SAFETY SCIENCE Monitor

ISSUE 1 2000

Article 5

VOL 4

A FRAMEWORK FOR ASSESSMENT OF ORGANISATIONAL CHARACTERISTICS AND THEIR INFLUENCES ON SAFETY

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Abstract - The purpose of this paper is twofold: (1) to present a conceptual framework for the assessment of human and organisational factors and their relations to risk and safety, and (2) to discuss some specific assessment methods used in the context of the Swedish nuclear industry. The presentation is mainly concerned with large-scale industry processes (i.e. commercial nuclear operations). This limitation in scope obviously put some restrictions regarding generalisation to processes and systems outside the nuclear. However, a large part of the here presented framework and associated methodologies are believed to be of relevance for risk assessment and management also outside the nuclear sector.

INTRODUCTION

In Sweden the so called MTO approach (Man, Technology, Organisation) has been one of the main theoretical frameworks for the enhancement of systematic approaches to integrate human, organisational and technological factors in the context of nuclear safety. In the last five years or so the MTO concept has also emerged as a source of inspiration for some aspects of Swedish occupational safety as well as medical safety. The thinking behind the MTO concept is not new, at least as seen from a research perspective. In retrospect it seems safe, however, to claim that the concept has been relatively successful in "marketing" a *system view* about safety as it is perceived in many day-to-day activities at nuclear plants in Sweden.

The development of MTO in Sweden has its parallel in a generally increased focus upon management and organisational factors as a source of risk and safety. There are many manifestations of this international trend in the nuclear community, for example: The development and use of the term "safety culture" (INSAG 4), international conferences about safety-culture, attempt to develop probabilistic safety analysis (PSA) that incorporates measurement of management and organisational factors (Dayoudian et al 1994) and recent attempts within the European Community to focus on organisational issues and their connection to nuclear safety (1). A similar trend also emerges in other branches such as offshore, transportation and medical safety.

One may easily find several explanations for this rapidly propagating interest in integrated system approaches to safety. One strong force has been empirical: in depth studies of causes behind accident reveals a strong contribution from human and organisational factors to explain these events. Another force is driven by worries that increased market deregulation's, harder competition, regulatory demands and internationalisation will need abetter understanding and praxis about how to measure and control risk: in dynamic environments, the "old approaches" may not be sufficient to handle rapid changes in technological and organisational structures. A third force is the development of information technology in itself.. new tools are today available that promote the exchange of information and knowledge about risk and safety. People using such tools for information exchange detect that many problems in the organisational and human domains are rather invariant and not dependent on specific technology used. Another driving force is the interest in the quality concept and associated certification praxis; this interest fosters a need for integrative safety. Finally, the general attention to the concept of culture seems to be a common factor that brings together many of the more particular trends. The culture metaphor is convenient when talking about the needs to prepare both management and workforce for rapid changes in economic and social factors. Efforts to measure and influence safety culture thus emerge as a focused strategy in current research and practice in may industries.

Despite all these efforts great confusion still exists regarding the meaning attached to some commonly used concepts such as "organisational factors", "safety culture", "safety climate", "learning organisation" and so on. The definitions and models that exist around these concepts are thus still open for many different interpretations. What people generally seem to agree on, however, is that those safety perspectives that only consider the technology hardware is not sufficient to understand and control risk and safety. More emphasis has to be invested to understand how differences in management and organisational factors (M&O) effects risk and safety.

The art and science of *general* M&O has, of course, been with us a very long time. However, many theories, methodologies and strategies *have not* been developed with *a primary focus* for prevention and avoidance of accidents but rather have had a focus on economy and production. In spite of this previous neglect for safety in general organisational theory, these accounts continue to influence safety to a large extent. A crucial question, then, is of course if the general organisational theories, methods and fashions are suited for their purpose when dealing with safety issues. Current popular trends such as outsourcing, downsizing, deregulation etc, may be assumed to have effects on safety but very little is known about the direction and magnitude for safety as a result of using these practices.

M&O factors in a risk/safety perspective have been rather neglected by the industry. It seems to me that one of several reasons for this situation may be a lack of bridge between theory and practice. Theory is of course important but it is essential to transform theory into practical methods that are easy to use. Today the situation is changing rapidly, however. The industry is today, more and more, asking for tools and theories that can be transformed into applied strategies and methods. In the next section we shall briefly and critically review some lines of thinking in current developments.

Top-down vs. bottom-up approaches

It is possible to discern at least two main analytical strategies in the search for how M&O factors may influence safety. What 1 refer to as the "bottom-up" strategy starts with the technology itself and tries to model deviations and their consequences in the technical core system. Human actions are looked upon primarily in terms of "human errors" taking place in *direct interaction* with the technological system. In some of these perspectives the human is treated more or less as a "machine part". Such views have limitations since they tend to neglect the intentional nature of humans. Organisational factors are in many of these accounts treated as "performance influencing factors", that is: factors that are assumed to influence the reliability of human actions (training, instructions, interface design, stress levels etc). Long lists of such factors are normally attached to human reliability analysis methods.

In recent years, the cognitive aspects in association to human reliability analysis have received more interest. The dynamic cognitive aspects taking place in different situations are now considered and the intentional nature of human cognition are recognised and studied. But most of these new "cognitive" traditions give little guidance for the modelling and understanding of such things as safety culture, organisational learning and other more complex "organisational factors." In order to understand these issues it seems necessary to depart from a complementary top-down perspective.

In the Human Reliability Analysis tradition (HRA) some of current research and methods are, however, seeking to go beyond the focus on performance shaping factors and also explore *more indirect* organisational influences on safety. The depths to which organisational factors are investigated vary considerably in these approaches. Some accounts focus on "team processes" and leadership while others take a somewhat wider perspective. A common goal for many of these traditions is to develop models that not only define influence from M&O, but also are able to quantify their strengths and then incorporate the measures in probabilistic safety assessments (PSA). It should also be mentioned that some approaches, in fact, are influenced from more general organisational research in their search for M&O factor candidates. For example, the WPAM model (Davoudian et al 1994) is a comparatively advanced technique that connects process operation tasks with a large set of organisational factors identified by Jacobs and Haber (1994). The set of organisational factors was identified from a database consisting of more than 3500 references.

A very strong advantage inherent in the bottom-up approach is its focus on *activities and situations.* The obvious observation that safety depends on human cognition and action taking place in different *role settings and situations* may easily be forgotten in abstract top-down modelling of general organisational factors. But much more could also be learnt about what *people actually feel, think and do* in activities such as: construction, analysis, investment decisions etc. A second strong advantage of the bottom-up approach is that it *maintains a close contact with the technology* itself. The number of factors that can be proposed is large and in order to distinguish what specific human and organisational factors that are most important for a given technical core system one must not lose focus on the sharp end (the technology itself).

Top-down approaches

With a "top-down" approach to M&O factors is here meant a deductive mode of reasoning that departs from general principles and observations rather than on specific situations and technologies. The problem with some "top-down" approaches in the present context is that they often tend to be too general to give much guidance for safety analytical purposes. For example, the often-used approach to characterise organisations in terms of "types" do not always seem to work: in USA the nuclear regulatory commission (NRC) has supported research to explore Mintzberg's model of "Machine Bureaucracy" (Mintzberg, 1982) as a framework to organise M&O factors and their influence of safety. However, recent work has shown that the original model had to be modified. Personally 1 find much of the theories and practices in the "general organisational theories" as stimulating but unfortunately seldom useful for safety analytical purposes.

Another problem with some general lists of "important organisational factors" is that they tend to lack descriptions of cause-effect. In order to use identified organisational factors, as a basis for effective preventive strategies one has to explore these causal relationships in detail. It is not particularly useful to say that organisations should be "learning organisations", show "management commitment" or have a "good safety culture" etc without an idea of what this means in terms of cause-effect relationships.

Some general "top-down" organisational perspectives do consider safety as a main point, however. An example is that of Perrow (1 984) and his notion of "Normal accidents". According to this theory, the high complexity and close interrelation of components in many modern systems creates situations with no escape: the systems are bound to fail in the long run. Such inherent latent failure tendencies are very hard or impossible to cope with according to Perrow. To my knowledge, these ideas have not been discussed very much outside the academic community, perhaps because they are rather pessimistic about the safe development of large complex systems. Perrow focuses, however, on important issues that are fundamental for safety science also regarded from an organisational perspective. Especially the notion of "complexity" is of much concern from both a technological and human perspective. Also Perrow's idea about "tight coupling" among elements in a system is important: small deviations may spread rapidly in complex systems and thereby create disturbances of larger scale. How such theories such as the one developed by Perrow could be used for assessment of M&O factors are far from clear, however. (It shall also be mentioned that several of the general ideas proposed by Perrow have for a long time been recognised in terms of general design principles such as the need to keep technical elements and systems separated).

A very different perspective has been taken by those who focus on so called "High Reliability Organisations (HRO)" (for a review see Short and Clarke, 1992). A basic question for this tradition is to understand why complex organisations in fact do *not fail.* Research in this tradition support some general statements of what appear to be characteristics of "safe organisations" such as: (1) These organisations have members that agree upon goals and objectives; (2) there are redundant controls and verification activities; (3) comprehensive training programs; and (4) the decision process is dynamic and depends on the situation. In terms of criteria for assessment of O&M factors much can be learned from the HRO research, such as: the importance of shared values for safety; the importance of redundant and efficient verification activities and; the importance of situational factors for decision making.

The theories developed by James Reason (Reason, 1990) are also examples of what I call "top-down" perspectives in the sense that they are rather general system theories and concepts related to safety. The notion of latent errors in organisational structures is important in Reasons reasoning as are the concept of protective functions (or defence functions). Bad decisions at the top of the organisations are assumed to spread into non-optimal work conditions that increase the risk for human errors.

Conclusions

A system perspective that recognises human, technical and organisational elements and their interactions is a necessary foundation for acquiring high safety in production systems. This, in turn, demands cooperation among many disciplines.

The somewhat fuzzy term "organisational factors" has many meanings in a safety context. For, what I refer to as bottom-up strategies, organisational factors can be identified from an analysis of human actions and the factors that seem to effect the reliability of these. Human reliability analysis has a tendency, however, to neglect human actions that are in *indirect* contact with the sharp end of the production system such as construction activities, analytical activities and management activities. The benefit of a bottom-up strategy to the analysis of organisational influences is that it tries to model cause-effect relationships, which connects to the physical system. An observed weakness with bottom-up strategies is that many elements that affect safety, such as "company culture" and "external pressures" on an organisation seldom have room in typical analytical efforts.

Seen from a top-down perspective, the term "organisational factors" is a broad concept that includes safety culture, organisational learning, organisational "types" etc. This perspective is important but sometimes difficult to use as a basis for assessment, partly because the concepts are difficult to transform into unambiguous measurement dimensions. Cause-effect relationships are also sometimes difficult to abstract in some of the top-down organisational theories.

It seems to me, then, that a framework for analysis of organisational factors and safety would benefit from a combination of top-down and bottom-up frameworks. From the top-down traditions we may explore concepts such as safety culture and learning in an ambition to assess different general or typical manifestations of these. A complementary bottom-up perspective is, however, needed to model specific organisational factors given specific technical core systems in various situations. A bottom-up perspective would also probably benefit from searching generic modelling categories that can be used as support to explore *indirect* influences from human actions on risk and safety. The framework presented below has an ambition to explore such a possibility.

A CONCEPTUAL MODEL FRAMEWORK

The model arose from a need to develop indicators and measures for human and organisational factors related to nuclear safety. A second related purpose was to support qualitative organisational assessments of nuclear organisations. We are also in the process of developing a computerised tool for the measurement of safety culture, which is based on an elaboration of the model.

The model presented below starts off with an attempt to explore generic categories that are believed to be present in most production systems. My hope is that these categories can provide support for modelling specific organisational factors found for many sorts of production systems.

The model also contains some rather abstract modelling categories such as "integration" and "formalism". These categories are used tentatively together with some observations of mine in order to explore potential research issues.

A GENERIC BOTTOM-UP MODEL

The model proposed is basically a bottom-up model in the sense that technology itself is regarded as important: different technologies present different demands on people. Technological structures and dynamics must be studied in order to understand the *direct* influences from people's actions on technology.

There are also many actions that people exhibit that create preconditions for direct encounters with technology. These *indirect* influences are considered as very important in the model.

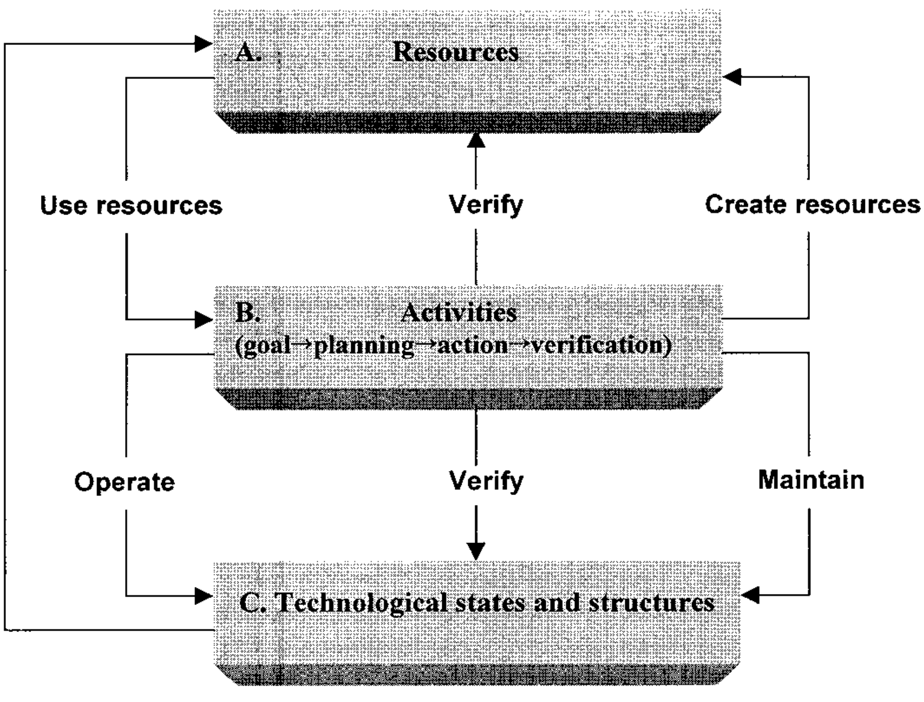
Basic concepts

The model is anchored in three fundamental conceptual categories: (A) *Activities;* (B) *Resources,* and (C) *The technological core* system (i.e. the hardware of the production system itself). These categories roughly correspond to the component classes in the MTO concept (but expressed in a different order in the MTO-concept).

People performing different activities are called "human resources". A human resource is both the individual actors in a holistic sense but also the particular knowledge, skills and attitudes that are associated with actors. The concept of "activity" is in the model separated from "the actor" as a resource simply because it is meaningful to discuss activities in themselves as an independent descriptive categories. Furthermore, an activity is a process in which the concept of setting goals; planning; and verification often constitute common sub activities attached to a main activity. The outcome of an activity can also be a goal or a plan.

The resource concept is used in a very general meaning in the present model. People create resources and use resources, they verify resources, operate resources etc. The model proposes a set of generic resource types: such as information resources, time resources, human resources etc. It is assumed that in order to understand and assess an organisation one has to understand what activities people do and what resources they create and use in their activities. Both activities and resources have, of course, to be organised in some way. This is in the model seen as a constructive activity that uses different types of resources.

As shall be evident later, a set of primitive action categories is proposed such -as verification, construction, maintenance etc. These activities can be combined in order to reach a set of specific activity classes, which can support organisational assessment.



A. Activities

Human activities are related to risk both directly and *indirectly:* a fact that can be easily derived from common sense and everyday observation and which also is supported by risk and event analysis.

The fields of ergonomics and human factors have been developed to systematically explore optimal working conditions for human activities. In the "activity category" it is, however, not the physiological, psychological or social aspects of human activities that are in primary focus, neither the support for these activities. This category focus instead on the *activities in themselves in terms of behaviour* both at a molar and a more specific level of description. Or put in a more straightforward way: We like to know *what actions people perform that are both directly and indirectly related to risk.* This basically means that a first step in analysis is to logically relate cause-effect relationships among different activities and trace their possible direct and indirect influences on the technical systems.

The term activity has a dual meaning in the model: (1) Activity may refer to a broad activity class such as design or maintenance and a set of predefined activity classes is proposed. (2) The term activity may also refer to a more detailed level of analysis. For example, the activity of construction/design is used to model the activity of constructing another activity (for example a plan to make verification activities). Another example is the verification of an analytical activity.

For some types of actions our approach obviously overlaps with tasks descriptions as they are used in human reliability analysis (HRA) in order to assess probabilities for human error in operation and maintenance. For some important action categories, however, the conventional HRA approaches are not particular suited for our purposes. Human reliability analysis has mainly been developed to model actions that are in *direct* contact with the core technological system (i.e. human operators). New approaches are needed, especially at the management level of description

As already mentioned, some activities are assumed to be part of many other activities, such as: (a) goal setting activity; (b) planning activity; (c) verifying activity. The act of *communication* is also assumed as a general action category associated to many other activities. Furthermore, these above-mentioned common categories are assumed to always be interesting to explore in association with analysis of human actions.

A set of default activity primitives

In the model some activities are believed to be of special concern in the context of risk. These activities may be part of other activities or they may be regarded at a more global level as characteristics of certain jobs or departments. The primitives are:

Construction/design:	The activity to construct something such as a machine, an instruction, a goal, a plan a verification routine etc.
Operation:	The activity to operate or use something.
Maintenance:	The activity to maintain something, a machine, an instruction, a goal, a verification routine, an administrative system etc.
Verify:	Activity to verify or control that "something" is according to specifications.
Manage:	Activity to plan, control and regulate others activities.
Analyse:	The activity to analyse a system or a process into smaller components and investigate their relations.

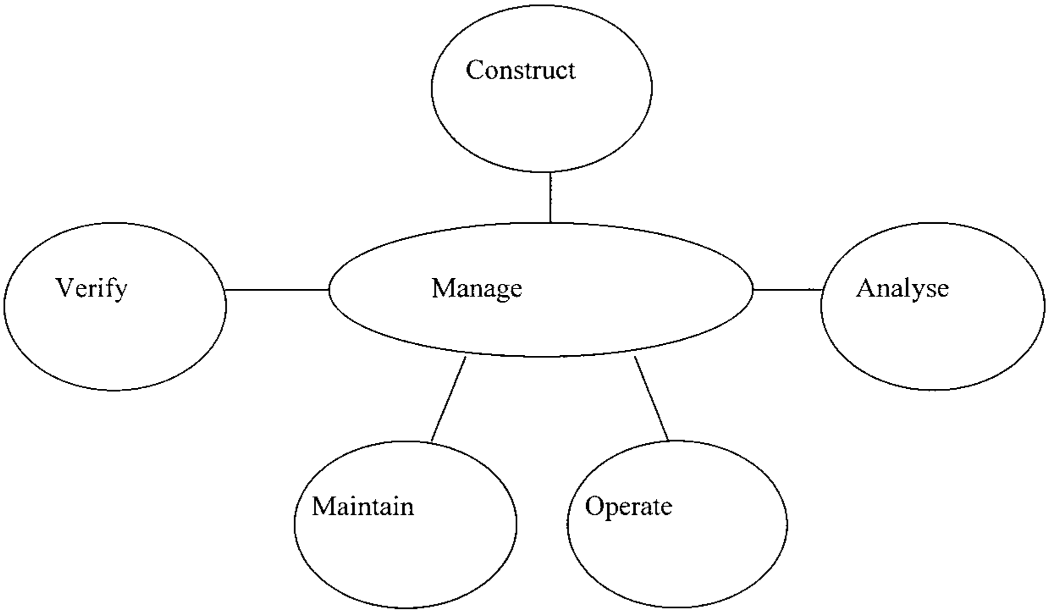


Figure 2 Activities that are assumed to be of primary importance for safety. These activities are not mutually exclusive but often integrated in different ways in an actual organisation. For organisational research it is an interesting issue to explore the pros- and cons with different activity arrangements seen from a safety perspective.

The above categories were selected because they often correspond to typical "jobs" in complex organisations. These jobs are also commonly implemented in an organisational structure as "operating department", "maintenance department", "safety department" (corresponding to the "verification" activity category). The construction/design activity is also often organised as a department of its own. Another reason to select these categories was that they could be used to model a large set of more particular activities, which can occur in any of the other activity classes. For example, the activity of "construction/design" is used to design verification activities, analytical activities and so on. A set of combinations of activities is depicted in table 1.

Table 1 Combinations of the activity classes. For example, cell 2 shall be interpreted as the activity of constructing an analytical activity, for example the planning on a risk analytical activity. Cell 6 describes the construction/design of verification activities such as setting up an auditing system. Cell 36 describes the verification of verification activities, for example an independent assessment that the verification system is working properly. The reader may for try to use the matrix as an exercise and explore how these combinations may be used to understand and describe the activity domain.

	Construct	Analyse	Maintain	Operate	Manage	Verify
Construct	1	2	3	4	5	6
Analyse	7	8	9	10	11	12
Maintain	13	14	15	16	17	18
Operate	19	20	21	22	23	24
Manage	25	26	27	28	29	30
Verify	31	32	33	34	35	36

B. Resources

The second main component class is called "resources". A resource in the model is anything that is utilised in order to conduct a human activity to reach goals. 1 have preliminary used and defined the following resource types:

- Information resources
- Information technology resources
- Human resources
- Time resources
- Financial resources
- Other resources

Information resources are divided into several subtypes (see table 2) such as policy, methods, data, descriptions etc. The common factor is that people use this knowledge to support their activities. For example, a safety policy contains some sort of information that is intended to guide hwnan actions. Another kind of resource type is called information support resources and describes the structures that carries or support the information. For example, meetings are seen as a support for use of information resources. Another example is man-machine interfaces that support information resources.

Human resources are, of course, the people. In the model, several "subcategories" or properties are associated with the human resources. The knowledge and skills that people carry with them as well as their motivation, values and attitudes are considered as essential subcategories.

Time resources and financial resources describe separate categories and finally a "other resource" category is proposed to include tools etc.

Table 2

Main resource type	Main subtypes	Specific subtypes (examples)
Information resources	Policy and Goals Rules and regulations Instructions Analytical methods Data derived from analytical methods Data from process information Descriptions of hardware	Safety policy Safety principles, safety rules Operating instructions Risk analysis, Event analysis, Organisational analysis, Indicators Identified root-causes, PSA risk estimates Reactor pressure Drawings
Information support	Meetings Computer networks Man-machine interfaces	Safety committee
Human resources	Procedural knowledge Declarative knowledge Episodic knowledge Values and attitudes Motivation	How to use a method Facts about the system Knowledge of previous events Attitude towards management
Time resources		
Financial resources		
Other resources	Tools Space	Measurement devices Space available for maintenance

C. Technological core system

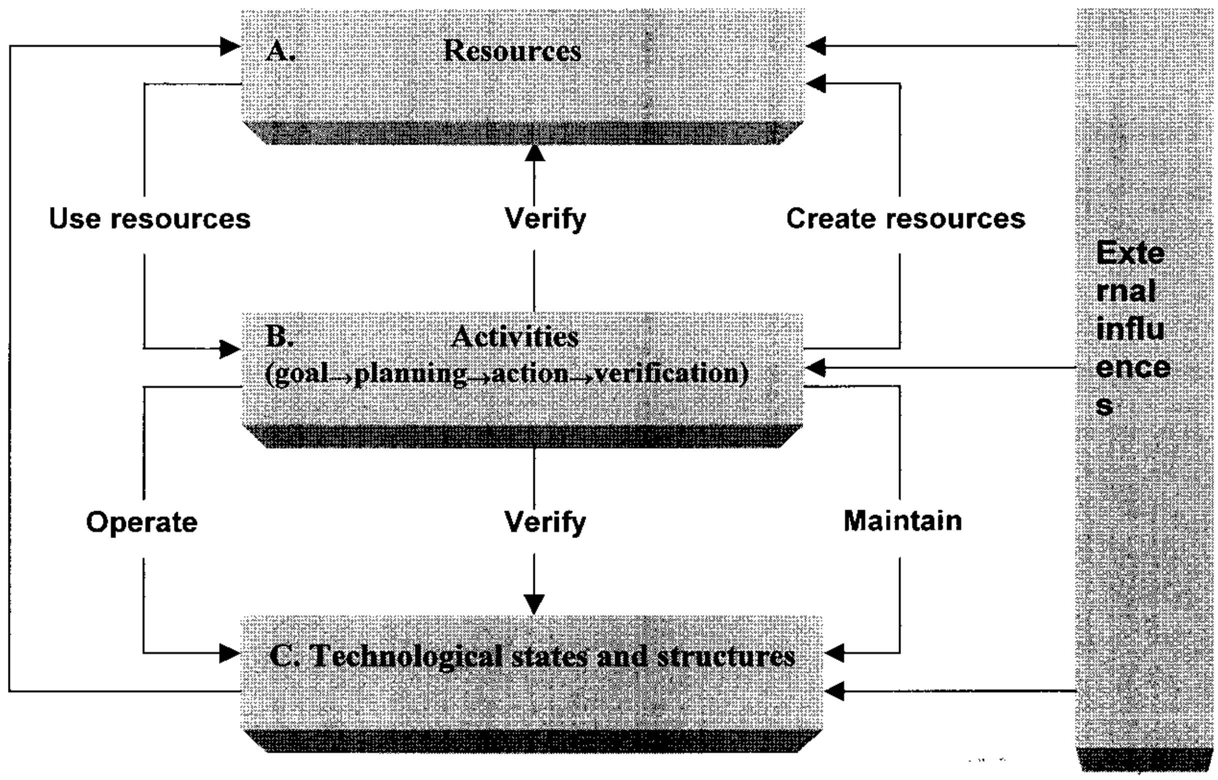
By the above descriptive category is here meant the hardware of the technological system as it isrealised in terms of components and systems (computer software is also considered in this group).

Especially the safety systems constitute important issues when they are analysed in relation to the activity domain. Passive safety systems present specific problems in this respect because they are verified for functionality and maintenance. This exposes these systems to a risk of human errors, which may create latent failures in the safety systems. Much more can, of course, be said about this category but due to space limitations we will here primarily concentrate on the other two descriptive categories.

Extending the model with external influences

Our proposed model is so far incomplete in the sense that influences from external sources have been neglected. This is a serious limitation because external pressures may strongly influence how an organisation is designed and managed. Influences may act directly upon activities and then effect resource management or the resources may be directly affected.

Many factors outside an organisation may create strong influencing factors on safety - both in the positive and negative direction. This rather obvious fact has to some extent previously been neglected in many models set out to describe organisational factors and safety. Factors such as deregulation of market, technological infrastructure, political decisions, economical structure, legal systems, regulatory practices, changes in values etc, all effect management decisions regarding safety. We will not further explore these factors here. It would be worthwhile, however, to direct more attention to these issues in the discussions of organisational factors and safety.



Evaluative dimensions

For a given organisation and technology, a specific and detailed modelling should take place which focuses on identification of activities, resources and technology and their specific interactions. The model may be used to support a set of questions, such as the following:

- *Are sufficient resources available* in order to conduct the actions efficiently and with high quality?
- What is the *balance* between different resource types?
- Are resources *utilised effectively* for different actions?
- Have all actions that are important for safety been *identified*?
- Are the *results* of the actions satisfying?

- What are the *connections* between different kind of actions?
- How *are resources* created by one activity *transformed and utilised* by other activities?

For each activity class and resource type, more specific questions can of course be constructed, for example by using the activity matrix in combination with different resource types. In a later part of this paper we will provide some more specific questions how a specific activity can be explored from the perspective of the model.

EXPLORING THE TOP-DOWN PERSPECTIVE

The above model framework explores human actions and their organisational resources in terms of predefined generic categories. Under the assumption that the selected categories have been reasonably well selected, they can be used as support for evaluations of organisations or in attempts to develop organisational indicators.

There are, however, also more subtle "organisational dimensions" that are in need of investigation when we talk about organisational factors and safety. Some of these, like "learning" and "safety culture" are not explicitly mentioned in the above framework but should rather be conceived of as emergent properties of the model. For example, if the informational resources are created and utilised efficiently, then the organisation most certainly exhibits "learning". A good "safety culture" would also be a result of efficient utilisation and balance of activities and resources. 1 find that it is probably better to discuss such things as learning and safety culture connected to specific activities and resources rather than as a general and abstract evaluative dimension.

Some abstract dimensions may, however, need a specific focus by themselves. Below I will discuss some propositions regarding two suggested dimensions: (a) degree of integration, and (b) degree of formalism. The selection of these dimensions is based on personal experiences of doing organisational assessments in nuclear organisations. Support for selection of these dimensions may however also been found in other sources (this is not discussed in this article, however).

Integration vs. separation

I regard this dimension as a general dimension that could be applied both for activities, resources and the technological core system. Let us, as an example, briefly explore the activity domain in association to this dimension.

Activities (tasks and jobs) may be more or less independent from each other. The traditional way of organising many activities by means of "departments" and functions, such as: operating department, maintenance department, construction department and so on, is necessarily not the most effective one seen both from an economical and safety point of view. Rather recently much more attention has also been focused on the analytical concept of processes and process analysis. Activities performed by a certain job function are often secondary in these analytical exercises, the important thing is to trace the flow of activities (tasks) from start to goal to and investigate output and input relations.

Organisations can obviously be characterised on the basis of degree of integration among activities. A basic (unresolved) question is: What is good and bad for safety with different positions in the integrative dimension? Unfortunately, no clear answer to this question can be made. (It can also be the case that no definitive answer or principles are ever to be found on this issue - perhaps it all depends on context and circumstances). Based on my experience of analysing nuclear organisations 1 will, however, make some reflections bearing on the issue:

- There are very different cultures associated with maintenance, operating and safety departments. Rather than to talk about a unified safety culture, then, it seems often more appropriate to talk about different safety cultures in an organisation. Of course, at some level of analysis these different cultures can be mingled to a common grand safety culture in an organisation. One of the reasons for the differences in safety cultures is the separation of activities into various "departments". More "integrated" organisational designs can perhaps make it easier to develop a more unified and common safety culture. On the other hand, because different activity domains also impose different demands on different behaviour related to safety, it can in fact be fruitful to focus on and develop safety cultures that are specifically tailored to activity classes. Consequently, it may also be wise to develop different assessment methods for different safety cultures. A risk with a too broad and generic conception of the term "safety culture" is that it becomes too abstract for measuring purposes.

- When many activity domains are integrated, communication hindrances, can sometimes be reduced. For example, in one case, the outage planning activities were positioned in close physical contact with control room activities. According to people interviewed this arrangement led to a much more effective outage management because information flew very smoothly.
- A bad side of attempting to integrate too many activity domains is that people may lose focus on their primary activities. 1 have seen examples where operating departments have been overloaded with secondary activities in attempts to create action integration. In a general ambition to cut costs there is sometimes also a tendency to overload people with, for their function, secondary activities. Before secondary activities are introduced it is consequently wise to investigate effects on primary activities.
- It is often interesting to apply the integration vs. separation dimension to verification and analytical activities: In general 1 have seen benefits from a strategy to integrate different analytical and verification activities. According to my experience, some safety analytical activities tend to become too separate from other analytical activities. For example, sometimes root-cause analytical activities live their own life unconnected to other risk analytical activities. Also, quality assurance activities can often be integrated with safety analytical activities and event analysis with great benefits.
- An obvious case in which great benefits often are achieved is when construction of manmachine interfaces is integrated with operation and management activities. Unfortunately, many examples can still be found where construction departments neglect experiences and knowledge from operation and maintenance departments.

The dimension of integration-separation can also be applied at the resource domain. It is important that the resources are properly balanced and integrated so that they are not in conflict with each other. For example, information resources such as rules and instructions must not be in conflict with time resources. One could, for example, not expect people to follow detailed rules and regulations if, at the same time, the time resources are so limited that it makes a task impossible with the time resources provided.

Some of the observations above are perhaps of a "common sense" type: people often have a fairly good idea of the ideal situation. The fact that problems often persist with respect to positive integration of activities and resources are, in this perspective, an interesting observation. Perhaps the strongest hindrance for positive integration is not found in organisational design principles, but in human nature and human values. Such a statement, if true, may imply that an organisation may benefit much from a more throughout investigation about human values and attitudes and that we perhaps expect too much of the technical and pragmatically oriented approaches to organisational assessments. 1 have repeatedly found that people tend to agree about how things should work, but for some reason activities and resources sometimes tend to be isolated and fragmented. To further investigate hindrances for positive developments is presumably a good strategy that needs further exploration in terms of research.

Formalism vs. informalism

A second global dimension 1 often have found interesting to explore is that of formalism on the one hand and informalism on the other. With formalism in this context is meant an organisation that has a culture of carefully documenting its functions and processes and which also stress the importance of adherence to formal rules and regulations.

At the other end we find organisations that have a very informal behaviour pattern with respect to documentation and rule systems. My general impression is that organisations that are small may go along well with the informal style without jeopardising safety. Informalism does not necessarily mean violation of safety rules - it can also mean that the boundaries for risky behaviour is anchored in genuine knowledge so that the boundaries of unsafe practices become visible without a strong support from a formal rule system. But the informal system is usually not a very structured system and it can easily turn into risky situations. If complexity grows, if changes occur in the organisational structure or if a rapid turnover of personnel occur, then the informal system may be very weak and dangerous without support from formalism.

There is an ongoing discussion within the nuclear sector regarding the risk of relying too much on instructions and rules, which in worst cases may lead to a drain of knowledge and flexibility. No one denies the importance of rule systems - but what happens if the rules do not cover all the cases that may occur and at the same time people have acquired a false belief that the rule system are stronger and cover more cases then is actually the case. The lesson to learn, then, is that formalism never can compensate for a genuine lack of knowledge among the people in an organisation.

Another common way to talk about formal and informal in the organisational context is associated with the gap that can occur between the two. An organisation that says something in its descriptive documents and acts otherwise is exposed to difficulties in the long run. One reason for this is the lack of trust that such an organisation created among its members and the surrounding world.

A CLOSER LOOK AT ONE METHODOLOGICAL RESOURCE AND ITS RELATION TO THE ORGANISATIONAL CONTEXT

In this section of the paper we shall take a closer look at one of the techniques used by a nuclear unit in order to asses human and organisational factors. In particular we will focus on Forsmark (FKA) power plant and the use of event analysis as a tool for learning from events that have human and organisational influences as cause categories. The example illustrates how the concepts of the model can be used to raise specific questions that need an answer in evaluation efforts. The example also illustrates some general issues and practices associated to root-cause analysis seen in a larger organisational context.

Event analysis at Forsmark nuclear power plant

The activity of performing event analysis (root-cause analysis) is essential in order to learn from experiences. Event analysis is both a reactive and a proactive method. It is reactive in the sense that something has happened that triggers the analysis but it is proactive in the sense that results from event analysis are used to prevent further incidents.

In terms of the model, event analysis is both an activity and a resource in terms of methodology and in terms of the information that comes out from an analysis. The activities involved in event analysis should, of course, be connected to other types of activities and these connections are always interesting to explore if one likes to evaluate a given activity.

A brief background of the organisational context

To efficiently use analytical techniques that focus on the interaction between human, technical and organisational factors people need basic training about human factors and organisational principles. In Forsmark the strategy has been to introduce an event analytical technique (HPES) together with a training program that focused on human factors seen in a larger system perspective. A majority of people from operation and maintenance departments at unit 1 and 2 thus received information about the general ideas behind event analysis. Such training activities, also for people that do not themselves perform event analysis, create a general understanding of why and how event analysis is performed. If such knowledge is generally acquired among the people in an organisation, it is much easier to gain general acceptance of event analysis as a method and thereby support learning and open organisational context in association with event analytical activities.

A second context focused in Forsmark when MTO-analysis was introduced was to set up an organisational structure that could support these activities. In this particular case so called MTO-groups were formed both at the individual units and at the central quality and safety department at Forsmark. The central group includes participants from the units and is chaired by personnel from the quality and safety department. The group classifies events that are judged to have had influences from human and organisational factors. This is done by the use of descriptive categories and the statistics is used for trending. The results are discussed annually at the central safety committee at Forsmark. The central group is also doing reviews of event analysis and provides feedback to the people performing analysis.

Questions for evaluation

Imagine that we now had the task to evaluate the efficiency of activities and associated resources in connection to event analysis in Forsmark. What questions should we ask as a consequence of the model proposed?

In terms of the generic activity categories proposed we should try to evaluate **construction/design** of event analytical activities, the method used and the creation of other associated resources.

In terms of **verification** activities we would be interested in how the results from event analysis is verified. Another aspect of verification activities is how the recommendations from an analysis are **verified for implementation.**

In terms of **maintenance activities** we would be interested to know if the methods used are maintained and updated as a consequence of the learning that take place when doing event analysis.

We would also be interested in the **management activities** associated with event analysis. Let us briefly explore some of these issues and the answers we find.

Construction/design activities

The methodology used was originally the Human Performance Enhancement System (HPES) developed by INPO in USA. It was realised, however, that the methodology had to be adjusted and simplified to fit the purpose. A manual was worked out that described the method and this manual is used in training.

The work accomplished to set up the MTO-groups is also a design activity that, as said above, led to an organisational resource that supports the analytical work.

Maintenance activities

In order to maintain the analytical tool several changes have been made in the analytical technique over the years. Recently the manual was updated and those experiences previously drawn were incorporated in the new manual. For example, in the new manual an organisational cause-effect model was introduced and more focus was put on getting "depth" in the analysis. This was done by introducing some elements form the ASSET method developed by IAEA.

Verification activities

Each MTO-analysis performed is reviewed by the central MTO-group with respect to content and methodology. In the process of doing an analysis there is also common practice that the people involved (interviewed) are given opportunities to verify the correctness of the analysis and give comments. It is, however, the responsibility of the analysts to judge the relevance of the comments.

With respect to how the recommendations from an analysis are verified for implementation we note that this could be much better. No systematic system is used (this has been realised and a system for this verification is now under construction at Forsmark).

In conclusion we find that our questions focused on important issues associated with this particular activity and that we received satisfying answers in the sense that this activity is supported by maintenance, verification, and an organisational context that support the activity. We noted, however, a weakness in the system of verification of how the recommendations have been implemented but is satisfied by the observation that this weakness has been realised and that activities intended to eliminate the weakness is under way.

Questions about supporting resources

In this case we note that there is an instruction connected with the use of event analysis at Forsmark. We can also see that the training programs have succeeded in developing wide spread knowledge of the method (human resources). We note that the resource of "information support" is integrated with the use of the method in terms of meetings where the results of the analysis are discussed. Yet there is, however, no computer support for the analytical activities - something that can be developed in the future.

How about the time resources? People performing event analysis are taken from the local' MTO-groups and they have time reserved for these activities (an analysis takes about a week). However, since the people at the plant also do other activities, and sometimes lack time resources to perform an analysis, for instance in time of outage, there is an arrangement to receive support from a consultant company.

Another resource derived from the present model is the values and attitudes connected with a particular activity. As was mentioned above, analytical activities such as event analysis usually must be "marketed" in an organisation in order to have success. Root-cause analytical activities usually demand a *nearly* blame free culture in the sense that people must be open information sources and not fear punishment from opening their mind. Forsmark has succeeded rather well in this respect by providing information to many people about the philosophy behind event analysis.

Of course, many more questions can be put forward regarding this particular activity and the model can help in structuring such questions. Hopefully, the example given above may shed some light on how the framework can support parts of organisational assessments.

CONCLUSIONS AND GENERAL DISCUSSION

A common strategy to evaluate organisational factors (in a safety context) is to depart from some kind of rule system provided by standardisation organisations, regulators or the organisation itself. These rule systems are then used as the standards to which observations and deviations are compared. The models underlying such rule systems are often implicit and based on a combination of common sense, experiences and beliefs. For instance it is often assumed *that if* a set of formal rules are produced and communicated in the organisation, then people are *assumed to follow these rules. If* deviations are observed, then people are given more training or new rules are produced that are supposed to be better than the previous ones. There are many problems associated with this traditional approach, as most people know. The normative approach is a *necessary but not a sufficient basis for organisational assessments.* One of the more recent examples of normative approaches is to depart from the concept of "safety culture" in order to assess human activities. This sort of regulation of human values and attitudes are associated with many problems; it has sometimes a tendency to be "moralistic" and support a blame philosophy, although this is, of course, not the intention with the cultural metaphor. Perhaps it would be fruitful to separate the concept of "safety culture" from a more restricted concept of "*safety ethics*" to support the extended normative approach (what values, attitudes and behaviours that people should exhibit).

A second strategy of organisational assessment is to choose *a more open and analytical approach.* Some strategies of this type correspond to a class of risk analytical frameworks or "bottom-up" approaches, as I have preferred to call them. These models have the benefit of exploring cause-effect relationships connected to specific work situation and technologies. It is, however, difficult to use these models for more global organisational dimensions.

Even more global models, which have been created in the context of organisational science, also support an "open" strategy by providing a set of interesting dimensions to explore. It is, however, not always easy to take a normative stance with the help of such analytical models which sometimes make them difficult of apply in a safety context.

For organisational assessments all of these above-mentioned approaches may, of course, be combined and each of them have their pros and cons. The rule system approach has the benefit of providing standards, which, in turn, makes some of the "organisational factors" and their associated activities explicit. Unfortunately, there are also some weaknesses associated with the rule approach: Auditing activities using rule approaches have a tendency to stay with verifications of "documents rather than to explore what is actually done in different processes in relation to various organisational variables. Another weakness is that a host of "soft issues" (such as attitudes and values) have a tendency to be excluded from the assessments: factors that in reality have proven very important for maintaining safety. Modem quality assessment is, however, much more flexible than previously was the case. The concept of "process analysis" has, for example, arouse as a strong analytical tool for quality assessment. According to my experience, however, typical process analytical approaches often lacks contact with many issues in the human factor and safety domains.

Process analysis is, however, an example of a more analytical approach to organisational assessment. Formal rule systems are here not the primary concern but focus is put on activities, input-output relations, supportive functions etc. The strengths of these approaches are, for example, their concern upon cause-effect relations and many "organisational factors" become explicit in these approaches. For example, "learning" may be investigated in terms of how efficiently an organisation makes use of its information resources, how the organisation succeeds in importing information from the outside world, how recommendations are verified for implementation, how transformation of knowledge occurs in the organisation and so on. The framework presented in this article may be regarded as a variant of a process analytical approach.

Another, even more open, analytical strategy of assessment is to place trust on experiences and intuition from the analysts: neither formal rule systems nor risk analytical modelling are at the core of these strategies. People familiar with some sort of production activities usually have a good eye for the things that are god and bad in an organisation. Expert panels consisting of very experienced people are asked to give their impression of an organisation. There are some strong benefits with such a strategy but also some inherent difficulties. One weakness is that there can be an over/under focus on some selected organisational factors that reflect the panel's cultural preferences or values.

One reason to develop frameworks such as the one presented in this paper is that it attempts to combine all the strategies mentioned above. The "rule oriented" approach is implicitly present in the model in terms of a set of primary activities that is assumed to always be of benefit for safety. For example, analytical activities such as risk analysis are assumed to be of much benefit for safety. This can be formulated as a rule stating that *risk activities should be present.* The organisation should also have a systematic way to learn from previous events: both own and others. Also the strategy used in the present model, that is, to combine activities provides a way to investigate important supportive activities. For instance, the organisation should have a way to maintain and develop its analytical and verification activities. A similar argument can be raised with respect to verification activities - the organisation *should have a structured way to verify other activities in terms of their efficiency for supporting and* developing safety.

The process analytical strategy is evident in the model in terms of a general framework that can be used to model the relations between different activities and their support.

The concept of "safety culture," as seen in the present framework, has two basic components: (1) a structural component and a (2) human component. The structural component is not dependent on particular individuals but shall rather be conceived of as the result of accumulated activities and the "traces" these activities have resulted in. For example, an organisation may have developed a good "memory" for previous events in terms of cause categories. This structural aspect is, however, of no value if there are weaknesses in the human activities that utilise information resources. The knowledge, values and attitudes present in an organisation thus interact with the structural safety culture component.

Safety principles for the organisational domain

A variation of a top-down deductive approach would be to search for safety principles applying to the M&O domain but trying to be somewhat more specific.

In the nuclear sector the concept of "defence in depth" has been a basic design principle for the technological system. By this principle is meant that there are several layers of defences or "barrier functions" are implemented. The principles of redundancy and diversification support this principle by providing redundant and diversified safety systems. Another main principle is that of "separation" i.e. to functionally and physically separated important systems and components from each other. Still another safety principal is that of "the single failure criterion" i.e. the safety systems shall perform all safety functions required for a design basis event in the presence of any other single failure in safety related systems.

What I find very interesting with these principles developed for the technological system is that they seem to have a correspondence also in principles for management and organisation. For example the principle of "defence in depth" for the technological system seem to have a correspondence in redundant and diversified verifications. Such verification or control activities must timely detect and "block" the further progression of human mistakes. The concept of defence-in-depth" thus have a clear parallel in the administrative and organisational domain (which also is realised in some current models). Another parallel is to be found in analytical activities. By applying the principle of diversification of analytical methods one may increase the chance that risks are viewed from different perspectives. Also the principle of separation is usually applied for many verification activities in the sense that they should be independent and "stand alone".

Taken together it seems worthwhile to systematically explore how safety principles developed for the technological core system can be generalised to the M&O domain and we are currently working with such an idea.

The tentative model presented here can be of help in the process of formulating interesting questions to explore by means of questionnaires or interviews. But it must, of course, also be realised that "organisational factors" are associated to specific organisations, technologies and situations. The cause-effect relations among the factors will consequently vary depending on different context. The ideas presented here can hopefully provide a conceptual core from which to explore these cause-effect relationships by means of raising specific questions to by discussed by an organisation.

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