# Towards a method for the assessment of safety activities and their associated organizational context

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## ABSTRACT

The present paper reports on the first steps taken towards developing a methodology for the assessment of safety activities and their supporting organizational and administrative context in complex socio-technical systems. The method is based on a framework model that identifies four conceptual spaces, M-space (human related factors), I-space (information, methods, resources), T-space (technology) and O-space (relations within and among the other spaces). A set of so-called fundamental safety activity classes is defined (safety analytical activities, verification activities, human resource management activities, management activities, activities associated with building and using quality systems and experience feedback). These activity classes are used to support identification of specific activities within each general activity class. Departing from a set of tentative criteria and a set of assessment dimensions (communication, resources, integrity, learning etc) a quantitative assessment method has been developed and tested in a pilot project with the activity of PSA (probabilistic safety assessment) as the chosen assessment object. Lessons learned and possible further development of the method is discussed.

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# 1 INTRODUCTION AND BACKGROUND

The present research grew out of an ambition and an identified need to create an assessment tool to support the diagnosis of what is often somewhat loosely referred to as "human- and organizational factors of safety". It is our hope that the tool, when it is complete, can support safety management activities by being a cost-effective and practical evaluation instrument to assess a number of fundamental *safety activities and the supporting organizational and administrative context for these.* This paper deals with the preliminary steps taken towards developing such a methodology.

Being able to continuously evaluate safety issues related to human and organizational elements has received increased attention within operator- and regulator organizations. In the Swedish nuclear power plants, organizational evaluations are performed on a regular basis, for example in the so-called ASAR-evaluations. Other evaluations in the area are represented by USK (honor of Swedish quality), external audits, work climate investigations and conventional quality audits. Such evaluations give indeed valuable information regarding conditions of importance for safety. Unfortunately, however, many of these evaluations tend to function as "stand alone activities" with no systematic integration among each other. This, in turn, makes it difficult for safety management functions to arrive to an overview of the safety status for the whole system. One of the reasons for this, sometimes rather fragmentary state of affairs, is that various tools have been developed in different cultural and theoretical contexts. We believe, therefore, that a first step towards developing a more integrated assessment tool is to depart from a general framework model that could represent basic conceptual categories found in various traditions of safety management and associated methods.

The method presented here may be used in rather short time intervals for the purpose of obtaining an updated and *integrated overview* of how well an organization has succeeded to set up, support, maintain and develop safety in nuclear installations. The method is focused primarily on the integration of information about the foundation/context for safety activities and not the direct results obtained from these.

## 1.1 A framework model

Even a quick overview of methodologies that support assessment and control of risk- and safety reveals that there are many different conceptual categories at work in these systems. Many of the concepts can, however, be conceived of as instances of three basic and broad conceptual categories. (1) Human related concepts (action, cognition, attitudes etc); (2) Resources in terms of information, methods, procedures, financial resources etc; (3) Technology in various forms (hardware tools, production technology, information technology etc). We name these conceptual categories; M-space (human), I-space (information resources, financial resources etc) and T-space (technology).

The elements in these three general, and partly overlapping, categories must furthermore be "organized" in relation to each other (within categories and between the categories). To grasp this organizational dimension we suggest a category called the organizational dimension, or O-space. A simple and tentative model based on the above four categories is depicted in figure 1 below.

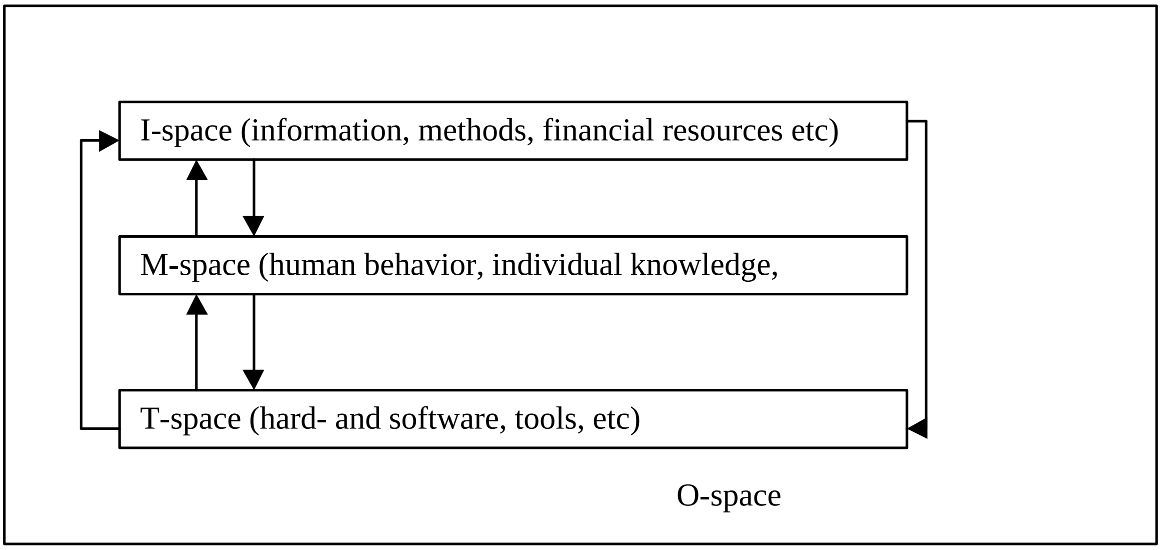



***Figure 1 A suggested framework model.***

It should be noted that the present conceptualization of the concept "organization" is more restricted than many other conceptualizations found in the context of discussions about "organizational factors" and safety. In our model, the concept of "organization" is reserved for the *relation among elements*, either within or between the three spaces (I-, M-, T-space). For example, in I-space, the organizational factors are the ones that describe how information, methods etc relate to each other. By the same token, the organizational factors of M-space include, for example, the relation among different activities in terms of communication, lines of authority, etc. Each space in the model includes a set of predefined elements (depicted in table 1.

**Table 1 Some examples of predefined elements of the M, T, and I-space.**

| Category space | Elements | Examples |
|---|---|---|
| I – space | Information (stored on paper, computers etc) | A policy, a drawing, an event report, results from a risk-analysis etc. |
| I - space | Description of methods | An method description for doing root-cause analysis. |
| I - space | Financial resources | Budget |
| M- spaces | Knowledge, attitudes, values of individual persons. | Knowledge of safety analysis, attitudes to violations. |
| M - space | Human activities | Maintenance activities |
| T - space | Technological element and systems, tools, buildings etc. | A safety system |

## 1.2 Human activities as a central departure

Central to our conceptualization, and as a result of the model above, is what we label as M-space. In particular we depart from the various *activities* that people perform to manage safety in complex systems. Activities, in our conceptualization, primarily belong to M-space but can be represented also in I-space (as organizational charts, descriptions of roles and responsibilities, job descriptions, instructions etc). Activities do also, of course, have organizational attributes in the sense that they relate to each other in various ways.

A cornerstone in the present model is a set of *generic activity classes*, see table 2. These classes have been derived both on a rational and an empirical basis and are assumed to be central to safety management of complex systems. We have restricted our search for these generic activity classes to those activities that have a particular goal to analyze, verify, and manage risk- and safety within and between the spaces of the model (for a somewhat more elaborate discussion of activity classes se section 1.3 below).

***Table 2 Generic activity classes.***

| Activity class | Comments |
|---|---|
| Safety analysis | An activity with an analytical approach that uses models/methods to identify potential risks in the system. |
| Verification/Test | Activities verifying that a real system/component or a representation of a real system/component fulfils specified requirements. |
| Quality related activities | Activities aiming to create, operate, and maintain requirements and a quality system and the process of verifying these requirements by auditing. |
| Management | Activities aiming to, on a general level, create, operate and uphold policies, programs and strategies for safety. |
| Experience feedback | Activities that construct operate and maintain systems in order to systematically make use of internal and external experiences. |
| Human resource management | Activities to find and develop, train etc personnel |

We furthermore assume that it should be possible to identify the generic activity classes as elements in any activity class of importance for safety. For example, a specific activity found in class X should have elements from the other activity classes.

The present framework do not include an explicit and generic accident model although it implicitly assumes that if the generic activity classes are present and well functioning then a strong base for safety is acquired. Validation of this assumption is not within the scope of this paper (the issue is furthermore discussed in the final section). Some brief remarks about accident causation in the context of the framework model are mentioned below.

Errors, deviations and latent weaknesses may arise as combination of elements both within and between the different spaces. Numerous pathways can be imagined that may produce harmful consequences; Information may be incorrect in I-space leading to actions that can influence T-space in a negative direction; Elements in T-space may deviate due to internal or external condition from other T-elements; Unsafe actions in M-space may arise due to lack of knowledge, attitudes etc, which, in turn, may produce deviations in both M-space, I-space and T-space etc.

Also note that actions in M-space may be located at many various “organizational departments” such as upper management, maintenance, operation, technical support etc and produce consequences in any of the spaces.
In O-space the elements can be reallocated both within a space as well as between the different spaces. This is also a commonly used safety strategy. For instance, elements of T-space may be located so that the physical distance increases to M-space or elements within T-space may be located so that disturbances in one T-element will not affect another T-element. I-space may be located closer to M-space so that necessary information may be easily retrieved or information may be located so that it is blocked to actors in M-space (for instance by passwords that block access to I-space). The most common basic safety strategy, however, is to use various defenses or “T-space barriers” to protect M-space from harmful energies from elements in T-space. In fact a basic safety strategy in nuclear power is to equip T-space with active and passive redundant and diversified safety functions (defense in depth).

## 1.3 Generic safety activities

We have already made the reader familiar with the general activity classes selected and shall below further elaborate on the rationale for this selection.

Since human resources, both from a logical and empirical perspective, are crucial for safety there should be efficient ways to manage these resources. We therefore conclude that *human resource management* should occupy a central role in safety management (training, development, assessment of attitudes etc). The importance of this general activity class is also frequently apparent in various standards, regulatory regimes, quality systems, human reliability models etc and it makes intuitively sense.

To understand the structural and dynamic conditions of the system it is necessary to build models that simulate both the interactions within as well as between spaces. Consequently, *risk assessment/risk analysis* should be basic to all safety science both to support construction and operation. We do not see it as necessary to prove or back up this selection since it follows from intuitive, empirical and rational arguments.

Because complex systems are dynamic and opaque with multiple interactions there should be strategies to continuously (for some elements) or periodically (for other elements) monitor both structural and dynamic features of the system. We call this activity *verification/test* and it includes, for example: test of safety systems, online monitoring of critical dynamic variables in T-space, non-destructive testing as well as some types of activities focused at I-space – for example check that procedures, drawings, etc are updated and correct. A great number of verification activities are found in complex systems and therefore we find it appropriate to suggest this activity class. (Admittedly, there may be some conceptual confusion regarding this class because the term "verification" has a broad general meaning in many contexts).

Since there are very large sets of components within each space and because of many possible interactions within and among the spaces it is essential to develop strategies to maximize learning and experience feedback. Consequently, we conclude that systems and activities bound to *experience feedback* should constitute an important activity-class. In this category we include, for example: event analytical activities, event statistics, and performance indicators.

Because we assume that all of the spaces outlined above are central to safety we conclude that there should be an overall supporting system that describes the general performance requirements and boundary conditions of the total system and its spaces. We call this a *quality system* and it should specify such things as roles and responsibilities for actors in M-space, the structure of I-space, etc. The quality system should also have an auditing function that periodically assesses the functionality of the system. The quality system movement has been developed from focus on T-space and more lately to include also the other spaces. Most nuclear installations also have regulatory requirements to implement quality systems and we therefore find it appropriate as a general activity class.

A final suggested activity class is simply called "*management activities*" to bring together specific management activities on a strategic level, for instance; strategic resource allocation, setting up safety policies, etc.

### 1.4 Relation to some other frameworks

It is not within the scope of this report to comment on all the related models and conceptual frameworks that can be found in the literature and bear similarities to the characteristics presented above. Some brief comments, however, are presented below.

In the literature focused on management- and management systems of safety, health and environment (SHE) we typically found so called “elements” of SHE management systems that are similar to the ones presented above.

For instance, in the E&P Forum´s SHE management model (1994) we recognize an attention on various sorts of *human activities*, such as evaluation or risk, review, monitoring, planning etc but also concepts focusing on both the necessary *resources* for activities as well as the *outcome* from activities in terms of goals, policies, procedures etc (these outcomes can also be understood as resources or inputs for other activities). In our model, the elements of I-space represent the outcome of human actions as “resources” (such as methods, rules, drawings, organizational charts etc). Resources may also be found in T-space in form of the production technology itself and in form of various hardware tools to operate and maintain T-space.

Another example of this general picture is seen in the very comprehensive questionnaire supporting the SMORT framework (see for example Kjellén, 2000). Among the questions at level 4 (i.e., higher management and management of SHE) we find questions focused on *activities* (resource management, identification and evaluation of risk, performance monitoring and auditing, resource management etc) but also questions focusing on the *resources* themselves (human resources, budget, time, etc) as well as a host of general support functions (informational resources) such as procedures, goals, plans, acceptance criteria etc (all of these may also be seen as outcomes from activities). Moreover, concepts such as “communication”, “responsibilities”, “culture and values” are frequent in most systems dealing with risk- and safety from a human and organizational perspective and these can, as shall be discussed later, be found in our model. Communication, for example is a property of M-space (oral communication) or it is transformed through I-space (written communication).

Essentially similar categories as the ones exemplified above appear in most systems supporting auditing, root-cause analysis, and risk assessment in various forms but framed in somewhat different ways depending on theoretical departures and traditions.

**To conclude**: Departing from a general framework model with the four spaces M-space, I-space, T-space and O-space we searched for a set of generic activity classes. These activity classes serves as a basis for; (a) organizing more specific activities belonging to the general activity class; (b) guiding the search for a set of evaluation dimension; (c) applying a recursive strategy were the general activity classes should exhibit elements of each other. For instance, in the general activity class called “risk- and safety analysis” we assume that the other general activity classes are present as important elements.

## 2 IDENTIFICATION OF SPECIFIC-ACTIVITIES WITHIN THE GENERAL ACTIVITY CLASSES

Given the preliminaries above – the four suggested spaces and the six activity classes of M-space– we now turn to a discussion of how one can go about to find a rationale for selecting the specific activities subsumed under each general activity class.

Finding the relevant specific activities can be done in several ways such as applying task analysis, risk analytical methods, process analytical methods and so on. Here, we shall concentrate on two more simple strategies, which we call the combinatory approach and "the empirical approach".

## 2.1 The combinatory approach

The model consists of the M, T, I-space and the organization between and within these (the O-space). The method identifies 6 important activity classes with the aim to evaluate specific activities subsumed under these. Each activity class should deal with the seven combinations of the M, T, I-space, see table 3. This is the combinatory/normative approach where one set up the 7 combinations and search for specific activities in order to verify that each relevant combination is covered by each general activity class.

***Table 3 The seven combinations of the M, T, I-space and their relation to the activity classes.***

| **Activity class** | **O-space** | | | | | | |
|---|---|---|---|---|---|---|---|
| Safety analysis | M-space | T-space | I-space | MT-space | MI-space | TI-space | MTI-space |
| Verification/Test | M-space | T-space | I-space | MT-space | MI-space | TI-space | MTI-space |
| Quality system related activities | M-space | T-space | I-space | MT-space | MI-space | TI-space | MTI-space |
| Management | M-space | T-space | I-space | MT-space | MI-space | TI-space | MTI-space |
| Experience feedback | M-space | T-space | I-space | MT-space | MI-space | TI-space | MTI-space |
| Human resource management | M-space | T-space | I-space | MT-space | MI-space | TI-space | MTI-space |

The above described combinatory approach departs from the general activity classes and searches for objects of these. For instance departing from "risk analysis" we look for what the possible objects might be in terms of the spaces; is there a specific activity looking for technical risks, for risk induced by humans, etc. In this case we would find that PSA as a risk analytical method is basically concerned with T-space. Not all combinations above are relevant.

## 2.2 The empirical approach

The other approach to discern specific activities subsumed under the general activity classes is simply to use general knowledge and experience from people within the system and ask them to make classifications. It is of course possible, as said above, to combine the combinatory and empirical approach to guide the identification process. But the empirical approach can also be done rather open by asking people to list activities and reasons for that these activities are seen as important for safety. If it is desired to quantify the more precise relative importance of these activities one should assign weights to the identified activities.

In a pilot test of the present model, the specific activities presented in table 4 were identified (the table gives only examples).

***Table 4 Examples of specific activities.***

| **Activity class** | **Examples of specific activities** |
|---|---|
| Safety analysis | PSA<br>Deterministic safety analysis<br>Process analysis (Work analysis, organizational analysis) |

| | |
|---|---|
| Verification/Test | Review of basis for design (modernizations, refurbishing)<br>Safety committee<br>Operation readiness verification<br>Non destructive testing<br>Functional testing<br>Verification & Validation of control room modernizations |
| Quality system related activities | Implementation of quality systems<br>Auditions and development of strategies/methods for the auditing process |
| Management | Initiation of organizational systems in order to maintain and develop safety.<br>Development of policies, guide lines, and program for maintaining and developing safety.<br>Resource allocation and general control of resource allocation.<br>Safety committee |
| Experience feedback | Use of indicator systems<br>Classification of events<br>Investigation of events (MTO-analysis)<br>System for external and internal feedback |
| Human resource management | General system for recruiting, keeping (and possibly down sizing) and also train personal. |

# 3 THE ASSESSMENT DIMENSIONS

In order to assess the activities, relevant assessment dimensions are needed. Our experience with quality audits, risk analysis, organizational assessments and event analysis together with a selective review of the literature focused on organization and safety indicated that the following general areas often are crucial in order to achieve a reliable safety process: (a) activities in terms of scope and depth. (b) resources for activities, and (c) outcomes from activities. The assessment dimension should, consequently, at least include these factors.

To grasp various dimensions of activities we use a recursive strategy (see section 4) and the dimensions scope and depth.

For resources we use the dimensions personal resources, time, financial, methods and “other”.

With respect to outcomes we use learning, efficiency and timeliness. Efficiency was selected because limited resources demand an efficient use. To use resources efficiently also becomes more and more important in competitive markets and this hold for safety activities as well as for other activities. Timeliness was selected since delayed projects/activities lead to stress and decreased motivation.

From a review of the quality literature it is also clear that one of the most important characteristics for a well functioning system is the existence of the PDCA-cycle (plan, do, check, act) and we therefore included a dimension to cover this area (completeness). Formalism as a dimension was selected to assess the extent to which activities are transformed to I-space and thereby could support the organizational external memory.

The present model also emphasize that the organization of (or arrangement within and between) the M, T, I-spaces are vital. We further assumed that there are several cases were it is important that the M, T, I-spaces are closely linked (communication, transparency) but, that there are also some cases where a close relation between the M, T, I-spaces are undesired (integrity).

With the above discussion as a general background, the assessment dimensions presented in table 5 were identified as important in order to assess activities and specific activities (the assessment dimensions are further defined in chapter 4:

***Table 5 Examples of assessment dimensions.***

| **Assessment categories** | **Assessment dimensions and categories** |
|---|---|
| Activities: (the activity classes are also used as assessment dimensions in the sense of asking if and to what extent they are represented for an activity) | Safety analysis<br>Quality system related activities<br>Management<br>Experience feedback<br>Human resource management<br><br>Scope<br>Depth |
| Resources: | Personal<br>Time resources<br>Financial<br>Methodological<br>Other, such as computers, locals, tools |
| Outcome: | Efficiency<br>Timeliness<br>Learning |
| Quality: | Completeness<br>Formalism |
| Concepts related to the M, T, I-spaces (O-space): | Communications<br>Transparency<br>Integrity |

One could always argue about the selection and completeness of the above dimensions. Some readers may lack their favorite dimension, other readers might think some are superfluous or overlapping. One may also suspect various dependencies among the dimension. Further research has to be conducted in order to ensure that the dimensions are sufficient in order to support the assessments. At this time, for example, we suspect that attitudes should receive a more explicit treatment in further versions of the model. However, one should keep in mind that it is necessary to restrict the number of dimensions used to make the tool practical.

# 4 REQUIREMENTS AND EVALUATION

## 4.1 Tentative requirements

### 4.1.1 Generic activity classes

To guide the search for specific criteria associated with the assessment dimensions for various specific activities we have developed a set of more general and tentative criteria. These general criteria are used to support the construction of detailed descriptions and associated measurement dimensions of the specific activities.

The criteria presented in table 6 are, by large, in line with many formal legal demands for operating a nuclear facility.

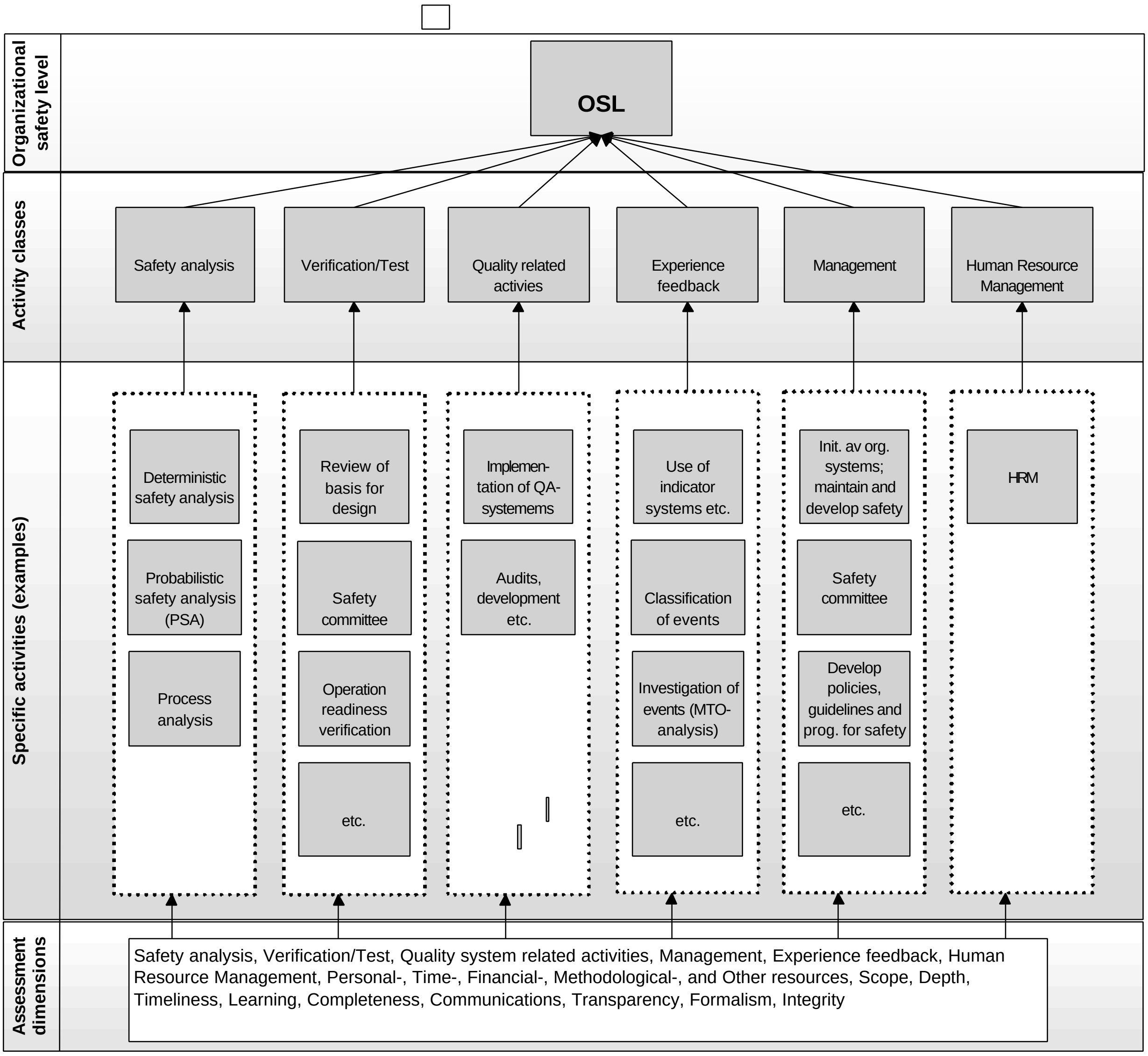



**Figure 2 Structure of the method for organizational safety level analysis**

***Table 6 Tentatively defined general requirements in order to ensure a robust organization with regard to safety work.***

| Component | Tentative (generic) requirements |
|---|---|
| Safety analysis | The organization shall work systematically by identifying and evaluating risks pro actively. The methods used shall consider technical risks as well as risks that can be linked to human behavior and the organizational/administrative design. |
| Verification/Test | The organization shall develop a systematic approach with a supporting methodology for a continuous verification/test/review of that technology, man and organization reach standards, quality demands and specifications.<br>**Note:** There is an overlap between the concepts verification/test and safety analysis. In this context, safety analysis is meant a more unprejudiced but systematic analysis (what if analysis) while verification/test have more clearly defined criteria. In reality, most verification activities have traits of safety analysis (from a qualitative point of view). |
| Quality system related activities | The organization shall have a quality system that describes and regulates the processes/activities and the requirements that goes along with these. To the quality system shall be an associated auditing process, which can control that the quality requirements are fulfilled. |
| Management | The organization shall demonstrate that it has a general system in order to preserve and develop safety with a clear management function that is ultimately responsible to develop policies, guidelines and programs to preserve and develop safety. |
| Experience feedback | The organization shall demonstrate that there is a system for collecting, analyzing and benefit from safety related information. The system shall take into account both its own and other operators experiences.  All parts of the MTIO-complex shall be considered. |
| Human resource management | The organization shall demonstrate a system for recruiting and training people in various functions. |

The general demands presented above are probably not especially controversial and are often found, in one way or another, in laws, regulations and quality systems. Given that an organization can demonstrate evidence that the above components are implemented and used properly it is reasonable to assume that there is a robust foundation for the safety work.

### 4.1.2 Resource requirements (tentatively defined)

An organization can be quickly degraded by lack of resources. The general requirements for resources has been based on the assumption that personal resources (nominal staffing and competence), time resources financial resources methodological resources and other resources (computers, tools, locals etc.) constitutes a foundation to preserve and develop the safety work both in the short and long run.

The access to resources such as personal, money, time, and methods can all be assumed to be critical in order to maintain and develop safety in the long run. This means that when focusing on organizational safety one should always pay attention to management of resources as an important factor. One important part of the method is therefore to examine the quality, amount and availability of the different types of resources. The tentatively defined general resource requirements are presented in table 7.

***Table 7 Tentatively defined general resource requirements***

| Resources | Tentative requirements/comments |
|---|---|
| Personal resources | The organization shall demonstrate that there are enough personal resources (own staff, consultants/entrepreneurs) in order to achieve the quality requirements regarding safety that has been set up for the operations. If the resources are not considered to be enough in order to achieve the quality requirements there must be an evaluation of how this could affect the risk level and that necessary actions has been taken in order to compensate for this increased risk level.<br><br>(The basic requirement is that the actors can demonstrate that they possess the practical/theoretical skills/knowledge and experience that is required in order for the specific activity to be performed with the standard that is demanded so that the safety is not endangered). |
| Time resources | The organization shall demonstrate that processes for planning, resource management etc. are in place so that conditions are created for the personal not to work under unacceptable time pressure |
| Financial resources | The organization shall show that they are aware of the potential conflicts between economical resources and safety/risk and demonstrate the strategy used for how to deal with possible conflicts. |
| Methodological resources | The organization shall present the tools/methods used in the safety work and demonstrate how the process works, for example by showing the methods used in risk analysis, incident analysis etc. |
| Other resources | The organization shall show that there are enough computers, room facilities , tools etc. in order for the specific activity to be performed to a satisfactory degree. |

### 4.1.3 Outcome, quality, and relation between M, T, I-components

For the outcome, quality, and relation between M, T, I-components we have suggested a set of general demands and recommendations, which have been used in order to evaluate the information that comes forward in the analysis with regard to the influence on safety. Note that the specific evaluation criteria used for these evaluation dimensions must be specific for each specific activity. Table 8 only list general requirements and comments that may be used to support this process.

***Table 8 Requirements and or/comments regarding the specific assessment dimensions.***

| Assessment dimension | Comment |
|---|---|
| Scope | For analytical/verification/test operations the activity area should have enough scope to cover all aspects of the MTIO-complex. For example, the safety verification/test should cover both the technology in itself AND its possible relation to man. In the same way risk analytical operations should include technology, human activity and the organizational context |
| Depth | Specific requirement cannot be made for this category. The aim is primarily to obtain a picture about how specialized the activity is and put this in relation to the specific demands that are possible to construct for different activities regarding specialization/depth. |
| Integrity | For some activities it is important that they are executed with high integrity, such as “independent” verifications of different types. |
| Timeliness | Fore some activities it is very important that they are performed within a specified time frame. This dimension investigates this property of some activities. |
| Efficiency | Investigates how actors experience the usefulness of the activity and its efficiency to utilize the resources that supports the activity. However, note that when it comes to resource utilization for safety work this category is hard to evaluate since different actors can hace very different opinions concerning the efficiency. |

| **Assessment dimension** | **Comment** |
|---|---|
| Transparency | It is an advantage if the different activities are transparent for other actors since this increase the likelihood that the results from the activity can be utilized by other activities. Very specific criteria are hard to establish. However, the assessment dimension is interesting in itself since it can say something about the efficiency in the safety work. |
| Formalism | Activities and processes should be formally described and traceable in documents/procedures/quality systems etc. The fact that an activity is not formally described does not necessarily mean that it is not performed to a satisfactorily standard. Formalism is, however, a quality requirement that can give several added values and is also a necessary quality requirements for many activities in order to achieve high reliability. |
| Communications | Describes the actors' ability to communicate the result from the activity to other groups that use or could use the product from the activity. |
| Completeness | The activity shall be complete in the sequence decision, planning, action, and evaluation,. |
| Learning | Describes the amount of learning/utilizing of the products and experience that the activity produces. One criterion for the lack of learning is if the events/incidents are repeated or if there is explicit information available internally or externally that has not been used in the safety work. A learning organization should also demonstrate how a function successively has been developed during the years on basis of made experiences. |

## 4.2 Evaluation

The specific activities are evaluated by judging the standard of the assessment dimensions. To achieve this goal a set of questions must be constructed. A central part of the evaluation process is therefore to frame the general criteria depicted in section 4.1 into more specific criteria for the different specific activities. A pilot test indicated that it is possible to also use some more generic criteria. For example, the recursive strategy used can make use of a general criteria stating that we should find elements of the general activity classes in all specific activities.

The activity classes are consequently used for a general evaluation of the specific activities. As said above, this is motivated by the fact that each specific activity in it-self should contain elements of all the general basic activity classes (that is, analysis, quality systems, management, HRM, experience feedback, verification/test). For example, when judging the standard of PSA-analysis (a specific activity of the activity class analysis) the general basic activities can be used in order to generate a number of questions for the analyzed specific activity, see table 9.

***Table 9 Examples of questions for the specific activity PSA generated from the activity classes.***

| Activity classes | Questions |
|---|---|
| Safety analysis | What analyses are performed in order to ensure that the studied specific activity is executed in a reliable way and with reliable methods?<br>*Note, this question deals with an analysis of analyses, i.e. tries to identify possible risks associated with an erroneous handling of the specific activity, for instance if the specific activity is performed using the wrong methods, data/models etc.* |
| Verification/Test | What methods are used in order to verify that the safety analysis is performed according to the specifications that are assumed?<br>*In contrast to the above question the verification/test does not primarily try to identify risks, but instead to review that the activity is actually performed as assumed and with the methods specified?* |
| Quality system related activities | What kind of regularly auditing is performed of the analytical activities?<br>*Here, a system is sought for which are used to perform the analysis and verifications that were investigated in the two previous questions.* |
| Management | How does the management system function that should make decisions regarding which analytical activities that should be performed and on what foundation are decisions taken about analytical activities? |
| Experience feedback | How is the system designed and how are the activities performed that shall make sure that the result from the analytical activities are executed into decisions and actions? |
| Human resource management | How is the system designed that shall make sure that there is a general system for recruiting, keeping (and possibly down size) and train personal. |

As said above, for many of the assessment dimension specific questions have to be developed for the individual specific activities previously identified. We suggest that this process is done with the support of experienced people representing the chosen specific activities. (see Table 10 for an example of generated questions).

### 4.2.1 Qualitative and quantitative approaches

The judgment of the standard for the assessment dimensions can be done either with a quantitative or a qualitative approach. In order to calculate the results we have chosen to quantify the assessment dimensions and we recommend that this should be done. It is of course also possible to use the present methodology in a more qualitative way and the examples provided previously can serve as an illustration of how supporting questions can be constructed.

For both the qualitative or quantitative approach there is a need to determine the standard of each assessment dimension. In the quantitative approach we used, numerical values are assigned to each assessment dimension. These where based on a number of predefined guiding questions and answers, se examples in table 10.

These values are then normalized so that each assessment dimension achieves a numerical value from 1 to 5, where 1 is weak support and 5 is strong support for the specific activity. (We do allow the interviewees to select an answer between the predefined answers, i.e. they can say that the standard of the assessment dimension is best described as being between the criteria for two non-normalized numerical values.

The standard of the specific activity is calculated by taken the mean value of the 21 constituting assessment dimensions (taken into consideration possible weights). The activity class is then calculated as the mean value of its constituting specific activities (taking into consideration possible weights). Finally, the organizational “safety level” is calculated as the mean value of the six constituting activity classes (taking into consideration possible weights).

### 4.2.2 Additional information collected

In order to cover important areas that might be overlooked by the assessment dimensions some open questions are also used which should cover the following areas:

- Weaknesses in, and threats to the specific activity, both in the short and long perspective.

- Strong points for the specific activity.

The above information is not used in association with the generation of the quantitative results but is supplemented in the result presentation.

### 4.2.3 Presentation of results

The results of the analysis are presented qualitatively, quantitatively and graphically (se examples in section 5.2). By doing the evaluations periodically and by using appropriate software, trends can easily be derived from the data.

***Table 10 Examples of evaluation criteria and derived points for the evaluation of the specific activity PSA's assessment dimensions.***

| **Assessment dimension** | **Questions** | **Points / Answers** |
|---|---|---|
| **Safety analysis** | Has the activity been analyzed as a process (from a safety analysis point of view)? | **2 P** The activity has been object for a process-oriented analysis where different elements and informational flows with regard to the activity has been identified. Risks in related to the performance of the activity has been analyzed systematically (for example the consequences of potential human errors).<br>**1 P** No systematic process- or risk analysis has been done for the activity. However, there are an acceptable level of knowledge in the organization regarding the process flows and the possible risks involved.<br>**0 P** No analysis has been made and there are considerable uncertainties regarding what kinds of risks that can be generated in case the activity is executed erroneously. |
| **Time resources** | Is there enough time in order for the work to be executed on a satisfactory quality level? | **2 P** There is, in general, enough time in order for the work to be executed with the desired quality level. Only, in exceptional cases there is such time pressure that the quality can be questioned.<br>**1 P** The lack of time is not considered to be a big problem. However, there are sometimes long intervals where the lack of time is experienced to be acute and substantially disturb the conditions for good work.<br>**0 P** Lack of time is a frequent and continuous problem and is considered to be a serious problem by a major part of those that are performing the activity. |
| **Scope** | Has all operational modes been modeled (for all stations)?.<br>For each operational mode;<br>Are all safety systems modeled?<br><br>Are all initiating events modeled? | **2 P** Yes, **1 P** If at least full power is modeled.<br><br><br>**2 P** Yes, **1 P** If yes with some exception.<br><br>**2 P** Yes **1 P** If yes with some exception. |

| Assessment dimension | Questions | Points / Answers |
|---|---|---|
| | Are HRA of category A, B, and C modeled? | **2 P** Yes, **1 P** If A and C. |
| | Are level 1 and 2 modeled? | **2 P** Yes, **1 P** If only level 1. |
| | Is a living PSA-model developed and is it in use continuously? | **2 P** Yes, **1 P** If there exists a living PSA-model and if it is occasionally used. |

# 5 PILOT TEST

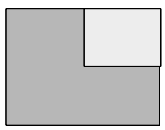
In a pilot test one specific activity in a nuclear power plant was analyzed with the suggested method. The specific activity selected for this analysis was probabilistic safety analysis (PSA), belonging to the activity class safety analysis. PSA is one of the most important analysis methods for conducting safety analysis in complex technical systems, and is performed by modeling technical systems (and some human actions) in logical trees and assigning probabilistic values for the malfunctioning of the respective components in this logical tree. As a result the probability for some unwanted events, for example core damage, is achieved.

The analysis group, who were all familiar with the PSA-process, generated the guiding questions (were almost all were quite “closed”, with only a few predefined allowable answers). These questions were later verified /complemented together with PSA-representatives. The analysis was then performed by having a work meeting with one representative from the PSA-group (which is the owner of the specific-activity PSA) and the analysis group that developed the method presented in this paper. In the work meeting the method was first described and the goal of the meeting was clarified; to evaluate the proposed method and get further feedback from the PSA-representative regarding the relevance of the questions. Then one member of the analysis group read the question and the PSA-representative answered. The answers were then analyzed and presented as shown in 5.1.

## 5.1 Summary of qualitative and quantitative results for the specific activity PSA

**Conclusions regarding the specific activity PSA**
The mean value of 3,6[1] was derived for the specific activity PSA, which is interpreted as the specific activity PSA is fairly robust and gives a good support for safety work. One area that should be further investigated, however, is the depth of the human reliability analysis.

**Color code:** Green with a yellow sector.
(The color code is short for ”As a whole an acceptable result, a mean value of above 3 has been derived but there are at least one assessment dimension that derived a value below 3).



[1] The numerical values assigned to the activity classes are normalized from 1 to 5, where 1 is weak support for the specific activity and 5 is strong support for the specific activity. If the value 4 is presented in the table were the basic non-normalized value could only get 0, 1 or 2, a value between 1 and 2 were selected by the PSA-representative.

*Table 11 Summary of derived values of the 21 assessment dimensions for the specific activity PSA.*

| Assessment dimension | Activity class: Safety analysis<br>Specific activity: PSA | Answers on guide questions, motive for derived pints, (The results have been deleted.) |
|---|---|---|
| **Safety analysis** | 3 | |
| **Verification/Test** | 4 | |
| **Quality system related activities** | 3 | |
| **Management** | 4 | |
| **Experience feedback** | 3 | |
| **Human Resource Management** | 3 | Not estimated, assume the value three. |
| **Personal resources** | 4 | |
| **Time resources** | 4 | |
| **Financial resources** | 4 | |
| **Methodological resources** | 4 | |
| **Other resources** | 4 | |
| **Scope** | 4 | |
| **Depth (PSA/HRA)** | 4 / 2 (3) | |
| **Integrity** | 3 | |
| **Timeliness** | 3 | |
| **Efficiency** | 3 | |
| **Transparency** | 4 | |
| **Formalism** | 4 | |
| **Communications** | 3 | |
| **Completeness** | 4 | |
| **Learning** | 4 | |
| **Mean** | **3,6** | |

**Answers on questions regarding threats, weaknesses, and strong points.**
(The result has been deleted).

## 5.2 Lessons learned

- The guiding questions and evaluation criteria for the assessment categories activities, resources, quality and relations of M, T ,I-components can be used quite generically. The guiding questions and evaluation criteria for the assessment categories outcomes, however, needs to be specific for each analyzed specific activity. Since these specific guiding questions and evaluation criteria need to be generated in close cooperation with the members of the analyzed specific activities, the relevance of the assessment dimensions are "anchored " in the groups.

- Specific weight factors should be developed for the assessment dimensions depending on which specific activity is analyzed. For example, there will specific activities where the assessment dimension integrity is vital and other specific activities where this assessment dimension is less important. The basis for these weight factors can be a combination of expert judgment, safety analysis and inspection of previous incident reports.

- The development of specific guide questions, evaluation criteria and weights will demand resources in terms of time and personal. After the guide questions etc. has been developed it is, however, our belief that the method will be quite resource effective.

- The method needs to be implemented with care, as it turned out that some of the steps, for example the recursive application of the activity classes on each specific activity was not entirely transparent to the users/interviewees. (The method has been simplified during/after the pilot tests).

- As it turned out, the results from the analysis of the specific activity PSA resulted in the conclusion that the specific activity was fairly robust. However, one shortcoming of the specific activity was later displayed in reality and this shortcoming was not identified in the pilot test. The cause of this was that the method was not used systematically enough. Had the assessment dimension “Human Resource Management” been used in a strict sense we believe that the shortcoming had been captured.

- The PSA-group agreed, on an overall level, that the qualitative results of the specific activity PSA suited their opinion of the specific activity.

# 6 DISCUSSION

## 6.1 GENERAL REMARKS

In view of the many activities typically identified in complex socio-technical systems one may wonder how it is possible at all to maintain a reasonable overview of what is going on and what risk level that can be assumed at a certain point in time. This is furthermore complicated by the rapid change that takes place in modern systems in terms of technology, fashions in management practices, changes in economic conditions, regulatory regimes etc. It seems rather obvious that personal both at management positions as well as those near the sharp ends of the technological productions systems are in need of updated information concerning both structural and dynamic risk related aspects associated with the various spaces in our framework. It is also rather obvious that not everything can be assessed in a complex system: priorities have to be made.

In a general sense, the process of maintaining an acceptable safety level in socio-technical systems can be regarded as a control problem with feedback control and feed forward control processes/activities and their combinations. Consequently such activities as risk assessment and experience feedback are, and should be, central objects to assess regarding recourses, methods, depth etc. Note also that it is not primarily the results of risk assessment, experience feed-back etc that are in focus but rather the “context” in which these activities occurs in terms of knowledge, resources, scope, methods uses etc. We assume that if a robust “context/structure” is present for the various activities, then there is an increased probability that the system would be more robust than otherwise.

The present framework has a focus on task, activities, control and resources, and this is also apparent in various analytical methods such as, for example, the Structured Analysis and Design Technique.(Marca, 1988) At present stage, however, the current methods is not developed to include support for detail modeling of the relation among different activities in terms of output and input relations. Instead we focus on a more general assessment of O-space in terms of communication, integrity, transparency etc.

The methodology has a certain degree of openness in that specific auditing/self-assessment questions should be worked out in close association with the members that occupy a specific activity. We see this as an advantage.

The here presented framework model and its associated evaluation tool share many aspects with other frameworks found in research focusing on assessment of safety management processes. It may be appropriate in this context to consider a framework by Hale et al (2000), which is based on an extensive research about strategies for supporting auditing of hazard management systems. We generally agree with these researchers in that there should be more focus upon making management models and tools more explicit in terms of tasks, functions, relative importance of certain aspects etc so that auditing methodologies can focus on what is important and not occupy themselves with details with no or an unclear relation to risk. We also find that, with a few exceptions, the requirement dimensions suggested by Hale et al (2000) share obvious similarities with the ones we suggested. For example, these writers suggest availability of time, competence, commitment, conflict resolution, internal communication and co-ordination, hardware, procedures and methods as important keyword for assessing the structure of management systems associated to various tasks. In our framework, similar concepts are present in the various spaces and assessment dimensions. We, however, note that "conflict solution" has not explicitly been mentioned in our model and note that as a weakness in our current framework especially since this factors is apparent also in other conceptualizations in various forms.

A perhaps "novel" feature of the presented framework is the somewhat odd, in this context, conceptualization of the term "organization" as reserved for a field that is used to order different objects in relation to each other. We generally find it confusing to name many elements belonging to what we call M-space, I-space and T-space as "organizational factor" which is done in some models and there is a tendency for inflation in what is called "organizational factors". We also find it very useful to keep a boundary between the cognitive aspects of M-space and their representation in terms of an external memory in I-space. (The organizational aspects of I-space are very interesting in itself because the structure of information in I-space may be assumed to determine how efficiently information is used in different situations).

Another somewhat specific aspects of our framework are the explicit use of a recursive strategy in order to support the search for assessment objects and dimensions. The predefined activity classes are assumed a normative status in activities related to risk- and safety. For instance, given an activity subsumed under the activity class "verification activities" we would look for tasks that involve risk assessment, experience feedback, human resource management, etc as well as verification applied on verification activities.

## 6.1 VALIDITY

Any model used in assessing safety should ideally go through tests of validity and reliability. In practice, however, many assessment systems are used with a rather weak background in those respects, which leads to considerable uncertainties regarding the results.

There are several general assessment dimensions that could be used to test the validity of a method of the kind that have been presented here: *Face validity*, for example, is a measure of how well a method is experienced to measure what it is intended to measure. We assume that our method has rather high face validity, at least in a more general sense, since it is focused on activities that both on rational, empirical and intuitive grounds have been found to be importance for safety. In the general organizational research and literatures and the methods used to assess this domain, it is not always clear how suggested organizational conceptualizations relate to safety. The basic cause for this is probably that much organizational assessment work is done with the primary focus on economy and not on safety. In discussing face validity one may perhaps react to our approach because it does not explicitly identify and use maintenance activities, construction activities, operation activities etc as key words. But as said previously, we see it as a point to create a conceptualization that may direct attention to those activities that explicitly focus on safety related issues and the context for these. For example, verification is a crucial activity in maintenance and our framework makes it explicit that these activities and its associated conditions should be identified and valued. By the same token verification is crucial in construction and we investigate the resources, tools etc (context) for these activities. This general strategy also has a point in that the created tool could withstand different organizational changes. Some verification activities, for example, may be transformed to an "operating department" in reorganization or be the subject of outsourcing but still be found on the list of safety related activities and receive focus.

Another dimension often mentioned is *construct validity* or how well selected concepts reflect the underlying theoretical model. Since the framework model is very tentative at this stage this dimension is not fully applicable in detail here. However, we have tried to select assessment dimensions that should present aspects of the general framework model (i.e. the four spaces) but we also do recognize that there are dimensions of M-space we do not address (for instance attitudes and values). Hopefully, however, we believe that these issues can be captured by other assessment methods. An alternative would be to also include aspects of, for example values, attitudes and safety culture. Indirectly the method captures part of this issue in terms of investigating the foundations for human resource management.

Another criteria for evaluating a method of the present sort is to ask to what extent it can be used with a *reasonable temporal span* to achieve *updated* information. We think that the method has a god chance to be used repeatedly, given that it is seen as cost effective and reasonable easy to use. One of the basic motives to develop the model was to receive updated information of the sometimes rather rapidly changing context. A general problem for safety assessment of "human and organizational" factors is that they cannot, according to our interpretation, be conceived with the general philosophy used in assessing technological components and systems. Humans and organizations are much more dynamic and less standardized than technological elements which implies the need for alternative strategies of assessment.

An assessment method should also give good opportunity *to reveal "new phenomena"* or areas not previously focused. We think that the combinatory approach in our method actually has possibility to direct attention to specific activities in the organization that easily may be forgotten in risk assessment and evaluations. The combinatory approach can be used in combination with expert judgment to support the search for areas normally not focused in assessments of this kind.

Another important concern in assessment methods is, of course, the *rigor and precision* that can be associated to the measurement itself. By adopting a quantitative approach we believe that we increase the probability for creating a tool that is more robust than otherwise had been the case with qualitative data.

Another question concerts the *control of variables* in the sense that the judgments may be affected by uncontrolled sources of errors such as general attitudes of the experts. Again, we believe that our approach to determine rather strict criteria for the assessment dimension do work against this risk. In the further development of this model there is, however, a need to control this issue by adopting various techniques associated to measuring the reliability of expert judgment.

An extremely important criteria for methods such as the one discussed is that it should be so designed that it can *motivate people to use it*. There are many excellent and theoretically advanced methods that, in fact, are never used because they are experienced as to complex and time consuming to have practical value. It is therefore important to further explore this dimension of the present method and to adjust it so it can receive a suitable interface towards the users.

## Final word

Although still at a developmental stage, we hope that the here presented perspectives and suggestions can stimulate researchers and practitioners to develop new ideas, concepts and tools in an important and interesting area.

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