to transfer (safety related) information that is implicit into an explicit form could be crucial for effective safety management. This problem is sometimes discussed in relation to construction/design activities, for example, when basic safety related assumptions (and values) have been "forgotten" by new generations operating a given technology. Projects with an ambition to reconstruct and to identify and transfer implicit assumptions in design into explicit form seem as an important endeavour.

Other issues concern the task of making implicit organisational (re)design issues more explicit so that personnel are given opportunities to understand why a given reorganisation should be launched. The safety significance of changing organisations can only be addressed efficiently given that the basic reasons and assumptions for the changes become explicit. Otherwise the change process might increase risks since it could affect both attitudes and behaviour in a direction negative for safety (for example by creation of conflicts and communication problems).

The implicit-explicit dimension is also evoked in terms of other "safety culture" issues. If not effective interface arrangements are present, then safety related (and important) information may reside in a function and thereby not reach decision-makers attention. To make issues explicit also demands a clear communication from regulators so that operating organisations understand why a specific issue is addressed and can judge its relevance in comparison to other identified safety issues of concern.

3.4 Interfaces among problem-finding activities

Different form of problem finding techniques and activities could benefit from each other. Unfortunately, however, different techniques for problem finding sometimes tend to be separated. For example, to perform event investigations and to collect experiences from events (such as component statistics) is an important component supporting risk analysis. By a similar token, performing audits and inspections reveals information about current states but such information can, of cause, also be used to shed light on past events and possible future events. Ideally, then, problem identification systems should be so designed that each particular process for problem identification can use and deliver information from different problem identification processes. This, in turn, creates a need to educate and inform various specific problem finding function about both values and basic philosophies underlying a given problem identification process/method.

3.4.1 Safety analysis

Various models about the target system usually support safety analysis as a problem finding activity. The socio-technical scope of such models varies considerable, which directly maps to the possible types of risks that are considered in a risk analysis. But even if a broad scope is considered in the used theory, problems could arise with respect to empirical data supporting quantification. Moreover, given rapid change in modern organisations and their environment, new factors constantly emerge which are possible associated with unknown risks. In view of such problems, and in need of a reasonable broad scope for possible risk factors, quantification must be complemented with simpler "what-if" types of risk analysis. For this purpose, information collected from event investigations, auditing, inspections and "professional experience" becomes valuable sources of information to support reasoning about the possible future. Such a strategy, however, also demands suitable interface arrangements among different problem finding activities and also suitable scenes to support co-operative information exchange.

3.4.2 Experience feedback in terms of accident investigation

To learn from accidents is a much-used strategy in the context of safety management. This area of inquiry resembles that of risk-analysis in the sense of applying explicit and implicit models for support. An interesting feature of accident investigation is the common assumption that event investigation/analysis is basically an *analytical enterprise*. One can question this assumption on several grounds, however. In an abstract meaning "analysis" means an act of decomposition departing from a reasonably defined whole (unity). Accident investigation is more of a *re-constructive* exercise than it is an analytical enterprise. The problem identification process that emerges in accident analysis is critically dependent on beliefs about what is *causally relevant* to consider and such information can only *partly* be derived from "accident models" or "technological models" ("the wholes") of the same sort that supports risk analysis. Much has to be *reconstructed* in terms of situational specific circumstances and interactions, which can be unique for the specific case.

The basic interface problem between problem finding and problem solving in accident analysis concern the transformation from identified weaknesses to solutions. Only a fraction of the experiences collected in accident investigations are usually passed over into the problem solving process. One potential weakness is that perceived causes (or weaknesses) might be "constructions" (information) stripped from the interesting contextual details that may contain effective solutions to the problems. Such details are not necessarily transferred from problem finding to problem solving (especially in cases where the problem finding process is separated from the problem solving process).

3.4.3 Auditing

Auditing in the context of quality systems describes a rather different area of conduct than the two processes described above. Auditing processes are usually based on a normative perspective (implicit or explicit) in which deviations from the norms are looked for. Auditing thus strongly resembles (and are sometimes identical) to the task on "inspection" and "review".

Auditing may proceed according to two principal strategies. The first strategy is based upon an *explicit set of norms/standards* and the auditing process investigates possible deviations from these. A second type of auditing is to trust on the *expert's implicit standards* and personal experiences. Both of these strategies may have their specific problems. In the first case, the standards used are crucial for focusing attention on the "right" issues. It is not necessarily the case that the given set of standards applied comprises the relevant set of issues – some issues might be over-focused, and other issues could be missed because they do not belong to the chosen set of standards. The other strategy, i.e. trusting on expert's implicit standards and experiences, could lead to a biased selection of what is perceived as "problems" since it departs form expert judgements which are highly specific to expert's personal experiences and values.

Another problem with some auditing exercises is that they sometimes stay with "observations" and "deviations" and fails to explore the more basic and generic causes for a given state. It is common to say that formal auditing should have an associated "root-cause" routine, but one may easily find examples of auditing report in which no causal analysis is performed. As a result, the problem finding process may only address "surface problems" or remain with purely formal issues not necessarily functionally related to more basic safety problems.

To overcome the above difficulties inherent in auditing as a singular method of problem finding, one may, as said above, attempt to combine various methods. Unfortunately this strategy is sometimes hampered by "interface problems". Various problems finding methods may be embedded in different context (subcultures), with different traditions and theoretical orientations. Different "cognitive" styles apparent in auditing in contrast to risk-analysis and experience feedback may also make communication among actors problematic.

4 SYSTEM GROUPS AS A METHOD TO DEAL WITH INTERFACE PROBLEMS

The "System Group" method has been suggested by Andersson and Rollenhagen (2003) as a tool to increase effectiveness in diagnosis of problem situation as well as to support problem solving in complex environments with many interacting functions (professional groups). The system group concept is based on the assumption that complex systems, with distributed decision making, present great obstacles for co-operative efforts since only a small part of the system is directly perceived by individual actors/functions. Knowledge in the system is thus distributed which tend to sub-optimise the problem solving solutions by giving priorities to only those needs perceived from a certain group perspective.

The system group is constructed as a multifunctional group that contains stakeholders representing the *whole system* (given a reasonable broad definition of system boundaries). System groups typically include representatives from both vertical and horizontal positions in a system, which contrast system groups from typical focus groups and other multifunctional group arrangements. System groups as a tool for developmental activities may also be contrasted with "expert group" representing only one or a few functions/subcultures. System groups also differ from traditional line manager decision-making strategies in which a small group of line managers develops a principal solution to a problem.

System groups are usually set up both to promote problem finding and problem solving and should be seen as a complement to other strategies. In system theoretical terms, the system group present an answer to the problem of creating a necessary variety in the control system (Conant and Ashby, 1970). By increasing the variation in the "control system" (i.e. the system group) there is an enhanced probability to both detect weaknesses, their interaction, and also to suggest robust solutions not detected otherwise. The system group concept thus presents *a possible way to reduce the effects of interface problems in the safety management process.*

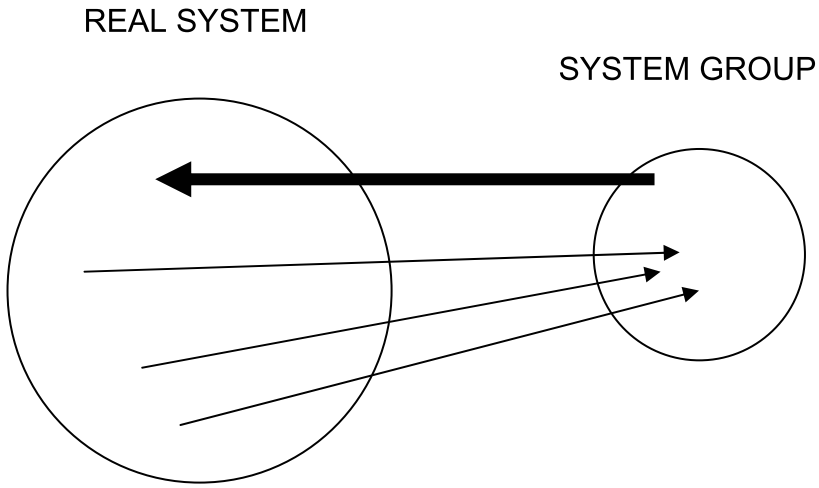

Figure 3. The system group creates a simulation opportunity by creating a “model” of the real system consisting of representatives from the real systems functions (managers, maintenance, operation, engineering etc). By an exchange of ideas regarding “problems” and “solutions” the group may collectively construct models of complex processes for the whole system and thereby optimise system performance and avoid unpleasant solutions that may arise from a limited view of complex interactions.

System groups present a suitable interface arrangement that may counteract the interface problems discussed above. The problem finding/problem solving interface problem is coped with since the same actors that are responsible for problem finding also participate in problem solving. Thereby information is not lost in the transfer process. Since the system group contains managers from different positions in a hierarchy, the interface problem due to transfer from one decision level to another is reduced.

In the collective process of modelling problems, the system group provides an effective tool for addressing *basic problems* and not only symptoms and the solutions may consequently be more robust.

Implicit assumptions are easily carried into an explicit form in system groups since various functions are given opportunity to reflect and communicate which each other. The system group context thus represents an arena for collective learning and understanding of system functioning.

The system group concept has been successfully used both in safety contexts and for supporting innovative product development. More details about system groups can be found in, for example; Andersson (1988, 1990, 1993); Hallgren (1992) and Axelsson (1991).

5 DISCUSSION

A basic (but unfortunately seldom found) ideal foundation for effective safety management is to have access to an explicit (dynamic) model of the system that has to be “managed”. Ideally such models should have a broad socio technical scope and be detailed enough to capture also minor state changes which could lead to large consequences because of tight coupling and interactive complexity (Perrow, 1984). Rapid change in environmental factors does present a difficult problem in quest for such ideal models, however. Qualitative changes may emerge in the system context that can be very difficult to capture simply because the system evolves with new attributes (and do not only present changes in a well defined state space). In view of possible relatively rapid qualitative changes in political and economical conditions, market changes, changes in legalisation, attitude changes, emerging new technologies etc, the possibility to analytically estimate the influence on safety from such factors is a very difficult problem. Problem finding in complex systems is therefore often limited to what appear as reasonable manageable issues complemented with rather crude guesses of the possible future. In fact, there is probably an inherent risk in attempting to analytically rationalise too much regarding the possible influences from external factors since such guesses might underestimate uncertainties.

A more modest (and probably also more realistic) ambition is to depart from a reasonable simple socio-technical category model in which a set of issue domains are identified. The MTO-concept (Man-Technology-Organization) used by the Swedish nuclear regulators and industry represents an attempt to widen the socio-technical scope of the issue domain in identification of problems and in the process of suggesting solutions. The system-oriented philosophy carried by the MTO-concept is far from unique and is today represented in most system oriented (meta) models of safety. However, it is one thing to depart from an academic research perspective in safety science and from that suggest system oriented models with a broad coverage, and quit another issue to transform such thinking into explicit methods and a collective awareness of what might constitute possible hazards.

One may perhaps argue that a “typical” safety manager (or general manager) in a complex system in practice and thinking already conform to a system oriented perspective in decision making but that this perspective is not necessarily made explicit. But exactly this might, in fact, be the problem since implicit assumptions are hard to evaluate regarding their realism and safety significance. What theoretical approaches and methods developed within safety science might contribute to (in this respect) is just to make models and the basis for decision making explicit by attempting to reveal those assumptions that might be hidden in daily practices.

Methods used for problem finding are in need of efficient interfaces among the individual methods themselves but also interfaces that could transfer problem finding into problem solving. If decision-makers are to separate from the problem finding process in itself, competing everyday management issues could divert attention from the complex and intriguing details revealed in the problem finding process. To efficiently cope with safety problems, compromises must often be found between various values focusing on different issues in the management decision process. This act of “balance” is much easier if suitable interface arrangements are produced that efficiently could collect experience from the whole system.

Several perceived problems in the safety management processes could be addressed in a more powerful and efficient manner given that interface problems are explicitly addressed in the design of safety management processes. To create co-operative arrangements in line with the system group concept supports a more efficient use of limited resources in systems by collecting experiences from stakeholders that each one carries important experiences and ideas about both hazards and strategies to cope with them. System groups do not replace other strategies to support safety management but they can be used as efficient complement to reduce interface problems.

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