

# Organisational learning in theory and practice – reflections from the nuclear industry<sup>1</sup>

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**Abstract:** Organisational learning has received a scholarly interest for some time. In parallel a recommendation has been expressed to the nuclear power plants to become learning organisations. The paper sets out from an introduction to theories and models in the field of organisational learning and proceeds then to specific characteristics of the nuclear industry. After that the paper gives a short description of the LearnSafe project and its main results in the field of organisational learning. From there it moves to a discussion of models that may provide fruitful guidance for reliability oriented organisations. A set of recommendations for safety management in the nuclear industry forms the last section of the paper. At the end some conclusions are drawn to give suggestions for future research in the area.

**Keywords:** Nuclear safety, organisation and management, organisational learning, learning organisations, strategy.

## 1 INTRODUCTION

Organisational learning has attracted scholarly interest already for some time (cf. [1], [2] and [3]). In parallel the recommendation to the nuclear industry has been that operators of nuclear power plants should become learning organisations [4]. In view of ongoing discussions in both fields, the purpose of this paper is to explore to what extent concepts of organisational learning and learning organisation can provide the nuclear industry with applicable guidance for development.

Organisational learning has been seen in the management literature as adaptations to a changed operational environment. The deregulation of the electricity market represented such a period of change for the nuclear industry, which during the years 1995-2005 introduced many tensions in the operation of nuclear power plants. Increased electricity prices during recent years have however caused a revival of nuclear power and the plants are now seen as cash-cows for electricity producers. Fulfilling the absolute requirement for safe operation is however still the major challenge to managers and organisations at the nuclear power plants.

The first major section of the paper summarizes theories and models of organisational learning and learning organisations in the form they have been developed in the academic community. The second section gives a description of the nuclear industry together with points of interface between theory and practice of organisational learning. After that an account is given of data that was collected in the LearnSafe project<sup>2</sup> and how it was analysed. Implications for additional model development are discussed in the next section. The final major sec-

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<sup>1</sup> Paper presented at the NeTWork workshop Event Analysis and Learning from Events, Steinhöfel near Berlin, August 28-30, 2008.

<sup>2</sup> LearnSafe – Learning organisations for nuclear safety. This work has been funded by 5th Euratom Framework Programme 1998-2002, Key Action: Nuclear Fission by the European Commission with the contract number FIKS-CT-2001-00162.

tion discusses what kind of guidance can be given to nuclear power plants in the area of organisational learning. The conclusions give some suggestions for further research.

## **2 THEORIES AND MODELS OF ORGANISATIONAL LEARNING**

### **2.1 Distinctions between individual and organisational learning**

Individual learning has been considered in many connections. Cognitive psychology has been interested in the formative aspects of knowledge and the learning of skills that transfer from a cognitive stage, through an associative stage and ending in an autonomous stage [5]. A similar observation has been made in the characterisation of behaviour as knowledge, rule and skill based [6]. Models of individual learning also consider how data is collected, generalisations are made, models are formed and decisions are made as the result of increased proficiency.

Organisational learning is enacted through individual learning, but organisational learning is often seen as something more than the sum of individual learning. Organisational learning has traditionally been seen as the outcome of training and development programmes, but the majority of organisational learning occurs in the day-to-day work, where the interactions between individuals within groups stimulate each other to acquire, interpret, reorganise and change information and thereby also skills, attitudes and beliefs [7].

In making a distinction between individual and organisational learning it is important to recognise the managerial role in organisational learning. Strictly speaking one may say that managerial learning would represent individual learning, but because of the managerial role of acting on behalf of the organisation a more correct categorisation is that it represents one form of organisational learning, albeit it's channelling through one or a few individuals. The managerial role in organisational learning can also be seen in the transfer of individual learning on a grass root level to influence the whole organisation [8].

### **2.2 Organisational learning and the learning organisation**

There have been discussions of the difference between the concepts of organisational learning and learning organisations. A simplistic definition is that a learning organisation is one that systematically builds organisational learning mechanisms [9], while others see the learning organisation as an unreachable ideal [10]. In trying to make a distinction between organisational learning and the learning organisation one may attempt to categorise content and processes of organisational learning to describe who is involved and what is taking place [11]. Another attempt has been to characterise different principles of collective learning, where teams or organisations are considered as units of learning and where learning occurs over time through collaboration and alliances [12].

The perhaps most important question is whether or not organisational learning can be managed [13]. It seems however clear that the learning process relies on a combination of deliberate and emergent strategies, which at least to some extent can be planned and controlled [14], [15]. However, learning often grows out of a situation of confusion, where the organisation has to generate answers to the three questions, where did we come from, where are we now and where do we want to go [16].

The distinction between single and double loop learning [17], has been further generalised into a third loop of organisational learning [18] and the feedback loops can be seen as a categorisation of where changes have to be made to make a difference in organisational behav-

ious. Another distinction is made between tacit and explicit knowledge and it is argued that organisational learning occurs through consecutive cycles of socialisation, externalisation, combination and internalisation [19]. Skills can also be tacit and methods for eliciting tacit skills have been proposed [20]. The important lesson here is that organisational learning has to be considered as a dynamic process [21].

### **2.3 Organisational components of learning**

There are many different components that have to be taken into account in a systematic study of organisational learning [22]. Some of these components have emerged to be research fields of their own, such as knowledge management and communities of practices. Others have their own connections to established fields such as politics and ethics. This has led to some disagreements on the nature of organisational learning and how research should be carried out.

Organisational memory is an important concept in organisational learning, where access to organisational memory is depending on the media for storage. The formal part of organisational memory is taken care of in archives, records and documentation that may be stored in different ways and in different formats. The informal parts are far more diffuse and encompass components such as culture, practices, structures and the physical environment, which have to be accessed through individuals, who can answer specific questions [23].

There are multiple facets of organisational learning, where transparency, integrity and accountability of the individuals as well as the orientation and form of inquiry become important [24]. Differences can also be seen depending on the forms of interaction to take place between two individuals, within a group, through the whole organisation or through a virtual network.

Power structures within the organisation can have their own influences on organisational learning independent of their influencing factors. In a skill oriented organisation they may depend on a mastery of tasks [25] and in a decentralised organisation on small group interaction between old-timers, young masters and newcomers [26]. More generally the influence of power structures can be seen as politics in a wider sense, with the consideration of rights and obligations [27]. These views also stress the need for considering acts of communication and negotiations as well as asymmetries of power.

### **2.4 Facilitators and hindrances for organisational learning**

Facilitators and hindrances for organisational learning can have both individual and organisational causes. Among the most important facilitators are gate keepers, team tenure, effective internal and external communication as well as efficient problem solving strategies [28]. Psychosocial filters by which social confidence and the credibility of knowledge source is taken into account can emerge as hindrances for organisational learning [29]. The learning perspective with the possibility of learning traps and premature learning can also create temporal and spatial boundaries to learning.

Individual facilitators and hindrances to learning may be created by perception of need, ability to learn, cultural values, beliefs, emotions and ability to communicate. Organisational facilitators and hindrances to learning may correspondingly be created through organisational processes that provide structure, feedback and rewards. Especially if the organisation identifies learning needs, sets learning goals, reviews performance, makes new experience and knowledge available, tolerates mistakes, encourages planning and review, challenges traditional practices, etc. it can have a large effect on organisational learning [30]. Similarly if the or-

organisation has a rigid hierarchical structure with poor communication and feedback, internal competition and small economic margins, it can stifle organisational learning.

Trust is among the most important facilitators of organisational learning. Trust is for example considered to be more important than formal collaborative processes [31]. Trust in intention, and trust in competence support reductions of uncertainty, give larger margins of freedom and supports listening [32]. Trust can also support openness in the organisation by rewarding voice as compared to silence in certain situations [33]. Trust can also decrease the number of power games played in the organisation [34].

## 2.5 Organisational learning in a systems perspective

Systems thinking has been proposed to support an understanding of organisational learning. The benefit of systems thinking is the division between whole and parts and a consideration of the dynamics in the phenomena observed. There is also a considerable amount of models, such as open and closed loop control, feedback and feed-forward, observability and controllability, adaptive and learning systems, etc. that can elucidate specific mechanisms observed.

Systems thinking grew out of control theory to provide a foundation for important concepts such as system *state*, state *trajectories* and *optimal* control [35]. A theory of learning cannot be separated from a theory of control, because learning carries an implicit conception of something better, i.e. a value function in the state space of the system. Learning also includes actors, who are able to sense how this value changes when the system moves along a trajectory and who have means to influence this trajectory by mounting forces to change. If the actors have largely similar possibilities to exercise force on the system, one may speak about an emergent trajectory. If there is one or a small group of actors, who have a larger influence than others, one may speak of planned or co-ordinated action.

Time constants that are observed in learning can with such models be understood to originate from the inertia of the system as compared with forces that are exercised on its state. If for example a manager with a strong personality is forcing an organisation to move in a certain direction, s/he can most likely overcome considerable inertia. Similarly a co-ordinated action of several less powerful actors can also overcome a similar inertia to initiate a change in the state of an organisation.

## 2.6 Applications of a systemic view

According to a systemic view learning is always related to a state change of the organisation, where the state is seen as a combination of the states of its members together with the state of formal and informal control systems. Learning is connected both to unlearning earlier and learning new practices [36]. For members of the organisation this would involve changes of attitudes and beliefs, which may require major efforts and take a considerable time. For whole organisations to change the effort may be even larger, because adopting new practices involves formal training, updating of the management system, new tools and machines, etc.

The time it will take to transfer from old to new practices will depend on many things, such as the perceived size of the change, a willingness to adopt new beliefs, the organisational climate, the power relationships between the actors in the organisation, etc. A trustful climate and open discussions are likely to help in bringing a change forward [37]. In some case it may even be fruitful to assist the development of constructive disagreements on important issues.

Organisational learning is in reality a complex process in which hundreds of actors may interact, all with their own aspirations, proficiencies and preferences. In this interaction they influence each other and learn. The difficulty is to create guidance for how this process should be managed. A thoughtless application of models and advice may make involved managers less credible and thereby decrease their ability to control of the process. The best controlling influence may actually be obtained without trying to exercise direct control, but instead by supporting empowerment and participation by stressing common interests and ethical issues.

### **3 ORGANISATIONAL LEARNING IN THE NUCLEAR INDUSTRY**

#### **3.1 Organisational characteristics**

Organisational structures in use at nuclear power plants are designed to meet the need to manage several areas of deep technical skills and knowledge that are necessary to run the plants. Organisational innovations such as lean structures with a few organisational levels, empowerment and process orientation have been tried, but a common view today is that operation of nuclear power plants has to rely on a hierarchical structure, with formalised procedures for decision making and work control. A continuous flow of technical modifications of the plants is handled through a parallel use of project organisations.

Nuclear power plants have a very long operational life. Most nuclear power plants that are in operation were initially designed for thirty to forty years of operational life, but today many plants are planned to run for at least sixty years. The long operational life places many challenges on the plants. One challenge is connected to technical development, which at some point of time will force the plants to modernise, simply due to the fact that they cannot get spares. Another challenge is connected to maintaining skills and competence for the personnel over several generations of staff.

Regulatory oversight implies that it is not enough that the plants are safe, but they are in addition forced to provide continuous proofs to the regulator that they are safe. International practice places the sole responsibility for safety on the operator of a nuclear power plant. This is a straightforward requirement, but it also carries a subtle contradiction in the assumption that the regulator should not manage the plants, but still influence what they do [38].

Nuclear power is a political technology, which stirs emotional reactions from politicians, media and the general public. This means that the nuclear industry's words and deeds are watched closely and that some decision power also is exercised in political processes. If something unexpected happens the scrutiny is started immediately and efforts to restore public confidence and trust may be considerable.

#### **3.2 Plant, people and processes**

The nuclear industry has since the first commercial plants that were built in the 1960s gone through important cycles of learning. This process of learning has however unfortunately been marked by incidents and accidents that have brought earlier shortcomings in plant design and operation to the surface. Early safety concerns were focused mostly on technical matters and considerable efforts were spent on defining principles to be applied in specifying the requirements that would ensure the plants to be safe. The deterministic safety principles that were created are still used today, but a few incidents in the early 1970s demonstrated the need for amending them with probabilistic safety criteria.

The TMI accident brought a focus on the people who operated and maintained the plants. The accident brought many improvements in control room design, procedures and operator training to nuclear power plants all over the world. This development also triggered research in human behaviour and probabilistic safety assessments to provide estimates of the likelihood of human errors. The early 1980s was however not yet ripe for more thorough discussions of the influence of organisation and management on nuclear safety.

The Chernobyl accident changed this situation. The post-accident meeting hosted by IAEA identified a deficient safety culture as the root cause for the accident [39] and a new cycle of learning was initiated in the nuclear organisations all over the world. Today it is common practice to address the three systems of the plant, its people and used work processes or with the use of a different set of terms man, technology and organisation. In hindsight it may be considered surprising that it took nearly half a century and two major accidents to create this insight.

### **3.3 Management systems**

The management systems in use at the nuclear power plants build on the quality systems that were introduced in the late 1970s [40]. At nuclear power plants today different concerns such as quality, safety, environmental protection, labour safety and security have been integrated to form a single management system. The management systems of today typically have a hierarchical structure starting from the top with descriptions of organisational values, mission and vision and ending at the bottom with detailed instructions for carrying out specific activities and tasks.

The instructions form an important part of the management systems and they can on a general level be divided into three groups: operational, maintenance and administrative instructions. The operational instructions are further subdivided into instructions for start up and shut down as well as disturbance and emergency instructions. The operational instructions are usually validated at simulators and they are assumed to be followed literally. Maintenance instructions are also assumed to be followed literally, but administrative instructions are often seen more as providing guidance to ensure repeatability in the activities.

The management of change at nuclear power plants goes through strictly controlled procedures, which are enforced by the regulator. Special administrative instructions are written and used to control this process. At nuclear power plants a separation is usually made between organisational changes and technical modifications of the plants. The formal procedures for the management of change are sometimes perceived as preventing even well motivated changes, but experience has clearly demonstrated the need for thorough reviews of all modifications and changes before they are introduced [41].

### **3.4 Organisational culture**

Where the management system can be seen as the formal part of the organisation, the organisational culture can be seen as its informal part. Organisational culture has to do with shared values and beliefs that determine attitudes members of the organisation have towards many different things. One model of organisational culture separates between artefacts, espoused values and basic underlying assumptions and argues that organisational culture is difficult to assess and change [42].

A common view is that organisational culture is an emergent property that does not lend itself to conscious control. Organisational culture will however change over time in response to ex-

ternal events and achieved and perceived performance. Good performance over extended periods of time has been claimed to increase the risk of complacency. Incidents and accidents have also shown that gradual changes in organisational culture have created more lax attitudes for example towards instructions. A common practice today is that nuclear power plant carry out organisational surveys that give reflections of the prevailing organisational culture.

IAEA has since the Chernobyl accident actively been advocating the concept of safety culture to the nuclear power plants [43]. Safety culture can in this connection be seen as an organisational culture that safety oriented organisations should have [44]. IAEA has been active in developing guidance for activities that can support a good safety culture [45]. The property of being a learning organisation has also been associated with a good safety culture [46]. In addition IAEA has recently developed a service of assessing the safety culture of organisations that is marketed to member states.

### **3.5 Systems facilitating organisational learning**

The nuclear industry has a tradition of sharing knowledge that over the years has contributed to world wide organisational learning. These traditions have resulted in formalised systems for an exchange of information operated by IAEA and WANO. One example is the feedback of operational experience that documents and shares lessons learned from incidents all over the world. These systems lay a dual responsibility on the nuclear power plants to report and analyse their own incidents and to extract and apply lessons from incidents at other nuclear power plants in the world.

IAEA and WANO peer reviews also support organisational learning. A team of 10-20 people from several plants visits a host plant for a period of 2-3 weeks to assess performance in several organisational areas. This practice gives the opportunity both for the host plant and for the people taking part in the review to learn. The effect of the learning is enhanced by revisiting the host plant some 18-36 months later after the peer review.

The management systems contain several functions that facilitate organisational learning. The yearly planning cycles in which plans are compared to performance outcomes to analyse deviations and to suggest improvements, is the most important of these functions. The regular audits of work processes and organisational units is another function that provides similar opportunities for organisational learning. Most management systems of today also include requirements on regular performance reviews by the senior management. A regulatory requirement is in addition that all nuclear power plants go through periodic safety reviews with a time interval of approximately ten years.

## **4 INSIGHTS FROM THE LEARNSAFE PROJECT**

### **4.1 The LearnSafe project**

The LearnSafe project was set up to address issues connected to organisational and management that have an influence on nuclear safety. The project was especially aimed at assessing consequences of a period of rapid change in the nuclear industry that took place after the deregulation of the electricity market at the end of 1990s [47]. The LearnSafe project was built on established channels of co-operation in an earlier project [48].

The LearnSafe project was divided into two major phases of which the first addressed *challenges* for the industry as seen by senior managers [49] and the second collected and analysed

views on *organisational learning*. The discussion below gives an account of results only from the second phase of the LearnSafe project.

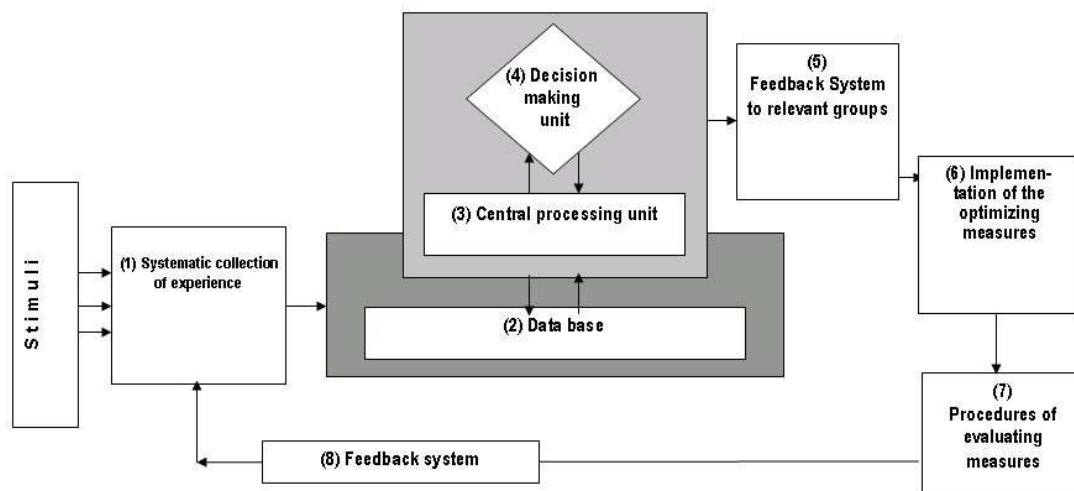
## 4.2 Data collection

Data in the second phase of the LearnSafe project was collected in response to the following three research questions:

- Q1: What kind of features and attributes characterize learning organizations?
- Q2: a) What are the most common hindrances to organizational learning and b) how can they be removed?
- Q3: How are various company cultures and sub-cultures influencing organizational learning?

The data was collected in a combination of group discussions and Metaplan (cf. [50]) sessions. The collected data consists of nearly 1000 statements given by more than 100 managers from nuclear power plants in five countries. In addition to the international data collection some spin-off activities were undertaken in Finland and Sweden, which generated additional background data.

Responses to the research question Q1 were generated in group discussions consisting of 2-4 managers (1st or 2nd line) who dealt with feedback experience, knowledge management, organizational development, training, evaluation of implementation of corrective actions, responsible persons for audits, etc. The Figure 1 was used in the discussions to illustrate the overall learning feedback to identify facilitators and hindrances at different steps. Furthermore, factors impacting learning together with formal and informal practices for learning were discussed and recorded.



**Figure 1.** The learning organisation metaphor that was created in the LearnSafe project to govern data collection.

The generated responses to research question Q1 were used to inform the Metaplan session participants in the collection of data for the remaining questions Q2 and Q3. The Metaplan session was conducted with groups of 5-10 managers from different organisational positions. There were some national variations in the data collection procedures as a result of the practical availability of people at the participating nuclear power plants.



### 4.3 The method used for data analysis

The difficulty in analysing sentences that are written in normal language is connected to a need for metrics in a space of statements. We developed metrics in three stages of which the first stage was connected to selecting a descriptive model that would be as simple as possible, but still be able to encode the richness of the material. This model was seen as providing dimensions according to which the statement could be assigned to fuzzy sets according to a coding guide (cf. Appendix). The data was coded by three persons to avoid bias in the coding. Each of the statements was in this way given an unambiguous quantified position in the space as defined by the model. The data was finally analysed with hierarchical cluster analysis.

This method has several advantages as compared with classical content analysis methods [51]. Firstly the descriptive model can be selected to depend on the intent of the analysis, which means that the analysis can be carried out with different interpretations of the data. Secondly by associating each statement to one or several dimensions, where the strength of membership is given a specific value, it is possible to model the ambiguity in a statement more accurately as compared with a binary logic of membership. Thirdly the solutions obtained in the cluster analysis has a natural variation, where a larger number of clusters gives a better total fit and a lower number implies that some of the clusters are amalgamated and the corresponding cluster centres are moved. Fourthly the cluster centres establish a metrics in the space of statements that can be used to compare positions of single statements. Finally the possibility to start the cluster analysis from different initial points makes it possible to evaluate the robustness of the obtained solution.

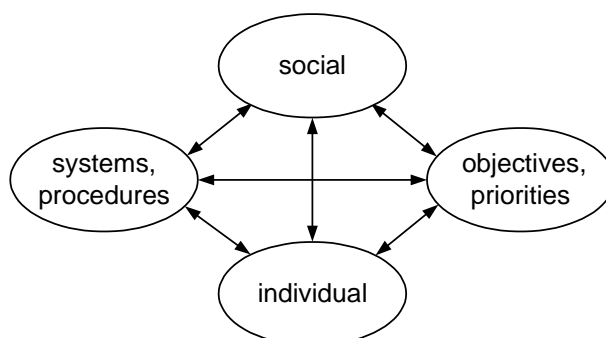


Figure 2. Model used for the coding of statements.

The arguments for using the model in Figure 2 was that it identifies four dimensions that can be interpreted to provide a simple way of categorising facilitators and hindrances on two axes. The first axis related is to the formal organisation with one pole of systems and procedures that reflect the present and the other pole of objectives and priorities that orients towards the future. The second axis is related to the informal organisation with the two poles of individual and organisational influences.

### 4.4 Results from the cluster analysis

The cluster analysis of the whole data set found feasible solutions with eleven, six and five clusters. Two additional cluster analyses were carried out, one restricting the data set to the facilitators and the other restricting the data set to the hindrances. From the facilitators' six and from the hindrances seven clusters solution were identified. The eleven cluster solution is listed in Table 1.

**Table 1. The eleven cluster solution with characterisations divided into facilitators and hindrances**

CL	CL name	fh	Characterisation	Statements next to the cluster centre
A	Objectives, priorities and resources	facilitators	Planning Prioritisation Use of resources	An organisation that is successful at learning is able to prioritise and to look to external bodies for support i.e. WANO, INPO, etc. the organisation has decided on what's important and it has been broken down to a level where it is understood Keeping away "cul-de-sac" projects but fashionable Resources will always be of short supply. The solution is not the resources themselves, but how the existing resources are used. To be discussed on a case basis. Sound activity planning. The Deming wheel of continuous improvements. How much time do we have for thought? Everything has to go so fast.
		hindrances	Time pressures Heavy workload Wrong priorities	Lack of time is partly dependent on an uneven loading and partly on difficulties to set priorities. Company management has a short-term focus A high operative loading prevents a strategic outlook. Economic pressure (negative) Lack of time in a choked organisation.
B	Formal systems and practices	facilitators	Exchange of experiences Efficient processes and practices Information management	Peer reviews were performed voluntarily-based regarding specific topics. Particularly national peer reviews were described as useful for the participants. One solution is to separate between brain storming, planning and decision meetings. It is important that ready proposals are brought to the meetings. (Co-operation with) operating company: internal experience exchange A software tool is used for in-depth-analysis, the administration of events and corrective actions, and the following up of corrective actions. Introducing continuous learning channels
		hindrances	Too complex systems Deficient follow-up Inadequate training	too complicated systems for simple functions Missing follow up. Missing follow up. Formal training (too much) An absence of review of effectiveness of previous changes (learning) Too many routes.
C	People's attitudes and orientation	facilitators	Knowledge sharing Interaction skills Motivation	it is necessary to plan and prepare oneself ability to learn from experience people have a skill in sharing knowledge persons, who show up at unexpected places Employee motivation to learn is thus crucial to learning as you can not force people to learn if they don't want to.
		hindrances	Self-conceit Disappointments Resistance to change	Focal point in self-image. Self-conceit Opposition in principle (a change creates work). Recurrent disappointment in promotion and career development plans Effects by individual
D	Corporate culture and traditions	facilitators	Common language Encouraging climate Informality	A common language was assessed as necessary precondition e.g. for learning by experience. staff parties The organisational climate should be positive and encouraging. There should be a common language, a feeling of togetherness and being of the same family. discussions in the corridor
		hindrances	Tradition Group think Inertia	Tradition. Group thinking Culture of self-criticism – always emphasising the negative Tradition Functionalisation/group thinking
E	Communication, guidance and appraisals	facilitators	Proactive management approach Clear messages Engaging people	There is a need to learn proactively so that the organisation can question what it is doing and understand how it can improve and do better. (Change initiatives should be) Well communicated Working groups should be given clear assignments. Goal oriented wages (When starting a new project) it is important that the correct organisational level is engaged.
		hindrances	Diluted messages Lack of guidance Poor HR management	Not being able to sew a clear message from top to bottom without dilution Lack of guidance Top-down driven: Organisational change driven from the top down may not always gain the full support of those who need to implement it. Consensus is a powerful tool Inadequate personnel or organizational development Comparison with 'world class' utilities is helpful to demonstrate standards but can also make 'learning' a daunting task
F	Maintaining touch and focus	facilitators	Subject-matter focus Realistic goals Active management	Don't attempt change that you can not see through There is a need to be patient with new initiatives. If you are not realistic at the start then you are simply setting yourself up for a failure. there is an ability to set priorities right Learning in project, show the challenge, projects are not just the question of timetables and costs. (Learn) Things necessary to survive.

		hindrances	No time for reflection Focus on immediate challenges and issues Inability to prioritise	Focus on individual problems and not so much on collective problems Lack of time Lack of management commitment Peoples priorities have traditionally been focused on sorting the immediate, local problems and in some respects learning is seen as something to be done when the higher priority work has been addressed Lack of time for reflection
G	Openness and trust	facilitators	Tolerance Openness Challenging old habits	there is an understanding that also minor things may be important there is a willingness to struggle on The willingness to challenge old practices on all level was described as essential for organizational learning. An organisation needs to be confident in its ability to learn and thus self-esteem is an important issue. Discussing "faculty thinking" several participants pointed to the need to center the overall achievements instead of the achievement of certain departments/groups.
		hindrances	Lack of questioning Repressive climate Fear for change	Lack of questioning Discrimination of other learners people do not dare to speak up Reluctance (fear) for changes. 'It's the way it is done on this station' - lack of willing to change
H	Work community	facilitators	Acknowledgement Respect Humility	Positive past experiences can also have an impact in that when an organisation is doing well its employees may not be motivated to learn. Acknowledging personal contribution Relate NPPs future success and 'learning' ability to personal job security and professional pride (in the nuclear industry) The visibility of managers is important. Visits by managers are always positive; it is possible to convey own views upwards in the organisation. How do we function as managers? Are we concentrating too much on our own things? Humility is important. An organisation needs to be able to identify and accept when somebody else is doing something better.
		hindrances	Frustration Fatigue Poor communication	Aged organizations Too much time in the same job Reluctance to think in systems Lack of communication Poor communication of the need for change (learning)
I	Encouragement and rewards	facilitators	Focus on goals Recognition Ability to adapt	(Change initiatives should be) Not allowed to fade away Recognition of achievements An organisation that questions what it does and changes in response to the questions that it asks. Reinforce the message that 'to do nothing is not acceptable' even if you believe that we are ok as we are Need to critically inspect activities that are done by tradition.
		hindrances	Bad leadership Missing rewards No room for critical thinking	No commitment from lead team to be involved in particular aspects of learning Missing rewards, fresh ideas are not supported. Pressure to perform Critical thinking is not supported Negative aspects of nuclear energy emphasized regularly and positive side rarely considered.
J	Adequacy of means and methods	facilitators	Building knowledge Understanding how the "system" works Paying attention to the individual	There is apparently a need to demonstrate organisational interactions in an interesting and pedagogical way. Individualized crediting Rules to / right to initiate work tasks. There is behave to experience from the outside, 1) there we are/do better 2) that's interesting, there we may be forced to do something. (Learn) Things that may be good to know.
		hindrances	Mismatch between needs and means Wrong methods Wrong assumptions	Missing requirements Operational experience different from operative manners in the plant Immediately when something is started it grows to be something large. theories that fit poorly into daily practices Opacity
K	Networking and co-operation	facilitators	Healthy criticism Networking and co-operation Performance appraisals	practices are called into question Building workgroups and teams Make the process of change easy, fast and efficient there are good contact networks Appraising daily work performance
		hindrances	Inefficient meeting and communication practices Overconfidence Missing reality checks	When a meeting is called with specific persons, it goes far into the future. Many issues could be resolved just going in and speaking with the right person. Safety indicators may create a false feeling of security. Risky if investigations are undertaken only when deviations from the "green area" are observed. Lack of communication channel tactical presentations of events

## 4.5 Clusters and their mutual relationship

All resulting cluster centres show loadings in all four dimensions. An analysis of the cluster centres in the different solutions revealed several similarities. For example four of the cluster centres (clusters A, B, C and D) were found to be almost identical in all solutions. Furthermore the fifth cluster centre of the five cluster solution was also found in the eleven cluster solution (cluster H) and similarly the two remaining clusters of the six cluster solution as separate cluster centres in the eleven cluster solution (clusters F and K). Similar correspondences were found between the six cluster solution of facilitators (clusters H and I) and the seven cluster solution of hindrances (clusters E, F and G) in the eleven cluster solution of the whole material. The cluster J and K did not show such similarities in the lower order cluster solutions.

A Euclidean distance model in a two dimensional plane of the cluster centres was calculated (cf. Figure 3). A short distance between two clusters centres suggests similarities between the clusters and vice versa. The two dimensions of the plane do not have any meaning, because they are iterated to give a reasonable approximation of the distances between the cluster centres in four-dimensional space.

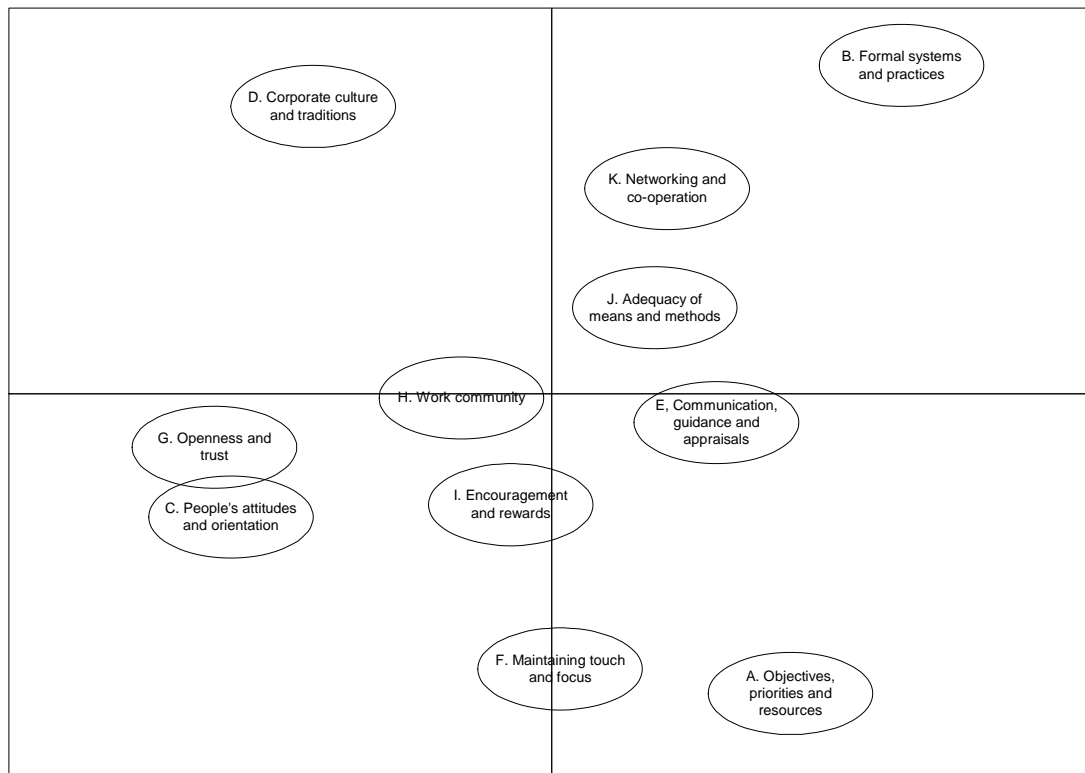


Figure 3. Euclidean distance model of cluster centres.

## 5 IMPLICATIONS FOR MODELLING

### 5.1 Fragments of a model

A model is a simplification of reality that is created for a specific purpose [52]. It is therefore interesting to assess components that should be included in a model of organisational learning, which could prove useful for the nuclear industry. The distinction between individual and organisational learning is certainly important to consider, because it is important to transfer

insights from individuals to organisational memory for the learning to take place. It is also clear that managers have an important role in promoting learning both as initiatives for the whole organisation and in the day-to-day activities.

The distinction between organisational learning and the learning organisation is relevant in pointing out that there always is room for additional improvements. It seems also necessary to discuss and describe the processes involved in organisational learning to make them understandable and accessible. The distinction between emergent and planned organisational learning is important in putting a focus on the deliberate act of creating new ways to operate as opposed to letting them develop by themselves. The feedback loops in organisational learning are important components in understanding that it is not enough only to reconsider practices as such, but also when necessary challenge more deeply buried values and assumptions.

It is important to consider organisational components of learning, because they help in indicating both larger and smaller issues that have their own important places in the process. Power structures that depend on organisational positions clearly come to play, but also more informal structures that depend more on knowledge and skills. A proper combination of old-timers and new comers of the organisation have their own important place in bridging generations of personnel during the operational life of a nuclear power plant [53].

## **5.2 Mechanisms to consider**

When a suitable number of modelling components have been selected one may concentrate on mechanisms of influence that should be considered. Such mechanisms will influence the learning process itself by becoming either facilitators or hindrances of different strengths. Certain components both on the individual and on the organisational level are expected to provide their own influence. On a second level one may differentiate between explicit and implicit traits and create measuring instruments that within an organisation can assess them with some reliability.

Trust is one important component for which measuring instruments can be created. Another is connected to the communication climate that in turn has both individual and organisational components. Trust and communication relies on openness and honesty, which may be stifled by rigid hierarchies in the organisation. Trust and communication also builds on individuals in important organisational positions who have sound images of themselves as well as a good understanding of others.

A final component to consider in assessing important influencing mechanisms is the mental models people use in understanding and maintaining control of their environment. It may actually be beneficial to provide people with model templates within a general frame of how safety is constructed. Such model templates could be targeted to the three systems of man, technology and organisation. In creating safety consciousness perhaps the most important component is an insight that nuclear power is different. The second most important component may be the understanding that continued successful operation has a tendency to create complacency.

## **5.3 The definition of something better**

Organisational learning carries the conception of something better. In judging what is better it is important to understand some basic dilemmas that have to be approached. The first one is connected with the newness of that something better, because without long term trials it can always be argued that the proposed improvements may involve unknown negative conse-

quences. A trivial approach would be to suggest modelling and simulation together with decision theory to evaluate costs and benefits of suggested new solutions. Unfortunately this trivial approach contains as many open questions as the original one, because new solutions always have large components of uncertainty [54].

A second dilemma is connected to the transfer of practices from one domain to another. The fact that a practice has demonstrated its fitness within one domain does not prove that it will be successful when transferred to another domain. Again modelling and simulation together with decision theory may provide support, but not any solution.

A final and third dilemma is connected to the time period over which the costs and benefits of the new practices should be accrued. It is evident that a transfer to new practices always involves some immediate costs, which should be compensated by benefits in the future. The first problem here is to make reliable estimates of costs and benefits over time and the second is to select an appropriate discounting rate. Taking these problems together implies that decisions on the applicability of a set of new practices at the end have to be made on gut feelings.

#### **5.4 An axis of analysis and synthesis**

An often heard saying within the nuclear industry is that their organisations are very good at analysing behaviour, but not very good at actually implementing remedies for the problems found. One explanation for this phenomenon can be found in considering an axis of analysis and synthesis or in terms of a decision process, the span between problem identification and problem solution. In considering the axis of analysis and synthesis it has to be observed that practical problems always involve varying degrees of both analysis and synthesis. It is however important to make this distinction, because a transfer from analysis to synthesis marks a difference in thinking. The move from problem analysis to problem solution will in addition mostly involve a transfer of responsibility from a specialist to a generalist i.e. from the analyst to a manager.

A transfer of responsibility between two persons in any organisation can produce possible misunderstandings in the communication. Perhaps the largest source of misunderstandings is connected to conveying the urgency of solving the original problem. A senior manager most likely has several concurrent problems that should be handled with a limited budget, which means that s/he has to set priorities. Depending on the situation the analyst may either oversell or undersell the proposed change, which may cause either unnecessary costs or some important safety related change to be postponed. If proposed safety related changes are postponed, it may influence the organisational culture negatively by causing indications of connected problems to be considered normal [55].

#### **5.5 Safety culture**

Safety culture has come to the safety field to stay, but thoughts are still needed on how to integrate the concept in management systems, in event investigations or in probabilistic safety assessments [56]. One proposal is to retain the concept as such, but to use it only as an aid for communication and exchanging experience between organisational units [57]. This may however not be possible given that the IAEA wants to provide a service for international assessments of safety culture at the nuclear power plants around the world.

If a system is to be developed for reliable and valid assessments of safety culture it is necessary to define the concept more accurately than what presently is done. In a process for arriving at such a definition it seems sensible to agree that safety culture has at least two compo-

nents, the first one formal and anchored in the safety management system and the other informal emerging from the organisational culture. Furthermore it would be necessary to recognise the fact that safety culture often is interpreted in slightly different ways among different functions such as operation, maintenance and technical support at the nuclear power plants.

The second step in the development of objective assessment methods of safety culture would be to agree on some more or less explicit norms for what should be considered acceptable for the factors assessed. Without a norm of acceptability the assessors would have to rely on their gut feelings as created in interviews. In this case the results of an assessment should only be considered as suggestions and points for discussions in developing organisational performance. An additional difficulty is encountered if assessments of safety culture are brought into regulatory oversight with threats for sanctions if the safety culture is considered deficient.

## **6 IMPLICATIONS FOR THE NUCLEAR INDUSTRY**

### **6.1 Organisational learning in a nuclear perspective**

In considering applications of organisational learning for a nuclear context there are some important observations. Firstly there are many formal systems in place that at least on paper will facilitate organisational learning. Secondly the nuclear industry is governed by regulatory requirements that prevent experimentation. Thirdly the dynamics of organisations exhibit long time constants, which means that it may take years to discover drawbacks with some new practice.

New practices that are emerging from uncontrolled exercises in organisational learning are not per se good, which means the management has to be conservative in deciding what to accept and what not to accept, because the nuclear industry has not the luxury to learn by trial and error. When something new has been proven good it should naturally be brought in, but then it is also necessary to allow time also for unlearning old practices.

The dilemmas of human decision making are one part of the daily life at the nuclear power plants, where situations with small probabilities, but high costs always will present threats to safety. However to claim that it is not possible to handle situations where a multitude of small things may go wrong and through tight coupling in the technical and organisational systems, to cause accidents to be a normal part of operating nuclear power plants seems to be an exaggeration [58].

### **6.2 Organisational development initiatives**

Judging from the academic literature the distinction between individual and organisational learning seems to focus more the social process than individual contributions of learning. To some extent this seems to be motivated also within nuclear organisations, because new practices have to transfer to organisational memory before they can be practiced more generally. That means that the new practices have to be documented in the management system and that the management system is maintained as a living tool for organisational control. However, it is also clear that senior management has a crucial role in all organisational changes both for the good and for the bad. Another important role is taken by specialists in different fields, which act as gatekeepers in bringing in innovations that are made in their own specialised field of competence.

The nuclear industry has a strict line of accountability, which implies that organisational development initiatives always have to be initiated and carried out in a structured process. Regulatory requirements presume that some kind of safety assessment is done before organisational changes are made. This implies that changes in practices that are not planned and assessed beforehand cannot be allowed.

### **6.3 The recommendation to become a learning organisation**

The recommendation to be a learning organisation is an obvious recommendation to give to any organisation. However, to be helpful it should be concrete and targeted to specific conditions prevalent in the considered organisation. This also implies that applicable models of organisational learning have to be placed in relation to an analysis of the organisation. An important question is also if an initiative to change is coming as a response to some specific concerns or in connection to a periodic review of organisational efficiency.

In assessing the recommendation to be a learning organisation it is necessary to differentiate between the types of organisation in consideration. Within the nuclear industry one has to separate between at least three distinct phases in the lifetime of a nuclear power plant. The first one may be termed design and construction, the second operation and the final phase decommissioning and dismantling. The recommendation to be a learning organisation has apparently at least implicitly been addressed to organisations in the operational phase. This is natural, because it represents the longest part of plant life and because the two other phases may be seen as restricted projects.

The operational phase could however also be divided in separate somewhat overlapping phases, which may be termed early operation, consolidation, modernisations and preparation for decommissioning. This division assumes that a phase of consolidation is required not only after the early operation, but also after each modernisation. In the early operation phase the organisational learning should focus on understanding the plant and its inherent properties. In this phase it is important to identify pressing technical problems and to modify the plant to streamline it for commercial operation. The phase of consolidation should similarly focus on a set of remaining small problems, which may or may not call for additional plant modifications. Modernisations are mostly triggered by technical improvements that provide opportunities for a better safety or competitiveness. In addition there are also phases of change, where retirements are beginning and more massive hiring of new staff is required.

### **6.4 Safety management**

The management of safety should be well integrated in the management system, but the activities should also be given clear signs of their safety importance. Safety management activities can be divided into feedforward and feedback paths, which both are equally important. The feedforward path is mainly concerned with risk analysis and activities aimed at decreasing identified risks and the feedback paths with operational experience and corrective actions programmes. Both paths include parts of both analysis and synthesis that should not be too much separated from each other.

In addition to the formally defined safety management activities it is important to recognise the informal part of the management system that is embedded in work practices. If the formal and the informal systems diverge too much from each other, it may be necessary to initiate strong control to decrease their distance from each other. Deviations between the formally defined and actual practises are identified in the normal auditing procedures that are defined in the quality systems. One way of ensuring that formal and actual practices are kept in line



with each other is to convey to all personnel an understanding of how and why accidents occur.

### **6.5 Managing organisational change**

Organisational learning should bring organisational change, but it is not always clear how this process is supposed to take place. In the nuclear industry a practice of analysing any change thoroughly before it is implemented is necessary. The view that organisational learning is taking place as an emergent process is therefore not acceptable. On the other hand it is evident that any organisational change is a social process that cannot be analysed fully beforehand. The lesson is perhaps to ensure that alternatives are considered and mental simulations are carried out to assess possible outcomes, but a requirement to make a very detailed analysis before organisational changes may be counterproductive.

When new senior managers are appointed they often initiate organisational changes. This is natural, because they have to organise work practices to fit their own working style. Such changes are also implicitly assumed, because a normal reaction on assumed or actual organisational deficiencies is to appoint new managers. Stepping into a new organisational position implies however respecting a few delicate balances. There is for example a need to balance between traditions and renewal and between forceful and enabling leadership in the change process.

Organisational change will always bring some costs and a general tendency seems to be to underestimate them. Organisational changes will have their winners and losers, where the later may mount a considerable resistance to change. Evolutionary changes are mostly preferable, but organisation may sometimes reach a state where revolutionary changes are necessary. Many organisations have developed lean structures with only a few hierarchical levels, but unfortunately this development has sometimes hampered organisational learning by removing a cadre of middle managers.

### **6.6 The concept of core competencies**

The concept of core competency is a topical issue in many organisations today [59]. It has also received scholarly attention [60] and it has been used to separate between activities in an organisation that can be outsourced and those that cannot [61]. Core competency also has an important relationship to knowledge management and sharing of knowledge in organisations [62].

The nuclear industry has like many other industries, applied outsourcing as a strategy for increasing organisational effectiveness. That strategy has sometimes been questioned by regulators due to its possibility to influence safety in a negative way. Plants have responded to such concerns by making systematic competency inventories. The creation of these inventories has also had a positive influence by introducing a systematic hiring of new staff and thoughtful career and succession planning.

Outsourcing does not necessarily lead to problems in organisational learning. Outsourcing may instead lead to an influx of new competency for example when the outsourced part is integrated in some specialised organisation with a large set of customers. It is however important to recognise that organisational learning has to be supported in different ways when several organisations are involved. One mechanism may for example be to build long term contracts with supplier organisations to improve the potential for mutual organisational learning.

The identification of core competency and nurturing skills of an intelligent customer are however important components in such a development.

## 6.7 Leadership

The organisational literature sometimes separates between leaders and managers. The nuclear organisations will like other organisations need leaders with visions and charisma, but these traits are not sufficient for organisational performance. Equally necessary are determination, integrity, stature, assiduousness, thrift, honesty, etc. If all possible virtues for good leadership are considered, it is not likely that they will be found in a single person. It is therefore necessary to establish a group of senior managers that as a group integrate skills and knowledge needed to respond to upcoming situations in a balanced way. Especially in decisions with safety implications it may be necessary that some of them take the role of the devil's advocate.

Senior managers have an important role in organisational learning, which is also identified in contemporary guiding documents on management systems [63], [64]. It is however important also to recognise that resources in attention, money, personnel and time are restricted. This implies that priorities always have to be set to achieve a balance between aspirations and available resources. In nuclear organisations this also implies that some slack resources are kept in reserve for the unexpected.

Leadership in the nuclear industry has to build on a good understanding of the requirements of the nuclear technology, which is combined with more standard management skills. Such skills include the need for creating balances to a set of seemingly contradicting requirements such as supporting at the same time traditions and renewal, uniformity and pluralism, consensus and constructive disagreement, efficiency and thoroughness, cautiousness and boldness, etc. Making these balances explicit is most likely making them easier to handle.

## 7 CONCLUSIONS

The most important part of organisational learning is to close the loop from analysis to actual and persistent improvements. This can only be achieved if identified problems are brought to recommendations that are practical and possible to implement. One general conclusion is that the recommendation to the nuclear organisations to become learning organisations is not very constructive, because it does not give concrete guidance to the managers at the plants. However, this does not mean that theories, models and findings from the research on organisational learning would be useless, on the contrary. Well used they can inspire applied research to propose models and tools by which organisations themselves can increase reflection and organisational development. For example a discussion on how one may improve individual, collective and structural capacities to learn may prove useful.

The learning organisation has been marketed almost like a panacea for ensuring safety in nuclear power plants. Organisational learning is certainly important, but it should be integrated in a larger research agenda on the influence of organisational factors on nuclear safety [65]. Finally the model of risk homeostasis [66] may provide an important piece of information when nuclear organisations try to maintain their vigilance during a long record of good performance.

One path of future development would be to integrate findings from academic research into models that can be used to illustrate important mechanisms of organisational development. Such a model could be the basis for developing analytic tools and prediction models to assess

possible effects of proposed organisational changes. More generally such organisational models can be of help also for making a transfer from tacit to explicit knowledge.

### Acknowledgments

The contribution of the LearnSafe partners in providing ideas and input to this paper is gratefully acknowledged. A list of the LearnSafe partners can be found at the web-site <http://www.vtt.fi/virtual/learnsafe/>, which also contains information on results from the LearnSafe-project.

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## APPENDIX. INSTRUCTIONS USED IN CODING OF THE DATA

The following coding instructions have been created to support a uniform coding of statements on the characteristics of, and hindrances to, organisational learning (OL). The statements have been extracted from the Metaplan sessions, interviews and group discussions carried out in 2003 as part of the 2<sup>nd</sup> phase of the LearnSafe project. In short, the objective is to repeat the treatment applied during the 1<sup>st</sup> phase of the LearnSafe project to the OL-related data using a different classification model.

The coding of statements is based on an underlying *model* that is assumed to incorporate the generic *issue domains* or *categories* of organisational development work. The model consists of the following four categories:

- Individual (IND),
- Social (SOC),
- Systems and procedures (SYS),
- Objectives and priorities (OBJ).

These four categories should be interpreted in their widest sense according to the descriptions below. It is also important to note that the above-mentioned categories are to be regarded as *fuzzy sets* and that a statement may therefore belong to one or several categories. This is to emphasise the fact that most organisational issues arise through two or more interacting factors and that managing such issues implies finding a proper balance between them.

The four basic categories can be described in the following way:

- *Individual*. This category relates to the personal characteristics of plant staff, such as attitudes, beliefs, orientation, know-how and capabilities. Any statement that is connected to the employees' or managers' individual attributes should therefore load this factor.
- *Social*. This category relates to the social and informal aspects of the plant organisation, such as values, norms, languages, cultures and daily practices. Especially issues that have to do with customary patterns of operation and interactions between various parts of the organisation should load this factor.
- *Systems and procedures*. This category is concerned with formal ways of structuring work at the nuclear power plant. It includes e.g. roles and responsibilities, functions and processes, instructions and manuals as well as various support systems and databases.
- *Objectives and priorities*. The category has to do with the publicly expressed strategies, goals and policies of the organisation. It also refers to prioritisation and allocation of resources as they occur in practice. Therefore statements that relate to decision-making in general should load this factor.

The coding of statements shall be carried out as follows:

Each statement shall be classified on the basis of its assessed degree of membership to each issue domain (category) on the scale of 0 to 100 points. 100 points denote very strong membership while 0 denotes no membership. Please observe that a statement may fit into one or several categories at the same time. If you cannot understand the meaning of a statement, leave the corresponding cells empty. If a certain statement does not appear to fit into any of the four categories, it may be coded with 0-0-0-0. If you decide to use the coding tool, please do not automatically accept the default values of 50-50-50-50.



A generic membership function to assist the assignment of membership values (applies to all four categories):

<i>Points</i>	<i>Meaning</i>
90-100	The statement strongly relates to the category under consideration.
40-60	The statement clearly relates to the category but only to a certain extent.
0-10	The statement's relation to the category is weak or non-existent.

An example of how the coding of the statements could proceed (please consider this as an example only):

<i>Statement</i>	<i>IND</i>	<i>SOC</i>	<i>SYS</i>	<i>OBJ</i>
Thinking in territories, pinching own information, desire for comfort.	100	50	10	10
Difficulties in recording and accessing experience.	10	50	80	5
Rationality in the strategic choice of policies regarding organizational change.	20	20	20	100
Reward is given to people who speak, not to people who do things.	20	30	0	80
Culture is 'all hands on deck' to solve operational problems – everything else goes out the window.	20	100	20	50