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ISSUES OF SAFETY CULTURE; REFLECTIONS FROM THE LEARNSAFE PROJECT

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ABSTRACT

The LearnSafe[1] project has been investigating processes of *management of change* and *organizational learning* at nuclear power plants across Europe. The focus of the project has been upon senior managers at nuclear power plants, who are responsible for strategic choice and resource allocation. This focus was selected due to the importance of their role in decisions, approaches and attitudes that have an influence on the safety and economy of the plants. In the project two large data sets have been collected with senior management perceptions at nuclear power plants in five European countries. The first data set contains challenges the managers see for continued operation of the nuclear power plants. The second data set contains views on facilitators and hindrances for organizational learning. The data sets have been analyzed to investigate similarities and differences between plants and countries. The results provide many interesting insights on issues related to safety culture.

1. INTRODUCTION

The concept of safety culture was introduced after the Chernobyl accident with a recognition that it was caused by a major deficiency in safety culture (IAEA 1986). International interests in the concept lead to the publication of a report making the first attempt to its definition in a nuclear context (IAEA 1991). Further work provided a suggestion for a method enabling nuclear power plants to assess their own safety culture (IAEA 1994).

An activity closely related to safety culture has involved investigations of how organizational processes influence safety (Jacobs, Haber 1994). This work created a list of 20 dimensions and it has been used in attempts to integrate organizational factors into the

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PSA framework (Davoudian et al 1994). A comprehensive approach towards the identification and assessment of organizational factors was taken in an international workshop (OECD/NEA 1999). The predecessor of the LearnSafe project also investigated how issues connected to organization and management may influence nuclear safety (Baumont et al 2000).

Attempts in introducing the concept of safety culture into the practical work at the nuclear power plants have demonstrated several obstacles. Firstly safety culture is a concept that is difficult to define, because culture is related to hidden and unconscious beliefs (Schein 1992). Secondly there is a large spectrum of views on what should be considered as indicators of a good or bad safety culture. In spite of the difficulties there is a widespread view that it would be necessary to measure safety culture to be able to control it. These controversies have lead to questioning the usefulness of safety culture in the management of safety at the nuclear power plants (Cox, Flin 1998).

The data collected in the LearnSafe project provides interesting views on some of the major issues connected to the concept of safety culture. A suggestion generated from the data is that attempts to define and measure safety culture may be counterproductive and a more fruitful approach may be to use the concept to stimulate discussions on how safety is constructed. These thoughts are expanded in more detail below.

2. COMPONENTS OF SAFETY CULTURE

2.1 Common views

The IAEA definition of safety culture reads: *Safety culture is that assembly of characteristics and attitudes in organizational and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance*. Further explanations stress the importance of the following components: Individual awareness; Knowledge and competence; Commitment; Motivation; Supervision; Responsibility. Two components are furthermore separated, of which the first is the safety management framework within the organization and the second is the attitude of staff at all levels in responding to and benefiting from the framework.

A later IAEA document (IAEAa 2002) listed key issues in safety culture as follows: Commitment; Use of procedures; Conservative decision making; A reporting culture; Challenging unsafe acts and conditions; The learning organization; Communication, clear priorities and organization. Further guidance on the use of the concept was given in a document that took a comprehensive approach to assessing, changing and controlling safety culture (IAEAb 2002). An important task is also to identify symptoms of a weakening safety culture (IAEAc 2002).

2.2 Different uses of the concept safety culture

The concept of safety culture has always the more or less explicitly stated intent to improve the safety of the nuclear power plants. Already a discussion of various interpretations of the concept can sensitize plant personnel to shortcomings that may have a negative influence on safety. An operational use of the concept would however imply a more

analytical approach, where components and subcomponents of safety culture are identified, assessed and acted upon.

In an attempt to identify different uses of the concept of safety culture, one can start with the general concepts of analysis and synthesis. The first can be associated to problem identification and the second to problem solving. A problem identification activity is looking for symptoms from which a search for causes and possible remedies can be initiated. A problem solving activity is again looking for actions that will change the conditions that have been identified as harmful for safety. The problem with changes is however that they may have unwanted side-effects that have to be identified and perhaps acted upon separately. The problem solving activity therefore should involve parts of both prediction and analysis not to go from bad to worse.

The concept of safety culture may be further used to assess and develop for instance concrete plant activities such as feedback of operational experience, incident analyses, safety analyses, design of management and quality systems, modifications planning, etc. Common to all these uses is that it would be necessary to further break down the concept and make it operational within the context where it is used. The question is then if it is necessary to use safety culture as a top concept in this kind of problem identification and problem solving structure.

3. ORGANIZATIONAL FACTORS

3.1 Models of organizational behavior

All models are built for a purpose and this purpose governs the simplification of some complex phenomenon into a useful instrument for investigations. The simplification is important, but it will also restrict the usability of the model (Wahlström 1994). The construction of models typically starts with a consideration of issues to be included. For models of organizational behavior this has typically resulted in various lists, which themselves may be useful in sensitizing managers to issues and influences that are important to consider. The problem however, is that these lists seldom are grounded on a validated theory of organizational and human behavior.

In an attempt of identifying issues that generally have been considered important in the construction of models of organizational behavior the following non-conclusive list of categories can be generated:

- Management and leadership (function, overview, situation awareness, supervision, ownership, commitment, motivation);
- Strategies and planning (goals, priorities, resource allocation, utilization of time);
- Organizational structure and practices (centralization, formalization, roles, responsibilities, procedures, coordination of work, organizational memory);
- Human resource management (selection, training, competency, performance evaluation);
- Communication (interdepartmental, horizontal, vertical, external, honesty, openness);

- Organizational culture (safety culture, organizational learning, organizational knowledge, confidence and trust);
- Operational environment (economics, regulatory oversight, educational system, societal attitudes)

It is important to note that this division into categories and issues is rather arbitrary and that the categories and issues are overlapping.

3.2 Influence diagrams

Influence diagrams are often used as the next step in a model building exercise to track dependencies between issues. It is relatively easy for people to identify up-stream causes and down-stream consequences of some specific issue. It is far more difficult to merge these influences to a comprehensive model of some interesting phenomenon, because there are usually very many influences to be traced. Sometimes the influences form loops, which in practice may render the influence diagram more difficult to use for making predictions of how some issue may influence another. When the influences are linear models are relatively easy to build and validate, but many systems include influences with threshold and saturation effects.

Influence diagrams are well suited for reasoning about technical safety, because the causal direction of influences is usually very clear and one way. When influence diagrams are used for organizational factors the first problem is to find a set of issues that can be considered to represent a reasonable subdivision of the investigated phenomenon. Secondly the influences are seldom one way, but more often mutual interdependencies at several levels. A further difficulty is that most decision making situations in organizations evolve dynamically in response to a chain of events, but influence diagrams are basically static. Models of influences on a very general level are on the other hand often too crude to be useful.

4. CHALLENGES IN THE MANAGEMENT OF NUCLEAR POWER PLANTS

4.1 The collected data

The LearnSafe project was empirically focused. The first phase of the project concentrated on *management of change*. In this phase manager perceptions were collected on challenges that face the nuclear power plants. The collected data set consists of nearly 800 statements given by more than 200 persons at 10 nuclear power plants in five countries and at one international organization. The major part of this data was collected in so called Metaplan sessions. Two sessions were arranged at each plant of which one session was conducted with members of the senior management group and the other with managers from selected plant functions.

The Metaplan technique was used as the main data collection method, because it encourages individual involvement by all participants and it facilitates group interactions. Metaplan is a data collection technique during which the researcher acts as a moderator to the process. The moderator would typically start the session by introducing the question to be discussed. Each member of the group is then asked to produce 3-5 simple state-

ments as answers to the question and record their answers on small cards. The cards are collected and stuck to a board in random order. After that the group is asked to sort the cards by content and to create clusters of cards with the same or similar meaning. Finally clusters are given names and the clusters and statements are ranked by priority.

All statements were coded using dimensions, which were interpreted as memberships in fuzzy sets. This gives the benefit that a specific statement can be considered to load several of the dimensions at the same time. The five dimensions were: Economic and financial; Workforce and competence; Technology; Systems and procedures; Environment. A cluster analysis was used to sort the statements. The following eight clusters were found: Economic pressures; Human resource management; Nuclear know-how; Rules and regulation; Focus and priorities; Ageing, modernization and new technologies; Public confidence and trust; Organizational climate and culture.

4.2 Views on challenges

It is interesting to note that the concept of safety culture gets very little attention in the statements on challenges that people see at the nuclear power plants. Of all the statements only eight of them gave explicit reference to safety culture. Three of these statements were according to the cluster analysis related to human resource management and five to organizational climate and culture. In a search using only the word culture four additional statements were found.

The clusters of challenges were used to initiate a collection of data in the form of case studies to identify strategies, plans and actions that are used to cope with them. The clusters appeared to be operations oriented in that respect that managers interviewed found it easy to orient themselves and provide example of ongoing activities from their own plants. In the examples of strategies, plans and actions that were given, it was obvious that they represent another dimension than the clusters of challenges, because specific programs and projects were often mentioned in connection to several of the clusters. One interpretation is that the tasks of senior managers involve the monitoring of ongoing programs and projects and the initiation of new initiatives in response to agreed strategies and goals. Such a task relies on a broader outlook on issues.

5. FACILITATORS AND HINDRANCES OF ORGANIZATIONAL LEARNING

5.1 The collected data

The second phase of the LearnSafe project, which concentrated on *organizational learning,* collected manager perceptions of facilitators and hindrances for organizational learning. The data set consists of nearly 1000 statements given by more than 100 persons. About half of the statements were collected in group discussions and the second half in Metaplan sessions.

The memberships of statements were coded using the following four fuzzy sets: Individual; Social; Systems and procedures; Objectives and priorities. Three cluster analyses were carried out, one with the whole data set, the second on the facilitators only and the third on the hindrances only. The first cluster analysis produced eleven clusters,

the second six and the third seven clusters. All cluster solutions showed strong relationships with each other and the eleven clusters solution was therefore selected for further analysis. The eleven clusters were characterized as follows: Objectives, priorities and resources; Formal systems and practices; People's attitudes and orientation; Corporate culture and traditions; Communication, guidance and appraisals; Maintaining touch and focus; Openness and trust; Work community; Encouragement and rewards; Adequacy of means and methods; Networking and co-operation.

5.2 Views on facilitators and hindrances

Again it is interesting to note that the concept of safety culture gets very little attention in the facilitators and hindrances to organizational learning, which people see at the nuclear power plants. Of all the statements only five gave explicit reference to safety culture. Two of these statements were according to the cluster analysis related to "Networking and co-operation", two to "Encouragement and rewards" and one to "Corporate culture and traditions". Using a search for the word culture gave a total of 23 additional statements.

Organizational learning is considered to be an important part of almost all lists of attributes to a good safety culture or to organizational factors important for safety. It is therefore interesting to see how the data gives a more detailed view of one of the important components of safety culture. A simplistic interpretation of organizational learning would be that strategies, which support the facilitators and suppress the hindrances, would be good strategies for an improved safety. A more detailed analysis of the data reveals however that almost similar statements are given both as facilitators and hindrances. This indicates that a more elaborate description of the facilitator or hindrance in consideration would be needed to select suitable strategies and actions that can be expected enhance organizational learning.

6. SOME REFLECTIONS

6.1 Interpretations of LearnSafe data

Culture and more specifically safety culture do not seem to be concepts used in the day-to-day operation at the nuclear power plants. On the other hand, many of the issues considered as important components of safety culture are mentioned explicitly in both data sets. Depending on the cluster in consideration and the narrowness of the interpretation one may say that something between 5 and 20 % of the statements have a more or less direct relationship to what commonly has been considered as a part of safety culture. This would suggest the interpretation is that safety culture is not a concept for itself, but it is instead ingrained in various aspects of the management activities.

The data collected in different countries and at different plants show large similarities, but also differences. On a qualitative level there seems to be a larger dependency on the specific plant or country in consideration in the case of facilitators and hindrances than in the case of the challenges. This would suggest that changes in the operational environment of the plants have introduced similar coping mechanisms, where the facilita-

tors and hindrances of organizational learning seems to be more connected to local practices.

One would expect that facilitators and hindrances would be largely symmetric, but the data shows that this is not the case. Facilitators and hindrances are symmetric in some of the clusters, some contain mainly facilitators and other hindrances. The appearance of largely similar issues both as facilitators and hindrances indicate a need for investigating local conditions in detail before implementing specific action plans to ensure a proper balance between positive and negative influences.

6.2 The construction of safety

The safety of nuclear power plants relies on a defense-in-depth concept. When this concept is applied in the design of technical systems it implies that there are several independent barriers to protect against identified threats. The design process goes through consecutive iterations of design and analysis, where candidate designs are analyzed and improved. These basic concepts can also be applied for human and organizational systems. The only problem is that models available for design and analysis of the human and organizational systems are far inferior as compared with models of technical systems.

The problem can be approached from another point of view. It is possible to define preconditions that have to be in place to ensure that the human and organizational system can fulfill their functions. Such lists have been generated and they can provide guidance for both design and analysis. These lists give however only qualitative guidance and not the relative importance of identified preconditions. The lists are also static, which means that the cope poorly with the interactions of many variables and the dynamics of rapidly evolving sequences of event.

One characteristic of human decision making is that people react on what they see and perceive. Maneuvers are triggered by signals from the process and by interpretations that are made. Signals from the process are mixed with process knowledge to achieve an understanding what is going on and how important the events are. When safety is the overriding goal, it would be important that there is an ongoing almost unconscious process of continuously evaluating possible safety influences. This can be interpreted that one precondition for a very high level of safety is that there is a continuous awareness of what is going on, which is combined with an good understanding of the plant and the means to maintain it within a safe operational envelope.

6.3 Safety culture revisited

Present interpretations of safety culture are based on practical, but rather unstructured ideas on what can be considered as good and bad practices. Tools to measure safety culture are correspondingly based on indicators that are perceived to have a relationship to safety, but this relationship has seldom been verified. Used methods and tools often contain implicit assumptions and models that have not been validated. Just to take one example, most reports on safety culture stress leadership as being an important component of safety culture. If the existence of a good leader is that important, one may ask if

the organization is robust enough to withstand the actual leaders it gets. A parallel question is whether or not it is possible to find leaders, who have all the required capabilities.

Safety culture has during the last years been seen as the grand unifying concept that will ensure safety of the nuclear installations. One can ask if the present interpretations of safety culture are rich enough to serve the need for a requisite variety; i.e. does the concept have the same order of complexity as the plant organization that it is supposed to control. With experience from actual work practices at the nuclear power plants, one observation is that it is there are a number of subcultures at the plants that may actually have a large contribution to safety. This would suggest as an interesting research area to investigate how safety is constructed in these multi-cultural interactions.

6.4 Another use of safety culture

If the aspiration of defining the concept of safety culture to make it operational is abandoned, one may actually consider a different way to use the concept. Safety culture has many different interpretations, but observations have shown that most people have a rather clear interpretation of what the concept mean for themselves (Hammar et al 2000). This would suggest that the concept can be used more as a kind of leverage to initiate communication between people. Following the international discussion of safety culture one may actually claim that this has been the largest benefit of the discussion of safety culture over the last ten years.

If the concept of safety culture is used for such a purpose it provides a kind of general frame, which can be used relatively freely to focus and rationalize important issues. This means that underlying theories and models for example from sociology can be brought into the discussion. Names like Weber, Durkheim, Habermas, Parsons, Bourdieu, etc. would then enter the scene with theories that may provide better explanations of various phenomena that are seen within the nuclear organizations. This would most likely enrich the discussion and help in the sense-making of day-to-day operations at the nuclear power plants. Regardless of technical improvements it is still cooperation between honest and knowledgeable humans that make the nuclear power plants safe.

7. CONCLUSIONS

The clusters found in the two LearnSafe data sets represent an aggregation of the data that can be used to suggest strategies, plans and actions for improving safety and efficiency in various work activities. The methods and tools used for the data collection have shown to be efficient and they can with suitable adaptations most likely be used for self-assessments of organizational performance at the nuclear power plants.

There have been many attempts to define safety culture. An implicit assumption in these attempts has been that safety culture is something to be possible to measure and control. This assumption contradicts however another trend in the discussions, which has been to include everything into the concept of safety culture that is not possible to place in another context. Safety culture seems in the view of experience from the LearnSafe project better fitted to become a common theme, which is used to facilitate the communication between various working groups at the nuclear power plant. Thus the concept

would become a pivot point in expressing personal interpretations of attributes and characteristics of safe operation.

It may be somewhat farfetched to relate perceptions on challenges in nuclear operation and facilitators and hindrances for organizational learning to the concept of safety culture. On the other hand the collected views within the LearnSafe project give a reflection of urgent tasks that more than 300 managers at the nuclear power plants are concerned with in their day-to-day work. The general concept of safety culture fell far down on the list of urgent issues, but many issues that have been considered as components of safety culture were brought forward as important issues to approach.

If the concept of safety culture is going to have an impact on safety, it has to come out of the reports and be something that is used in the day-to-day activities. Taking into account of the diversity of the tasks, which are carried out at a nuclear power plant, it is not likely that the concept will be given the same interpretation and be used in the same way by everybody. Therefore it is suggested that safety culture instead should be made a concept to be used for communication between different organizational groups to bring forward views on safety and how safety can be achieved. This interpretation should not in any way diminish the importance of the concept of safety culture, but it would instead help to become a living concept within the organizations.

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REFERENCES

Baumont, G., Wahlström, B., Solá, R., Williams, J., Frischknecht, A., Wilpert, B., Rollenhagen C. Organisational Factors; their definition and influence on nuclear safety, VTT Research Notes 2067, Technical Research Centre of Finland, 2000.

Cox, S., Flin R., 1998. Safety culture: philosophers stone or a man of straw? *Work & Stress*, **12**, 3, pp.189-201.

Davoudian, K., Wu, J.-S., Apostolakis G., 1994. Incorporating organizational factors into risk assessments through the analysis of work processes, *Rel. Eng. & Syst. Safety*, **45**, pp.85-105.

Hammar, L., Wahlström, B., Kettunen J. Views on safety culture at Swedish and Finnish nuclear power plants, NKS-14, Nordic Nuclear Safety Research, Febr. 2000.

IAEA. Summary report on the post-accident review meeting on the Chernobyl accident, INSAG-1, International Atomic Energy Agency, 1986.

IAEA. Safety Culture, INSAG-4, International Atomic Energy Agency, 1991.

IAEA. ASCOT Guidelines: Guidelines for organizational self-assessment of safety culture and for reviews by the Assessment of Safety Culture in Organizations Team, TECDOC-743, International Atomic Energy Agency, 1994.

IAEAa. Key practical issues in strengthening safety culture, INSAG-15, International Atomic Energy Agency, 2002.

IAEAb. Self-assessment of safety culture in nuclear installations, TECDOC-1321, International Atomic Energy Agency, 2002.

IAEAc. Safety culture in nuclear installations; guidance for use in the enhancement of safety culture, TECDOC-1329, International Atomic Energy Agency, 2002.

Jacobs, R., Haber S., 1994. Organizational processes and nuclear power plant safety, Rel. Eng. & Syst. Safety, **45**, pp.75-83.

OECD/NEA. Identification and assessment of organisational factors related to the safety of NPPs, Vol.1&Vol.2, NEA/CSNI/R8(98)17, Nuclear Energy Agency, Febr. 1999.

Schein E., H., 1992. *Organizational culture and leadership*, Jossey Bass, San Francisco.

Wahlström B., 1994. Models, modelling and modellers; an application to risk analysis, EJOR, **75**, 2.