ESPOO 2005 VTT RESEARCH NOTES 2287

Björn Wahlström, Jari Kettunen, Teemu Reiman, Bernhard Wilpert, Hans Maimer, Juliane Jung, Sue Cox, Bethan Jones, Rosario Sola, José M. Prieto, Rosario Martinez Arias & Carl Rollenhagen

LearnSafe

Learning organisations for nuclear safety

VTT TIEDOTTEITA – RESEARCH NOTES 2287

LearnSafe
Learning organisations for nuclear safety

Björn Wahlström, Jari Kettunen & Teemu Reiman
VTT Industrial Systems

Bernhard Wilpert, Hans Maimer & Juliane Jung
Technische Universität Berlin

Sue Cox & Bethan Jones
Lancaster University Management School

Rosario Sola, José M. Prieto & Rosario Martinez Arias
CIEMAT (Universitat Autónoma de Barcelona, Catedratico de Unversitad)

Carl Rollenhagen
SwedPower AB

ISBN 951–38–6538–X (soft back ed.)
ISSN 1235–0605 (soft back ed.)

ISBN 951–38–6539–8 (URL: http://www.vtt.fi/inf/pdf/)
ISSN 1455–0865 (URL: http://www.vtt.fi/inf/pdf/)

JULKAISIJA – UTGIVARE – PUBLISHER

VTT, Vuorimiehentie 5, PL 2000, 02044 VTT
puh. vaihde 020 722 111, faksi 020 722 4374

VTT, Bergsmansvägen 5, PB 2000, 02044 VTT
tel. växel 020 722 111, fax 020 722 4374

VTT Technical Research Centre of Finland, Vuorimiehentie 5, P.O.Box 2000, FI–02044 VTT, Finland
phone internat. +358 20 722 111, fax +358 20 722 4374

VTT Tuotteet ja tuotanto, Tekniikantie 12, PL 1301, 02044 VTT
puh. vaihde 020 722 111, faksi 020 722 6752

VTT Industriella System, Teknikvägen 12, PB 1301, 02044 VTT
tel. växel 020 722 111, fax 020 722 6752

VTT Industrial Systems, Tekniikantie 12, P.O.Box 1301, FI–02044 VTT, Finland
phone internat. +358 20 722 111, fax +358 20 722 6752

Technical editing Anni Kääriäinen

Otamedia Oy, Espoo 2005

Wahlström, Björn, Kettunen, Jari, Reiman, Teemu, Wilpert, Bernhard, Maimer, Hans, Jung, Juliane, Cox, Sue, Jones, Bethan, Sola, Rosario, Prieto, José M., Martinez Arias, Rosario & Rollenhagen, Carl. LearnSafe. Learning organisations for nuclear safety. Espoo 2005. VTT Tiedotteita – Research Notes 2287. 58 p. + app. 7 p.

Keywords nuclear safety, organisational factors, safety management, earning organisations, culture, management of change, human factors, safety culture

Abstract

The nuclear power industry is currently undergoing a period of major change, which has brought with it a number of challenges. These changes have forced the nuclear power plants to initiate their own processes of change in order to adapt to the new situation. This adaptation must not compromise safety at any time, but during a rapid process of change there is a danger that minor problems may trigger a chain of events leading to a degraded safety. Organisational learning has been identified as an important component in ensuring the continued safety and efficiency of nuclear organisations. In response to these challenges a project LearnSafe "Learning organisations for nuclear safety" was set up and funded by the European Community under the 5th Euratom Framework Programme. The present report gives an account of the LearnSafe project and its major results.

Preface

Organisational learning is a crucial component of operational excellence in nuclear power plants. Organisational learning relies on performance assessments, change management and continuous improvements. Organisational learning has become increasingly important for the nuclear industry in its adaptation to changes in the political and economic environment, work force, technology in plants, and organisations of the nuclear utilities. A danger in this process is that even minor problems may trigger a chain of events in which the risk of deteriorated safety and/or diminishing trust in the safety standards of the particular nuclear power plant becomes possible.

In response to these challenges a project LearnSafe "Learning organisations for nuclear safety" was set up and funded by the European Community under the 5th Euratom Framework Programme 1998–2002, Key Action: Nuclear Fission. The project was started 1st of November 2001 and was finished 30th of April 2004. The project partners included five academic and research organisations together with eight operators of nuclear facilities and one international organisation.

The LearnSafe project has considered the demands that have been placed on the nuclear power plant management in the process of change that was initiated by the deregulation of the electricity supply in Europe. The project has created methods and tools to approach the *management of change* as well as for the facilitation of *organisational learning*. The LearnSafe project enabled the participating operators of nuclear facilities to benchmark their approaches to safety management. An additional benefit for the participants was obtained through the generation of various spin-off activities in which early project results were tested and adapted to practice.

The present report presents the key findings of the LearnSafe project. The report is targeted towards both practitioners and researchers with an interest in high reliability organisations. Additional information on the LearnSafe project can be accessed using the LearnSafe web-pages http://www.vtt.fi/virtual/learnsafe/.

Contents

List of abbreviations

LearnSafe	The project "Learning organisations for nuclear safety" operated under the contract FIKS-CT2001-00162 from the European Commission.
MoC	Management of Change
NPP	Nuclear Power Plant
OL	Organisational Learning
ORFA	The project "Organisational Factors; their definition and influence on nuclear safety" operated under the contract No. ERB FI4S-CT98_0051 from the European Commission.
PLEM	Plant Life Extension and Management, a cluster of projects within the 5th Euratom Framework Programme.
Q1 ... Q6	Research questions Q1 to Q6 (cf. page 13)
SHE	Safety, Health and Environment
SQEP	Suitably Qualified and Experienced Personnel
WP1 ... WP7	Workpackages 1 to 7 (cf. page 10)

1. Introduction

The nuclear power industry is currently undergoing a period of major change, which has brought with it a number of challenges. Changes in the political and economic environment, changing regulatory requirements, and a changing work force, changing technology, changing organisations within the nuclear industry have resulted in the need to adapt. Adaptation must however occur without compromising safety at any time. During a rapid process of change there is a danger that minor problems may trigger a chain of events leading to a degrading of safety and/or diminishing political and public trust in the safety of a particular nuclear power plant, utility or corporation. Organisational learning has thus been identified as an important component in ensuring the continued safety and efficiency of high reliability organisations.

The main objective of the LearnSafe project was to create methods and tools for supporting processes of *organisational learning* at the nuclear power plants. The focus of the project was placed upon senior managers at the nuclear power plants and at corporate levels who are responsible for strategic choices and allocation of resources. The project was established following the successful completion of a previous project called ORFA "Organisational factors; their definition and influence on nuclear safety" [1]. The LearnSafe project has in the same way as the ORFA project established a platform to further research in this area.

The LearnSafe project has played an important role in ensuring the continuing safety of the nuclear installations in Europe by addressing management and organisational issues. In its exploration of innovative management concepts the project has contributed to the maintenance of high levels of expertise and competence in the nuclear field. Project results have shown to be of interest outside the nuclear field within other safety critical industries. A good understanding of systemic issues connected to organisation and management can have a large influence on safety and economic competitiveness. These issues are crucial in achieving a proactive approach to the lifetime management of existing nuclear installations.

The motivation behind the funding from the nuclear fission safety programme is a result of the differences between the nuclear field compared to other high-risk industries. These differences are reflected in the following sentences:

- Nuclear reactors require continued oversight, because even when shut down the residual heat removal has to be functional.

- The societal concerns of risks connected to nuclear power, are larger compared with actual risk estimates.

- The burden of proof that a nuclear power plant is safe is larger compared with other high risk applications.

- The nuclear industry is global in that respect that bad performance anywhere could result in decreased confidence and trust in the industry everywhere.

- Even a suspicion that a nuclear power plant is not safe, may be enough to shut it down for extended periods of time.

The project has provided a forum for information exchange between practitioners from the nuclear power plants and researchers. The project has facilitated a sharing of views on safety management between organisations and countries. The LearnSafe project has collected examples of good practices in the field of management of change and organisational learning. Such examples could potentially provide a basis for developing methods and tools for organisational self-assessments.

2. Project structure

The project was divided into two distinct phases of empirical and theoretical considerations. The first phase was focused on *management of change* and the second on *organisational learning*. In addition to these parts a number of spin-off activities were undertaken together with the nuclear power plants to enlarge the data collection towards activities of a more immediate concern and to test and exploit early project results.

The LearnSafe project included seven workpackages as follows:

1. *WP1: Refinement of the research model*. The objective of the workpackage was to establish a framework for the work in the whole project. Literature on challenges and practices within high reliability organisations was surveyed. Based on this material and discussions within the project a set of working papers on the research frame, organisational practices and data collection methods were written.

2. *WP2: Field study 1, collection of challenges in the management of change*. The first field study of LearnSafe collected challenges to the management of change as seen by managers at the participating nuclear power plants. In the workpackage background information on approaches for organisational change and feedback of operational experience was also collected.

3. *WP3: Analysis and refinement of the collected data*. The collected data was analysed in the workpackage to establish an understanding of strategies, plans and actions used to cope with the challenges. The workpackage integrated results and findings from the first phase of the LearnSafe project. These were discussed at the Mid-Term seminar was held at 22–23.5.2003 in the WANO premises in Paris, France. The seminar was also used as an additional data collection exercise among the participants.

4. *WP4: Field study 2, facilitators and hindrances for organisational learning*. The workpackage represented the second major data collection at the participating nuclear power plants. As a part of the workpackage working papers on the use of organisational self-assessments were also written.

5. *WP5: Comparative analysis and development of assessment criteria*. An analysis of the data collected in the second phase of LearnSafe was carried out in the workpackage. Criteria were established for efficient organisational learning in discussions between the partners.

6. *WP6: Development of recommendations for learning organisations*. The workpackage produced an inventory of good practices and recommendations by which nuclear power plants can implement and maintain efficient organisational learning. The workpackage also brought together results and findings of the whole LearnSafe project at the Final Seminar, which was held at 29–30 April 2004 in the VTT premises in Espoo, Finland.

7. *WP7: Project co-ordination and management*. The workpackage consisted of the project co-ordination and management activities. It also produced the Final Technical Reports and the Technological Implementation Plan. The workpackage was completed at the end of June 2004 with the submission of the required administrative reports.

A comprehensive overview of the project is presented in Figure 1. In this overview specific research questions are indicated with circles and reports with rectangles. The arrows represent couplings between different parts of the project.

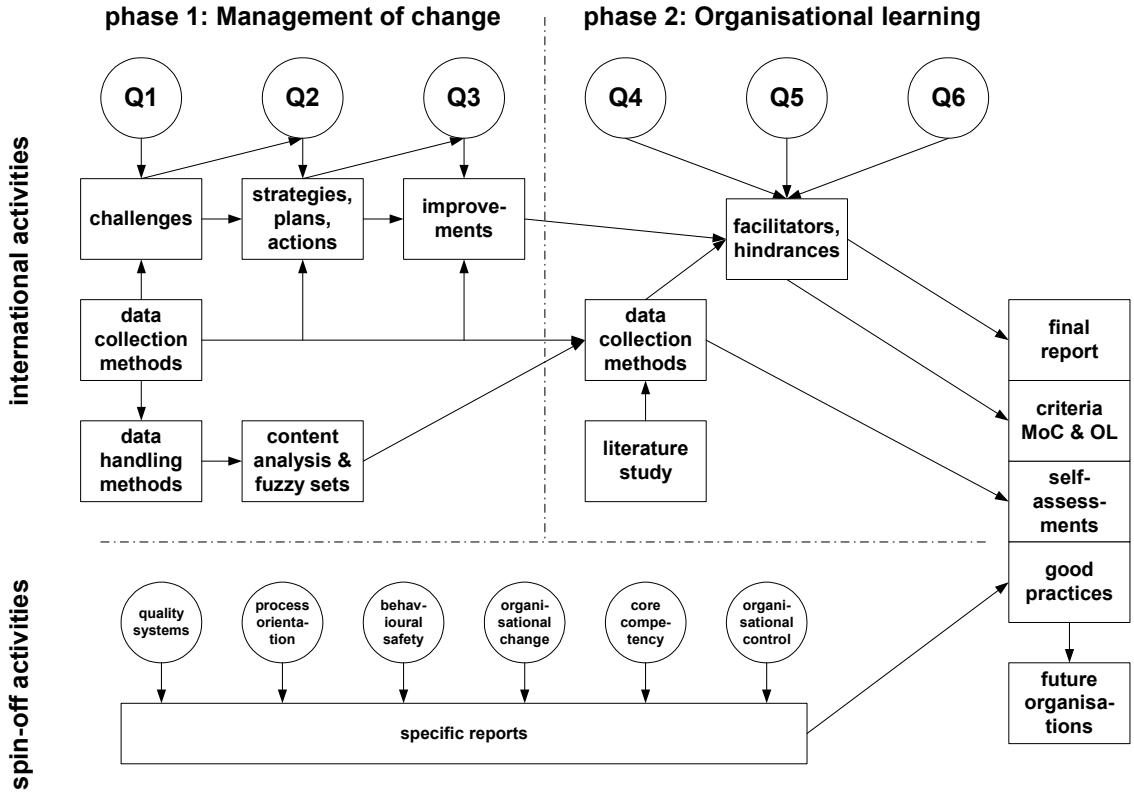

Figure 1. General overview of the LearnSafe project.

3. The research framework

Early on in the project the research team a framework for describing the essential characteristics of organisations and management processes was established, which was used to direct evolutionary processes. This framework was used in the project to structure both theoretical and empirical work. Throughout the LearnSafe project researchers built upon this framework to reflect concepts and understanding of both practitioners and researchers participating in the project.

3.1 Central theoretical concepts

The LearnSafe research frame distinguishes between issues, influences and models. This distinction implies that the development of models begins with the definition of issues to be considered and the mapping of influences between issues. This gives a qualitative approach to a model, which can be further refined following empirical investigations. Because a model should be a simplification of reality, it is important to restrict it to the phenomena of interest. At the same time it is important not to move outside the range of validity for the selected model. In practice this implies that a range of models should be used that are internally consistent with each other.

The research frame argued for a division between the five interacting systems of *technology*, *individual*, *group*, *organisation* and *environment*. These concepts were introduced in the ORFA project and have been used throughout the course of the LearnSafe project. A second distinction emerges between three different views, the *administrative view*, the *political view* and the *cultural view*. This distinction gains validity by separating the formal management systems and the emergent practices that are fostered over time. Models of organisational failures were taken from the literature to define organisational deficiencies. The concept of generic dilemmas of management has shown fruitful and much of the collected data demonstrate important balances that can be explained with this concept.

One of the project deliverables discusses ways in which organisations can be described. The rationale was to create an understanding of the similarities and differences between all participating nuclear power plants. Due to the large amount of work involved, this task was performed only on a qualitative level. The concepts brought forward proved however to be useful in later data collection exercises as it familiarised the LearnSafe team with common practices utilised at the nuclear power plants.

3.2 The research questions

The first phase of the project was devoted to *management of change* in recognition that various mechanisms of change bring new challenges to the senior management at the nuclear power plants. This led to the formulation of the following research questions for the first phase of the project:

- Q1: What are the perceived emerging challenges in the management of nuclear power plants?

- Q2: How do senior managers cope with emerging challenges in the management of nuclear power plants?

- Q3: What improvements could be made in respect to coping with emerging challenges in the management of nuclear power plants?

The second phase of the project was connected to the concept of *learning organisations*. A considerable amount of research within organisational and management sciences has been devoted to investigating how learning occurs and what characteristics facilitate organisational learning. Therefore the results obtained in the first phase of the project supported the development of the research questions for the second phase of LearnSafe. The following research questions were formulated:

- Q4: What kind of features and attributes characterise learning organisations?

- Q5: What are the most common hindrances to organisational learning (Q5a) and how can they be removed (Q5b)?

- Q6: How are various company cultures and sub-cultures influencing organisational learning?

3.3 Data collection methods

The LearnSafe project used several data collection methods, including questionnaires, Metaplan sessions, semi-structured interviews, group discussions and case studies. The main part of the generated data consists of qualitative statements. A total of more than 300 managers ranging from utility top managers, upper nuclear power plant managers to functional managers from several plant functions participated in the data collection exercises.

The Metaplan technique was used extensively in the LearnSafe project, because it encourages individual involvement by participants and it facilitates group interactions and discussion. Metaplan is a data collection technique during which the researcher acts as a moderator to the process. The moderator would typically begin the session by introducing the research question asked. Each member of the group was asked to consider 3–5 answers to the research question and record their answers on the cards provided. The cards are then collected, read aloud and stuck to a board in random order. The group is then asked to sort the cards by content and to create clusters of cards with the same or similar meanings. When the participants finished sorting the cards the moderator proceeded by asking participants to find a suitable title for each of the clusters that is able to encompass the contributions within a particular cluster. Finally the clusters and the statements within the clusters are ranked according to their importance.

3.4 Areas of management attention

During the course of the project it became evident that a model reflecting the span of attention of managers was needed. The model below was originally developed to support an understanding of the balances between various tasks within safety management [2]. It was used as the basis for the coding of the data using the fuzzy set approach. The model is schematically described in Figure 2.

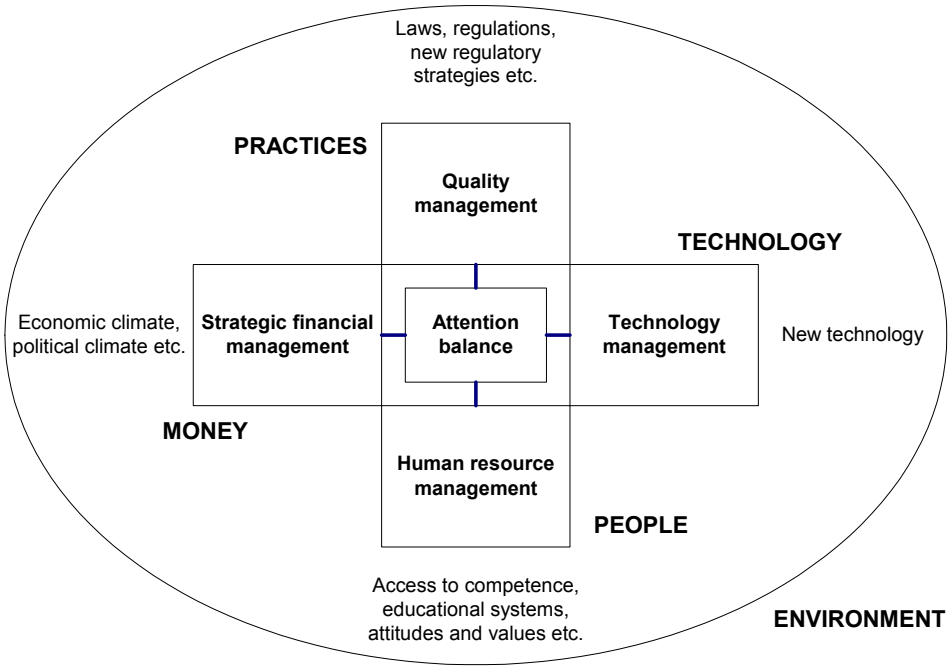

Figure 2. A model of areas of management attention.

The five areas can simply be given the shorthand labels *money*, *practices*, *technology*, *people* and *environment*. These areas can be characterised in more detail as follows:

Money. Financial management is connected to ensuring that economic goals of the organisation and associated strategies are handled to ensure that the owner's expectations are fulfilled. This specific focus has been emphasised by the deregulation of the electricity market.

Practices. The practices at a nuclear power plant are on one hand geared to ensuring appropriate quality and on the other to ensuring efficiency in all work activities. Practices are governed through the quality management activities, which include the set up and use of a quality system with associated internal auditing functions. The external mirror image of these functions is the regulatory bodies and related organisational structures, processes and rule systems.

Technology. Technology management can be associated with activities and issues both operative and strategic, which are linked to operation, maintenance and long term development of the technological production system. Technology and quality management are related, in that norms, standards and regulations introduce restrictions for the change processes.

People. Human resource management involves the access, maintenance and development of human resources that are crucial for safe operation of nuclear power plants. Knowledge, experience, attitudes and values held by managers and other personnel, especially seen in a longer time perspective, are associated with external factors, such as changes in values, access to competence, contractor competence, etc.

Environment. The operational environment of the nuclear power plants has an important influence on what managers can and will do; however their actions have a relatively small influence on the environment. The environment has a direct influence on all of the other focus areas through factors such as, the economic and political climate, laws and regulations, available industrial infrastructure, labour force and educational system.

In considering these five focus areas it is evident that all managers have to reflect them all in one way or another. Furthermore many managers are specialised, for instance some are focused more on money, others on people and so on. Their focus can vary over time, but it is generally reflected by a combination of organisational position, aptitudes and preferences.

The model carries the notion of attention balance, which recognises the limitations in human cognition and decision making. This notion implies that all areas should be given the attention they require, because otherwise important information may be

disregarded in management activities. The attention balance also carries the implication that a change in the environment may require a restructuring of the organisation and a redefinition of the tasks in different management positions. In the short term such demands may lead to changes in management focus that, if not monitored and balanced efficiently, may jeopardise safety.

3.5 Analysis of the data

The analysis of data containing mainly qualitative statements presents a large challenge. The analysis of the statements was carried out using two methods, content analysis and a new method based on fuzzy sets developed by the research team for use in the LearnSafe project.

3.5.1 The content analysis method

Content analysis [3] is a phase of information processing in which communication content is transformed, through objective and systematic application of categorisation rules, into data that can be summarised and compared. Content analysis is most frequently used to describe attributes of messages, without reference to either the intentions of the sender or the effect of the message upon those to whom it is directed. Using content analysis hypotheses may be tested by comparing the messages produced by two or more different sources. The benefit of content analysis is that it allows researchers to generate frequencies from qualitative data, whilst maintaining the richness of the data. The method involves the generation of key words and phrases, from the Metaplan and the interview transcripts being listed, counted and categorised. LearnSafe researchers used computer assisted qualitative data analysis software to carry out the content analysis. N-Vivo 2 was selected for use by the research team, as it is better suited to social science research compared to other available packages [4]. N-Vivo 2 for example encourages an exploratory approach to data analysis and allows for fine-grained analysis. The process of content analysis was used to analyse data gathered (related to Q1, Q4, Q5, Q6) from the participants of both the semi-structured interviews and the Metaplan sessions.

In the content analysis the challenges were inputted into a coding sheet under one of the following six sub-headings:

- Economic.
- Regulatory.
- People.

- Plant and technology.
- Organisation and management.
- Political.

The frequency of occurrence of each of the challenges was recorded each time it appears within a participant's transcript.

3.5.2 The fuzzy set method

The fuzzy set method is based on the interpretation that the statements represent expressions of perceived challenges (research question Q1), facilitators (research question Q4) or hindrances (research question Q5), which may have many different origins or characteristics. The statements can thus be coded by their memberships in selected fuzzy sets. The selection of appropriate fuzzy sets can then be achieved using a model that can be assumed to represent a common underlying characterisation the respondents have of the issue in consideration. Based on the model of areas of management attention (cf. Figure 2) the following dimensions (fuzzy sets) were selected:

- Economic and financial.
- Workforce and competence.
- Technology.
- Systems and procedures.
- Environment.

Based on the analysed results from the responses to the research question Q1 a slightly revised model was proposed by identifying four fields that may either facilitate or hinder organisational learning. The selected dimensions (fuzzy sets) were:

- Individual.
- Social.
- Systems and procedures.
- Objectives and priorities.

The fuzzy set method has the benefit that it can be separated into distinct phases and tasks, which can be subjected to independent scrutiny and variation. For example the selection of the underlying model gives a possibility to systematically search for

interpretations of the data. The coding of the data sets was made using three independent coders to ensure consistency in the coding. A simple average of the coded membership functions was used during the cluster analysis. The method makes it possible to do numerical experiments in relation to the interpretation of the distance function within the resulting n-dimensional space. This analysis was not completed during the project due to limitations in time and resources. The method is summarised in the Figure 3.

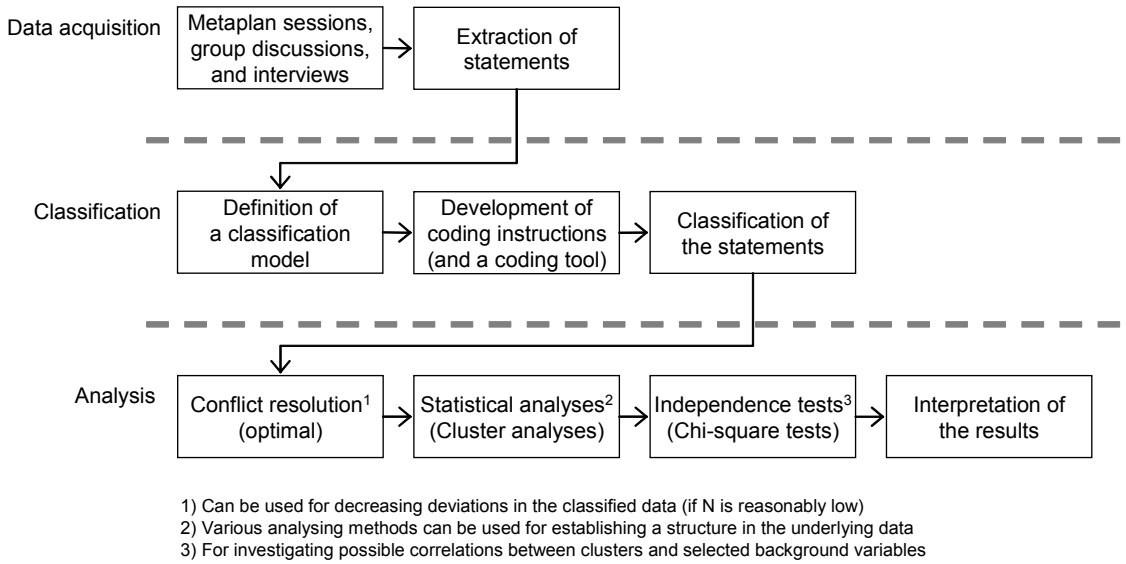

Figure 3. The process of collecting statements, coding the statements and analysing them.

4. Emerging challenges in the nuclear field

The managers of nuclear power plants are confronted with a wide variety of novel demands, which require new methods for dealing with such demands. These demands are the result of ongoing changes; hence managers are required to manage change processes efficiently and effectively in order to ensure safe and economic production. These demands originate from various domains and they reinforce each other. Some of these changes can be listed as follows:

- Changes in the political and economic environment
- A changing work force
- The changing technology in the plants
- The changing organisations of nuclear power plants and utilities.

4.1 The collected data

The LearnSafe team selected several methods in order to answer research question Q1. Technically this approach is referred to as triangulation i.e. the approach encompasses the use of a number of methods of data collection to improve the validity of a particular study. The following target groups of respondents generated data in response to research question Q1:

- Experts in safety, health and environmental issues (SHE experts).
- Utility top management.
- Upper nuclear power plant managers.
- Multifunctional Managers.

The target groups and the chosen methods are illustrated in Figure 4.

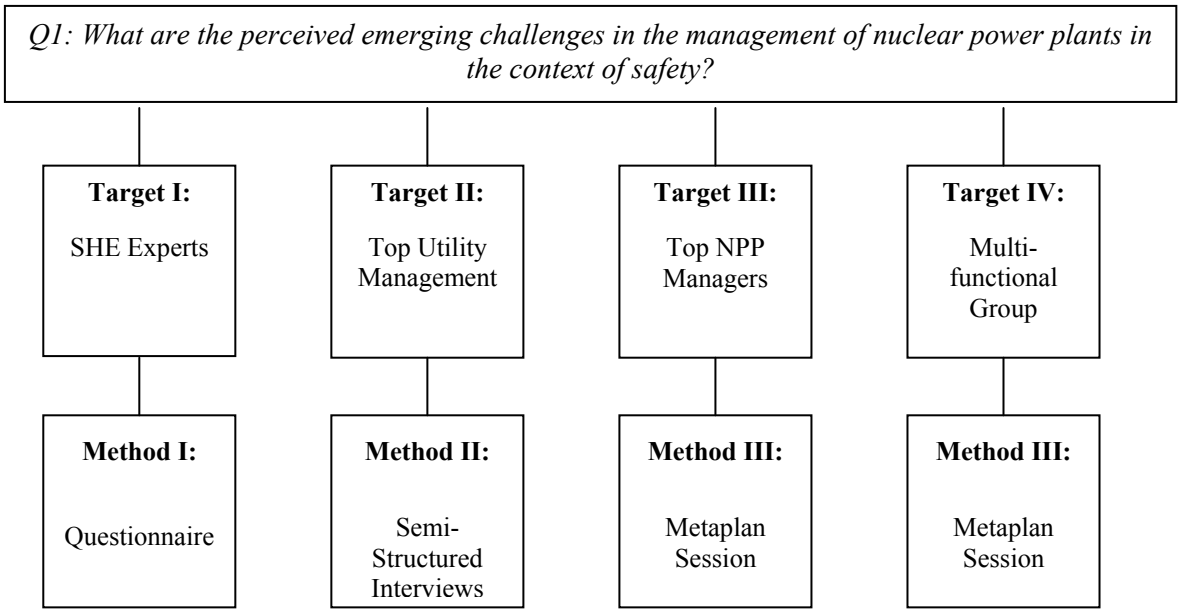

Figure 4. Methods utilised for answering the research question Q1 of the LearnSafe project.

The generated data set from the Metaplan sessions consist of approximately 800 statements in response to the research question Q1 and they reflect the views of more than 200 persons at 10 nuclear power plants in 5 countries and at 1 international organisation.

4.2 Analysis results

4.2.1 Content analysis

Using the content analysis the challenges were grouped into the following five underlying themes: Economic and Financial; Workforce and Competence; Technology; Systems and Procedures; Environment. These were further analysed to uncover sub-categories and the results are presented in Table 1.

According to the analysis human resource management presents the most important challenge for senior management. Furthermore, issues within the operational environment of the nuclear power plants over which the management has little or no control were also regarded as a large challenge. In this group of challenges public opinion pressures were considered to be the most important.

Table 1. The results of the content analysis of the challenges.

Economic and Financial (132)[1]	Lack of Resources Corporate Pressures Deregulation and Competition Mergers and Acquisitions Shorter Outages Decommissioning Management of Resources Reduction in costs
Workforce and Competence (343)	Generation Turnover and maintaining SQEP Personnel management and policies Attitudes and health Recognition of the importance of human factors
Technology (102)	Ageing Technology New Technology Safety and Maintenance Competence
Systems and Procedures (132)	Excessive Inefficiencies and Difficulties Management Priorities Responsibility New Requirements Modernisation
Environment (308)	Attractiveness of the Industry Sabotage and Terrorism Global Perception Public Opinion Regulator Political Climate Tension in the Sector

4.2.2 The fuzzy set analysis

The cluster analysis identified a total of nine clusters of which one consisted of unrelated miscellaneous items. In considering the statements near to the cluster centres, the following names were given to the clusters: Economic pressures, Human resource management, Nuclear know-how, Rules and regulation, Focus and priorities, Ageing, modernisation and new technologies, Public confidence and trust, and Organisational climate and culture. These clusters can be further described as below.

[1] The number within the parenthesis indicates the number of statements recoded in this category.

Economic pressures. In this group of challenges competition caused by deregulation in the electricity market was one of the major themes. The competition on the market has led to the need for cost reductions and adaptations to new conditions. According to the responses there are both national differences and differences between forms for electricity production, i.e. taxes and subsidises. The need to maintain competitiveness on the market has increased corporate pressures on nuclear power plants, which sometimes lead to conflicts between costs and safety.

Human resource management. In this group of challenges the main concern was directed to how to maintain the competency needed at the nuclear power plant. Many comments were concerned with the age distribution of personnel and possible early retirements. Concerns were also expressed that recruiting of new personnel would be more difficult in the future. One underlying theme in this group of challenges was connected to the need for maintaining the specialised nuclear competency.

Nuclear know-how. This group of challenges addressed in particular the decreasing number of vendors. A concern for the competency of contractors and other suppliers was also expressed. The problem of maintaining the specialised nuclear competency was expressed, but with a different direction as compared with the challenges as described in the previous section. There was a large agreement that nuclear power plants will become increasingly reliant on the availability of external competency support, but it seems difficult to predict how the availability of various services will develop.

Rules and regulation. Many challenges in this group addressed new regulatory requirements. Furthermore, the excessive need for bureaucracy and paperwork was also considered a key issue. Many of the collected statements identified the need to maintain open communication with the regulator. Some of the challenges were questioning the regulatory focus together with an expressed fear that regulatory action in some cases might be counterproductive for safety.

Focus and priorities. This group of challenges relates to management focus and priorities. Management focus and commitment together with an informed use of resources are necessary for attaining the goals of the organisation. The challenges mentioned in this group refer to the need to keep procedures, instructions and documentation up to date. Some comments could even be interpreted as indicating an excessive focus on formalities. Organisational change and their consecutive influences were also brought up in this connection.

Ageing, modernisation and new technologies. This group of challenges made reference to the need for maintaining plant technical condition. Many comments focused upon the gradual ageing of the plants. This general trend can only be met in modernisation

projects, which themselves may have an impact on several other challenges. Many comments also made reference to new technology, which should be taken into use.

Public confidence and trust. This group of challenges was concerned with the societal acceptability of nuclear power. Some comments made reference to the irrationality of anti-nuclear attitudes while others pointed to the hostility in the mass media. There are also misunderstandings that are necessary to combat. There were comments concerning distrust in local or regional authorities. Several comments did explicitly take up the global position of nuclear power inherent in the statement 'an accident anywhere is an accident everywhere'.

Organisational climate and culture. Motivation and attitudes were considered to be the major issue addressed within this group of challenges. Comments on safety culture were also part of this group together with the need to fight complacency. There were a few comments in this group related to mental and emotional strains. Many respondents made reference to organisational and human factors.

5. Strategies, plans and actions

The analysis of the challenges showed a rather similar picture of the participating nuclear power plants. It was therefore natural to continue by considering the research question Q2 by evaluating strategies, plans and actions that are used to cope with the challenges. This information was collected in semi-structured interviews and group discussions at the nuclear power plants. Finally data was generated in response to research question Q3 using group discussions following a presentation of the results of the analysis from research questions Q1 and Q2.

5.1 Data collected

The step from the challenges (research question Q1) to the coping strategies (research question Q2) was taken by collecting case studies at the nuclear power plants. The availability of managers from the nuclear power plants resulted in the use of different methods for data collection i.e. semi-structured interviews and group discussions. The resulting case studies took both a broad outlook in assessing the whole set of challenges and a more in depth consideration by focusing on a specific group of challenges. The case studies were written as a co-operative effort between plant employees and the researchers. The case studies were written as internal LearnSafe reports.

The challenges and case studies were analysed to produce a draft document on strategies, plans and actions that was presented and discussed at the Mid-Term seminar of the LearnSafe project. The subsequent discussions using three different discussion groups were recorded and transcribed to form a joint document, which was circulated amongst the project participants. This document was later analysed to produce a draft report on possibilities to improve (research question Q3) that was circulated and commented on.

5.2 Coping strategies

Following the analysis of the case studies it immediately became clear that there was not a one-to-one relationship between challenges and strategies, plans and actions the nuclear power plants apply to cope with the challenges. There was instead a complicated relationship in which challenges arise from changes in the operational environment of the nuclear power plants and new opportunities stemming from technological and organisational innovations. The plants build their strategies, plans and actions within their strategic and annual plans as comprehensive programmes or projects. These are given specified goals defined in states or conditions that have to be reached.

This complex relationship between challenges, strategies, plans and actions, and states and conditions are described schematically in Figure 5, which illustrates examples of couplings that were identified in the case studies. As it can be seen there is no simple relationship between challenges and strategies, plans and actions. Instead there are certain states or conditions that are pursued by various programmes that are identified in the strategic planning and implemented as parts of yearly plans.

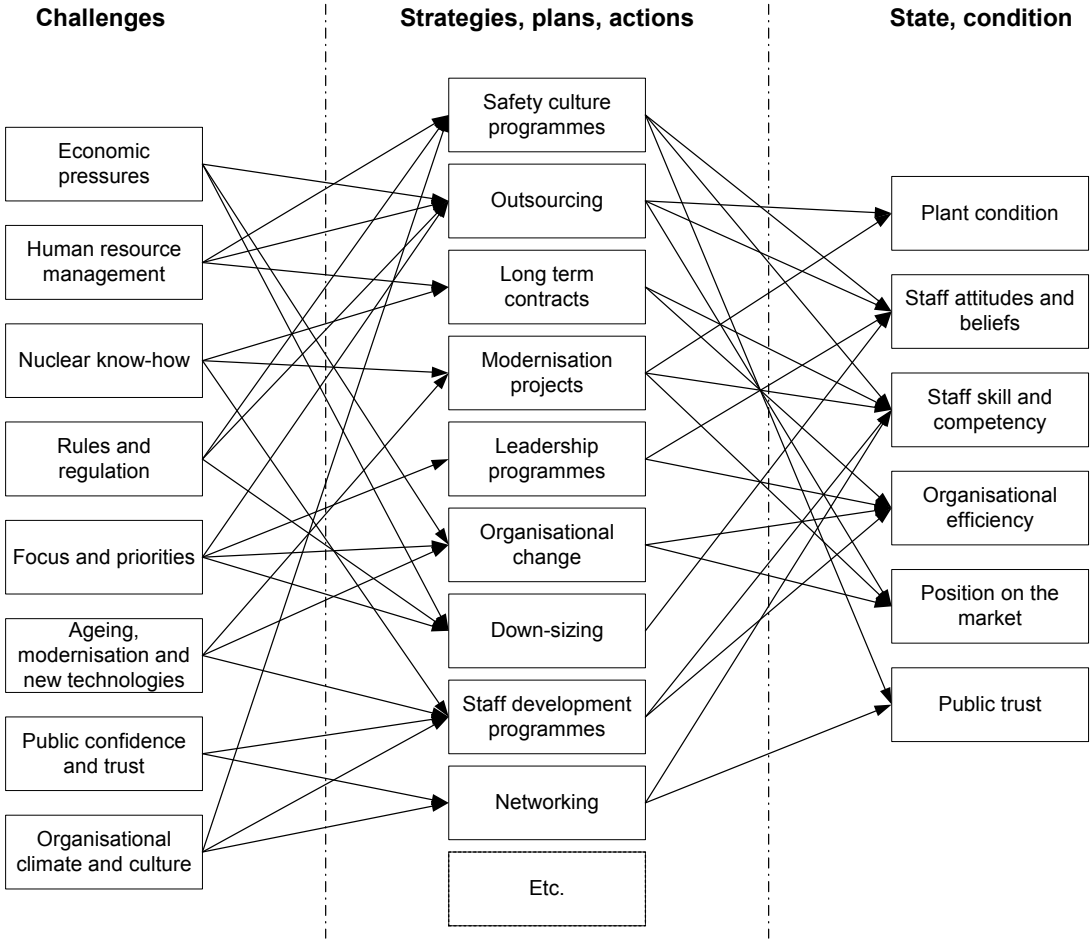

Figure 5. Relationships between challenges and strategies, plans and actions, together with their influences on the state and conditions at the plants.

On a general level the strategies, plans and actions that were identified in the case studies can be grouped according to the five areas of management attention (cf. Figure 2). These strategies, plans and actions have briefly been summarised in the as given in Table 2:

Table 2. Summary of strategies in coping with emerging challenges.

Money	Create cost awareness within the personnel. Share costs with partners in co-operation. Create efficient work practices. Conduct a careful planning of investments and outages. Use best available practices.
People	Take care of people. Invest in internal training. Conduct career planning. Provide interesting tasks for people. Pay fair salaries. Express clear expectations on people. Give frequent feedback. Do regular competency surveys.
Technology	Keep plants in top condition. Build away problems with materials and equipment. Create a long term technical development plan and keep it updated. Invest in R&D. Keep plant documentation up-to-date.
Practices	Promote leadership. Make priorities explicit in strategies and plans. Motivate all decisions taken. Encourage open communication. Define borders for acceptability. React rapidly in the case of malpractices. Use conservativeness in decisions.
Environment	Maintain good contacts with stakeholders. Network broadly. Avoid isolation. Follow what is going on within the industry. React when changes are emerging. Try to understand trends. Behave as a good citizen.

5.3 Possibilities for improvements

The responses to the research question Q3 were generated from discussions of strategies, plans and actions to coping with the challenges during the LearnSafe Mid-Term seminar held at the WANO premises in Paris 22–23 May 2003. From the discussion a set of possible actions for improvements were derived and grouped according to the major stakeholders in the nuclear field, i.e. Nuclear power plants, Power utilities, Vendors and contractors, Regulators, International organisations, and Society. The suggested improvements can briefly be summarised as follows:

Nuclear power plants. Balance the tensions between the need to bring in new practices and traditional approaches for ensuring high safety commitment. Resistance of temptations to making shortcuts in response to economic pressures. Remembering that pursuing some moderate savings can generate larger costs later. Ensuring that there is enough slack in organisational resources to cope with uncertainties and contingencies. Assessing the pressure that is put on people. Ensuring proper focus and priorities and setting ambitions on a realistic level. Finally, ensuring that plants have integrity to withstand undue pressure from the corporate level.

Power utilities. Building political stability to enable plans to be made for the future. Ensuring that the business risk of not being safe at the nuclear power plants is understood at the board level. Awareness of risk when entering business areas with high economic risk levels. Ensuring that productivity targets set for the plants are realistic. Searching for benefits through sharing of practices and knowledge with other utility companies.

Vendors and contractors. Vendors and contractors have observed a shrinking market in the nuclear field, which has made it difficult to maintain critical knowledge. Networking with power utilities and other vendors and contractors may help to create the critical mass for maintaining important knowledge.

Regulators. Assessing regulatory impacts and trying to ensure that regulatory oversight is correctly targeted. Moving away from prescriptive regulation towards risk informed safety requirements. Becoming active in striving for increased harmonisation in national safety regulations. Continue dialogues with the utility industry to clarify roles in regulatory oversight. Setting realistic levels of requirements for the plants currently operating. Agreeing on reasonable licensing procedure for plant modernisations. Increasing dialogue between nuclear safety regulation and other regulatory bodies.

International organisations. Continuing the collection and distribution of operational experience between plants. Encouraging support from plants, regulators and research organisations to be able to draw on their experience in structuring and analysing collective experience. Ensuring openness from the plants via strict protection of the confidentiality of obtained information. Building direct contacts to the nuclear power plants through enlightened gate-keepers. Supporting the emergence of harmonised international safety requirements for nuclear power plants.

Society. Creating a realistic energy policy for nuclear power. Maintaining support to national and international research programmes. Creating opportunities for networking internationally in the university education in the nuclear field. Establishing risk and safety research centres, which more broadly could, conduct research in all aspects of safety and security. Creating a political understanding of the obligations of the international Nuclear Safety Convention.

6. Characteristics of learning organisations

The second phase of LearnSafe concentrated on organisational learning and collected responses to research questions Q4, Q5 and Q6. The data was collected using Metaplan sessions and group discussions and the data was analysed using content analysis and the fuzzy set method.

6.1 The collected data

Responses to the research question Q4 were generated from group discussions consisting of 2–4 managers (1st or 2nd line) who deal with feedback experience, knowledge management, organizational development, training, further development, evaluation of implementation of corrective actions, or responsible persons for audits etc. In the discussions Figure 6 was used 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.

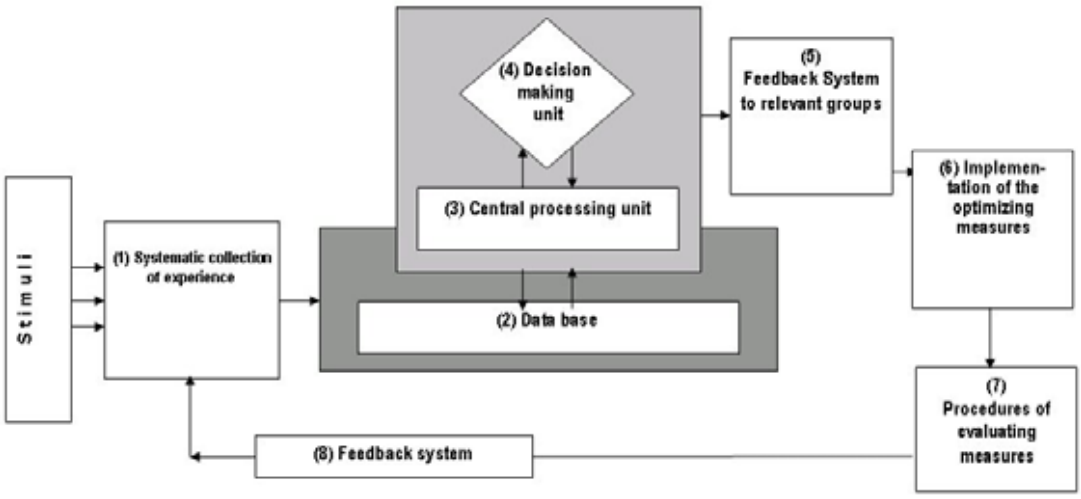

Figure 6. Model of structural aspects of organizational learning.

The generated responses to research question Q4 were used to inform the Metaplan session used to generate data for the remaining research questions Q5 and Q6. 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 nuclear power plants.

All recorded inputs were collated using one large database of statements. The statements were coded according to their content i.e. whether they reflected a facilitator or a hindrance to organisational learning. The database of responses consists of approximately 1000 statements given by more than 100 persons.

6.2 Analysis results

The data collected in relation to both the facilitators and hindrances of organisational learning were analysed using content analysis and fuzzy set method. The tight time schedule set for the completion of the LearnSafe project unfortunately did not allow for a lengthy discussion of the differences and refining of the analysis.

6.2.1 Content analysis

The content analysis was carried out using four separate analyses of the data collected in relation to the research questions Q4, Q5a, Q5b and Q6. The analysis of the data collected in response to research question Q4 uncovered three underlying themes within the data: structural, psychological and support systems. Each of these themes was then subjected to further analysis to subsequently reduce the data and to uncover additional categories evident within the data set. The result of this analysis is given in Table 3.

Table 3. Features and attributes of learning organisations (254)[2].

Structural (112)	Questioning and challenging approach (12) Dissatisfied with the present situation (8) LearnSafe Model (17) Learn from self and others (22) Time and patience (8) Visible benefits (7) The learning process (25) Organisational focus (13)
Psychological (59)	Empowerment (10) Trust (5) Communication (15) Culture (20) Motivation (9)
Support systems (83)	Formal (53) Informal (30)

[2] The number within the parenthesis indicates the number of statements that was recoded in this category.

Similarly the analysis of the data collected in response to research question Q5a uncovered five underlying themes within the data: individual, management, organisation, culture and external pressures. Further analysis of these themes is provided in Table 4.

Table 4. Hindrances to organisational learning (476).

Individual (181)	Behaviour (105)	Routine and Turnover (28) As an agent for organisational learning (33) Communication (30) Competency (7) Insularity (7)
	Attitudes (76)	Resistance to change (24) Trust (5) Motivation (26) Self-conceit and attitude towards others (21)
Management (164)	Focus and Priorities (42) Decision making (10) Commitment (6) Responsibilities and guidance (27) Workload, time and resources (61) Management of change (18)	
Organisation (57)	Technology (8) Strategic learning and training (4) Support and tools (17) Structures and procedures (28)	
Culture (51)	Not invented here (7) Influence of the past (11) Sub-cultures (15) Trust (3) Defensive and critical (15)	
External Pressures (23)	Social (3) Political (5) Regulator (9) Competition (6)	

The analysis of the research question Q5b uncovered five categories within the data, i.e. individual, management, organisation, culture and external. Further analysis uncovered results as listed in Table 5.

Table 5. Removal of hindrances (192).

Individual (63)	Communication (13) Participation and benefit (27) New personnel and job rotation (15) Sensitivity (3) Information overload (5)
Management (57)	Clarification of Focus and Priorities (42) Management of change (14) Clarification of responsibilities (11)
Organisation (48)	Methods and tools to support organisational learning (29) Clear procedures (6) Allocation of time and resources (13)
Culture (18)	Recognition (7) Continuous Learning (6) Trust (5)
External (6)	Society (4) Regulator (2)

Finally, the analysis of the data collected in response to research question Q6, i.e. Cultures and sub-cultures influence on organisational learning (55), uncovered three underlying themes within the data: Leadership focus (25), Change management (9) and Group differences (21).

6.2.2 The fuzzy set analysis

The whole data set was analysed with the method based on fuzzy sets. Altogether three analyses were carried out, one for the whole data material, one for the facilitators and one for the hindrances. The full analysis produced an eleven cluster solution and the two other analyses one six and one seven cluster solution. The three solutions could consistently be fitted together in such a way that some of the clusters were overlapping while others were found only among the facilitators or hindrances. The full eleven cluster solution together with the characterisations of the clusters divided into facilitators and hindrances is presented in Table 6.

Table 6. The eleven cluster solution with characterisations divided into facilitators and hindrances.

Objectives, priorities and resources	Facilitators	Long term outlook. Ability to prioritise. Clear goals and policies. Goals and resources match. Sound activity planning. Analysis of what's positive and not only what's negative.
	Hindrances	Lack of time. Lack of resources. Too broad focus. Too many important issues. Several concurrent activities. Bad prioritisation. Issues are shuffled around. Deficient preparation. Conflicting goals. Short-term focus.
Formal systems and practices	Facilitators	Circulation of people within the organisation. Benchmarking. Support and tools. National and international exchange of experience. Adequate communication channels. Efficient meetings. A structured approach to educate and train.
	Hindrances	Mass of data to be analysed. Difficulties in recording and accessing experience. Too many formal meetings. Missing follow up. Absence of review of earlier changes. The hierarchy.
People's attitudes and orientation	Facilitators	Ability to learn from experience. Ability to co-operate. People do not take defensive positions. People have skills in sharing knowledge. People feel to be participating. There is a personal benefit in learning.
	Hindrances	Resistance to change. Opposition in principle. Lack of motivation. Self-satisfaction. Lack of understanding. Self-conceit. Complacency. Apathy. People do not know how things are interlinked.
Corporate culture and traditions	Facilitators	Positive and encouraging organisational climate. Well functioning safety culture. Team work. Willingness to listen. Informal contacts. A questioning attitude. Sub-cultures that enhance learning.
	Hindrances	Protection of turf. Group thinking. Inadequate culture. Tradition. Division into them and us. Criticism is not allowed. Absence of a common language. Lack of trust.
Communication, guidance and appraisals	Facilitators	Capacity to adjust. Co-operation between sites. Promoting top-down communication. It is possible to try new things. It is easy to initiate change. Understanding of the system. Initiators of change are rewarded.
	Hindrances	Unclear responsibilities. Lack of guidance. Overload of information. Lack of information. Knowledge and training is not viewed seriously. Feedback is interpreted as critique. Organisational lines of command and reporting are not followed.

Maintaining touch and focus	Facilitators	Leadership, management and commitment. There is a willingness to learn. The right things are done and the things are done right. There is realism when new initiatives are started. People are honest about expected outcomes.
	Hindrances	Missing decisions. Missing loyalty to decisions. New tasks are coming in, old tasks are not removed. Lack of management commitment. Lack of time for reflection. Lack of foresight and fantasy.
Openness and trust	Facilitators	People trust each other. Team spirit. The organisation tolerates deviation. There is a willingness to challenge old practices. There is an understanding that also minor things may be important. Openness.
	Hindrances	Resistance to change. Entrenched old habits. Missing trust. Lack of consensus. Lack of communication. Not invented here syndrome. Lack of questioning. Absence of humility. Enviousness. Loss of face. Fear.
Work community	Facilitators	Humility. Visibility of managers. Creative thinking. Everybody has a chance to join. Exchange roles and positions; see the arguments on both sides. Commitment, motivation and perseverance. Empowerment.
	Hindrances	Low turnover. Reluctance to think in systems. Unwillingness to admit weaknesses. Guarding territory. Unwillingness to accept new demands and changed conditions. Prestige.
Encouragement and rewards	Facilitators	Stable and shared goals. Important issues are put on the table. Critical thinking is endorsed. There is time to meet without a meeting. The organisation has confidence to move. Various events, travels and meetings.
	Hindrances	Opposition to change. Cost/utility is questioned. Lack of organisational commitment. The business culture has too large influence. Speakers are rewarded, not doers. Lack of variability. Too much change.
Adequacy of means and methods	Facilitators	When you have had an incident. Two roles needed the innovator and the devils advocate. Do not promise too much. Presentations and training from vendors. Internet.
	Hindrances	Hierarchical organisation. Hostility towards nuclear. Cut and paste engineering. Opting out. Theories that fit poorly in daily practices. Reactive fire fighting. Right of veto.

Networking and co-operation	Facilitators	Direct feedback. Debriefing when a task is finished. Safety culture seminars. Training and development programmes. Good contact networks. Efficient change processes. Suitable fora for learning.
	Hindrances	Devious communication channels. Tactical presentation of events. Lack of interfaces to real world. Ready made thinking models. Difficult to get information to right people.

7. Conclusions and recommendations

The LearnSafe project has generated many conclusions and recommendations, which have been documented in various subject reports. These will be further refined and exploited in follow up projects by the LearnSafe partners. Presently many of the reports that have been written within the LearnSafe project are confidential to be used by the partners only. Further activities will however transfer a major share of results and reports into the open domain.

7.1 The international part of the project

The collected data sets on challenges, case studies, facilitators and hindrances of organisational learning paint a detailed picture of the conditions within which the nuclear power plants in Europe operate. On a general level the conditions seem to be very similar although some national differences can also be seen. This implies that the industry as a whole would benefit from increased sharing of experiences and solutions. On the other hand it seems difficult to build up the necessary channels for such an exchange of operational experience.

The five research organisations, which collaborated in the LearnSafe, all had previous experience and contacts with the nuclear industry in their own countries. This proved to be very important, because it made it possible to ensure the necessary openness in the data collection sessions. However, it sometimes was difficult to find the necessary time from the managers at the nuclear power plants to participate in the LearnSafe activities. The mix of the earlier experiences of the five research organisations also proved to be important in setting up the necessary methods and tools utilised during the project.

The LearnSafe project applied an empirical approach to the research questions. In hindsight this was a wise decision, because the data sets of actual statements of managers in five European countries and one international organisation on the work they do represent a very unique collection of information.

The results from the first phase of the LearnSafe project included an inventory of organisational challenges at nuclear power plants and approaches for their resolution. During the second phase data was collected in relation to the facilitators and hindrances for organisational learning. These results support a better understanding of crucial components of safety management at the nuclear power plants. The results can help nuclear power plants in developing their work practices. The methods and tools that were used for the data collection during LearnSafe can be used for assessment and

reviews of organisational efficiency and safety culture at the nuclear power plants to assist them in ensuring continuing safety and efficiency in all work activities.

The results of the project as a whole have been used to write two overview reports. The first report addresses criteria for change management, which can be used to ensure that modifications and changes are scrutinised in detail so as to avoid threats to safety and efficiency. The second report collated good practices that were observed within the LearnSafe project and its predecessor, the ORFA project. Both reports rely on the empirical material obtained during the various data collection exercises and discussions together with managers at several nuclear power plants in Europe. The reports have not yet been released on the open domain, instead they have been written an audience of managers at various levels in the nuclear power plants in mind.

7.2 The spin-off activities

The various spin-off activities have explicitly targeted issues of a more immediate concern at the nuclear power plants. The LearnSafe project benefited from the spin-off activities as they provided an opportunity to discuss the intermediate results at the participating nuclear power plants. The spin-off activities proved to be very important in establishing a broader picture of some of the ongoing activities at the nuclear power plants. The following spin-off activities have been completed and reported to the respective target organisations.

A discussion and assessment of peer review activities. Peer reviews have an important position in the nuclear industry in the support of continuous improvements of safety. The main objective of such peer reviews is to identify possible weaknesses to enable the nuclear power plants to make their own improvements in areas identified. The reviews have in addition an important function in the collection, documentation and distribution of good practices. The peer review process is in many ways an ideal tool for improving performance, but there are also many challenges to overcome in order to making such reviews efficient.

Participation in the evaluation of a behavioural safety process. LearnSafe researchers participated in the evaluation of a programme of behavioural safety within one of the partner organisations. Its purpose was to describe how employees within reactor plants view behavioural approaches to safety management. In particular the programme addressed the perceived strengths and weaknesses of such approaches to safety management as well as identifying both current and future potential for learning.

A benchmarking exercise on quality activities and operations management. A benchmarking exercise of quality activities and operations management was carried out by LearnSafe researchers at two of the participating nuclear power plants. The quality activities and operations management play an important role in safety management activities at nuclear power plants. During the exercise views were also collected on the benefit of process orientation in the structuring of work activities. Relevant documentation concerning quality activities and operations management was collected and compared. This information was supported by semi-structured interviews.

Merging of two organisational cultures. The merger of two organisations was observed and reported by LearnSafe researchers. The study proved to give valuable information on how organisational change should be planned, implemented and followed up to be successful. Among the more generic results is an identification of the need to find a balance between various forces that have an influence on the process of organisational change.

The path to a new organisational structure. The study investigated the process leading to a large organisational restructuring of one of the participating nuclear power plants. The study generated generic lessons on the process of organisational change. The experience from the organisational change was largely positive, but some fine tuning of organisational functions still remained when the report was written.

Organisational controllability. In connection with the studies of organisational change a discussion of the concept of organisational controllability emerged. An understanding of organisational controllability relies on a combination of systems thinking and the use of models from management science and the behavioural sciences. It is necessary to bridge several disciplines that all have their own concepts, models and traditions. It can help in making concepts and models explicit and used in the discussion of upcoming decisions connected to organisational control.

A discussion of core competencies. A study of the interpretation and use of the concept of core competencies was conducted together with two of the participating nuclear power plants. The concept of core competency is important also as seen from a LearnSafe point of view, because it has several connections to learning organisations, organisational learning and knowledge management. The study brought together insights on the concept of core competency and provides a wider perspective on human resource management issues.

7.3 Good practices

A report on good practices was written to highlight good practices that have been observed within the LearnSafe project and its predecessor the ORFA project. The report relies on empirical material from a large number of data collection exercises and discussions with managers at several nuclear power plants in Europe. The report has been written for an audience of managers at various levels in the nuclear power plants, who are responsible for small or large groups of people. The report concludes that there are many good practices connected to organisation and management, which may have a positive influence on the safety of nuclear power plants. A final conclusion drawn from the report is that there is no mystery to good organisational performance, but only a good understanding of requirements and solutions together with hard and determined work.

It is difficult to condense good practices into simple advice, because simplistic statements may be considered trivial and long explanations will never be read. Perhaps the simplest recommendation that can be given is to continuously strive for excellence in all aspects of plant operation.

Simply listing good practices in short statements can never reproduce the richness of a theory that is grounded in empirical material. Unfortunately such a theory is still to be constructed. Most of the statements collected in the LearnSafe project have a relationship to the observed good practices.

In an attempt to summarise the good practices in just a few statements, the first is perhaps to ensure that key people have a good understanding of the requirements placed upon the nuclear industry and the implications they carry. The second is that the senior managers should select a proactive strategy to operate their plants. Finally, a systemic view should be applied whenever activities are managed; thus it is important to understand how different issues interact, which sometimes may happen in unexpected ways.

Perhaps the most important lesson to be drawn from the good practice examples is that there is no gimmick nor philosophers stone to be found in the pursuit of nuclear safety. Positive results can be achieved only with hard work that is based on a good understanding of the issues involved.

7.4 Exploitation and dissemination

Participating nuclear power plants use project results in their own work in their quest for improved safety and efficiency. The LearnSafe main partners will use the results in their research and consultancy work both within and outside the nuclear industry.

A better understanding of crucial components of safety management at the nuclear power plants can be drawn from the project findings and has implications for both the management of change and organisational learning. A collection of good practices as observed at the participating nuclear power plants has been generated. The project has during its course developed methods and tools that can be used for self-assessments and review of organisational efficiency and safety culture at the nuclear power plants. Courses and seminars at the participating nuclear power plants have facilitated the dissemination of results.

The exploitation of the LearnSafe results has taken place during interviews, discussions and seminars at the participating nuclear power plants. An interest has been expressed by the participants from the nuclear power plants continuing to share experience across the sector. The preparation of the case studies gave a good inventory of on-going activities at the participating nuclear power plants. Participating managers have commented positively about being forced to take time to discuss important preconditions for safety during discussions and interviews. The spin-off activities have provided immediate benefits for the plants that have been involved in them.

In a discussion of exploitation and dissemination of results it is also interesting to note that LearnSafe has received interest from other safety areas such as medical safety. This interest reflects similarities in safety management practices across different industrial areas.

The project has used one open and one closed web-site for the dissemination of results. According to statistics on visits the web-sites have shown to be very useful for the dissemination of project results. The closed web-site [5] is accessible to partners in the LearnSafe project only through user identification and a password. While the open web-site [6] is intended to provide information on the project to outsiders and to invite comments on early results that have a generic nature. By the end of 2004 the project web-page had recorded more than 30,000 hits, 7500 page views and 10,000 visits. There have been more than 7000 unique visitors who have downloaded 20,000 files from the site. Based on the success with the web-site VTT has volunteered to maintain the web-pages until 30.6.2006. In that period new reports by the partners will be uploaded on to the web-pages.

7.5 General conclusions

The results of the first phase of LearnSafe project included an inventory of organisational challenges at nuclear power plants and approaches for their resolution. The second phase collected facilitators and hindrances for organisational learning. These results support further understanding of crucial components of safety management at the nuclear power plants.

An increased understanding of systemic issues connected to human errors and organisational deficiencies can have a large influence on safety and economic competitiveness of nuclear power on a broad scale. These issues will be crucial to achieving the successful lifetime management of existing nuclear installations. Finally, safety cannot be built just as a collection of good practices, because practices have always to be adapted to local conditions.

The contacts between the research organisations were excellent during the whole project. LearnSafe has brought together a unique blend of researchers and practitioners. The involvement of nuclear power plants in five European countries has made it possible to address similarities and differences in organisational structures and work practices. The partnership has been close and has benefited from very open internal communication.

The LearnSafe project has shown the need for additional research on issues connected to organisation and management, because they are the most important factors contributing to events and incidents at the nuclear power plants. New research has been put forward to be carried out within the area of safety management. The LearnSafe project has shown that a combination of empirical and theoretical research can help in establishing scientific and technical platform by which safety requirements and organisational designs can be assessed.

Current understanding of human and organisational factors provides a poor scientific platform by which to consider sound requirements for activities within safety management. There is a gap between theory and practices when attempting to understand how people and organisations influence safety. Ongoing research in human and organisational factors in the nuclear industry is fragmented with only minimal interactions between research groups. Academic research has been quite theoretical, whereas practical guidance in the field has a poorly grounded scientific base. A stimulation of multi-disciplinary research in nuclear safety has a large potential for improvements in the prevention of minor events that may lead to incidents.

There are many good practices related to organisation and management, which can have a positive influence on safety of nuclear power plants. However, there are no short cuts by which good organisational performance can be reached, but only a good understanding of requirements and solutions, paired with hard and determined work.

7.6 Recommendations

Further understanding of systemic issues of human and organisational factors will need deliberate efforts of education and training. Placing these issues on the agenda of the nuclear power plants may require pedagogical approaches to bridge the typical engineering suspicion against the soft issues of safety. Some of these issues can be included in safety culture programmes that are typically carried out at all nuclear power plants.

On a general level the major challenge for the nuclear industry in Europe is to operate present nuclear power plants to the end of their remaining technical life, with economic margins, which includes the possibility to opt for plant life extensions, power upgrades and improved economic performance. This option for an extended utilisation of earlier investments is possible if and only if a management process can be found, which is compatible with present and upcoming societal requirements and which at the same time makes safe and economic use of both material and immaterial assets. A clear organisational structure with clear managerial accountability for safety at all levels is a precondition if such a process is to succeed. Structural solutions for organisation and management have therefore to be adapted continuously in response to changes both within the electricity market, the workforce and within the regulatory regime.

Approaching these challenges will require continued investments together with excellence in planning for safe operation over many years. If an extended co-operation within safety management can be achieved between the nuclear power plants in Europe it seems evident that savings can be achieved in terms of used resources and as a consequence of the increased safety. As a suggested framework of research co-operation within safety management is suggested, which would include activities within the following broad areas:

– *Leadership and management*. Management and organisation, quality systems, methods and tools for self-assessments and safety reviews, processes of continuous improvements, safety culture, etc.

- *Communication*. Deficient communication is a root-cause for many problems. Solutions are needed to ensure open and efficient communication internally at the nuclear power plants and between actors within the nuclear field.

- *Processes for decision making*. Structured decision processes for operations, maintenance and plant modifications. Practices to establish authority, responsibility and accountability.

- *Experience feedback and organisational learning*. Benchmarks of event analysis, experience feedback, self-evaluation and continuous improvement processes. Facilitators and hindrances to organisational learning.

- *Competency*. Management of generation change, methods for maintaining and improving competency, leadership training.

8. Summary

The main objective of the LearnSafe project was to create methods and tools for supporting processes of *organisational learning* at the nuclear power plants. Organisational learning has become increasingly important for the nuclear industry in its adaptation to changes in the political and economic environment, changing regulatory requirements, a changing work force, changing technology in the plants, and the changing organisation of nuclear power plants and power utilities. The danger during a rapid process of change is that minor problems may trigger a chain of events leading to actual degrading of safety and/or diminishing political and public trust in the safety standards of the particular nuclear power plant, utility or corporation.

The focus of the project has been on senior managers at nuclear power plants and power utilities who are responsible for strategic choice and resource allocation. This focus was selected with the understanding that their decisions, approaches and attitudes have an important influence both on safety and economy of the nuclear power plants. The LearnSafe project has developed methods and tools that can be used in the management of change and in ensuring efficient organisational learning.

The project was set up in two major phases, which covered both empirical investigations and theoretical considerations. The first phase placed a focus on *management of change* and the second on *organisational learning*. The empirical part of the first phase of the project collected senior manager views on challenges that are facing nuclear power plants today. This data set contains approximately 800 statements collected from nearly 200 persons in five countries, ten nuclear power plants and one international organisation. The analysed data was used to further assess the strategies, plans and actions for coping with the challenges. These were further developed to form concrete suggestions for improvements targeted to major stakeholders in the nuclear field.

The empirical part of the second phase of LearnSafe focused on facilitators and hindrances for organisational learning. This data set consists of nearly 1000 statements from more than 100 persons in five countries and ten nuclear power plants. This data set has been analysed to identify major groups of facilitators and hindrances to organisational learning. The LearnSafe results also include descriptions of methods and tools that can be used by the nuclear power plants themselves in assessing and improving their performance. Furthermore, LearnSafe has also collected and documented good practices for safety management.

One important feature of the project has been the continuous interaction between researchers and managers in addressing issues of organisation and management that are

important for both safety and efficiency. This has further been facilitated by spin-off tasks in which participating nuclear power plants have expanded some of the early results from the LearnSafe project to answer interesting questions of their own. Several such spin-off tasks have been completed, reported and discussed in small workshops at the nuclear power plants.

The LearnSafe project has developed and used several models connected to management and organisations. These models can prove useful in structuring managerial activities that aim at ensuring continued safety within nuclear power plants. An open final seminar was held 28–29 April 2004 to disseminate project results. The proceedings of the seminar have been made available at the LearnSafe open web-site http://www.vtt.fi/virtual/learnsafe/. A closed web-site was used during the project to facilitate communication between LearnSafe partners.

Acknowledgements

The efforts of many people from the partner organisations are acknowledged. Without the open and candid discussions, the project would have been impossible to bring to a successful conclusion.

The funding of the LearnSafe project (Project N°: FIS5-2001-00066, Contract N°: FIKS-CT2001-00162) by the European Community under the 5th Euratom Framework Programme 1998–2002, Key Action: Nuclear Fission is gratefully acknowledged.

References

[1] Geneviève Baumont, Björn Wahlström, Rosario Solá, Jeremy Williams, Albert Frischknecht, Bernhard Wilpert, Carl Rollenhagen (2000). Organisational Factors; their definition and influence on nuclear safety. VTT Research Notes 2067, Technical Research Centre of Finland, Espoo. 65 p. ISBN 951-38-5770-0; 951-38-5771-9 http://www.vtt.fi/inf/pdf/tiedotteet/2000/T2067.pdf

[2] Carl Rollenhagen (2002). Safety management of nuclear power plants: Values and balance of attention. PLEM – LearnSafe – P001.

[3] Holsti, O.R. (1969). Content Analysis for the Social Sciences and Humanities. Addison-Wesley, Reading, MA.

[4] Gibbs, G. (2002). Qualitative Data Analysis: Explorations with N-Vivo. Open University Press: Buckingham/Philadelphia.

[5] http://proxnet.vtt.fi/learnsafe/.

[6] http://www.vtt.fi/virtual/learnsafe/.

Literature in the field of organisational learning

There are many references to literature in the LearnSafe reports. The list of references below summarises some of the more important information sources connected to the subject field of the LearnSafe project.

Anheier, Helmut K. (ed.) (1996). Organizational failures and bankruptcies. American Behavioral Scientist, Vol. 39, No. 8, August.

Antal, A.B., Lenhardt, U. & Rosenbrock, R. (2001). In: M. Dierkes, A.B. Antal, J. Child. & I. Nonaka. (Eds.). Handbook of Organizational Learning and Knowledge. New York: Oxford University Press Inc. Pp. 865–885.

Argote, L. (1999). Organizational learning: Creating, retaining and transferring knowledge. Kluwer, Norwell, MA.

Argyris, C. & Schön, D.A. (1978). Organizational learning: A theory of action perspective. Reading MA, Addison-Wesley.

Argyris, C. (1982). Reasoning, Learning and Action: Individual and Organisational. San Francisco: Jossey-Bass.

Argyris, C. (1993). Knowledge for Action: A Guide for Overcoming Defensive Behaviours. San Francisco: Jossey-Bass.

Argyris, C. & Schon, D. (1996). Organizational learning II: theory, method and practice. Reading: Addison-Wesley.

Bateson, G. (1972). Steps to an ecology of mind. New York: Ballantine.

Baumont, G., Wahlström, B., Solá, R., Williams, J., Frischknecht, A., Wilpert, B. & Rollenhagen, C. (2000). Organisational Factors; their definition and influence on nuclear safety. VTT Research Notes 2067, Technical Research Centre of Finland, Espoo, Finland. 65 p. http://www.vtt.fi/inf/pdf/tiedotteet/2000/T2067.pdf

Becker, G., Hoffmann, S., Wilpert, B., Miller, R., Fahlbruch, B., Fank, M., Freitag, M., Giesa, H.-G., Hoffmann & Schleifer, L. (1995). Analyse der Ursachen von "menschlichem Fehlverhalten" beim Betrieb von Kernkraftwerken (BMU-1996-454). Bonn: Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit.

Beyer, J.M. (1981). Ideologies, values, and decision making in organizations. In: P.C. Nystrom & W.H. Starbuck (Eds.). Handbook of organizational design. Vol. 2. New York: Oxford University Press. Pp. 166–202.

Bier V.M., Joosten J.K., Glyer J.D., Tracey, J.A. & Welsh, M.P. (2001). Effects of deregulation on safety: Implications drawn from the aviation, rail, and United Kingdom nuclear power industries. U.S. Nuclear Regulatory Commission, NUREG/CR-6735, June.

Boerner, C. Macher, J. & Teece, D. (2001). A Review and Assessment of Organisational Learning in Economic Theories. In: M. Dierkes, A. Berthoin Antal, J. Child & I. Nonaka (Eds.). Handbook of Organisational Learning and Knowledge. Oxford: Oxford University Press.

Boud, D., Cohen, R. & Walker, D. (1993). Introduction: Understanding Learning from Experience. In: D. Boud, R. Cohen & D. Walker (Eds.). Using Experience for Learning. Buckingham: The Society for Research into Higher Education and Open University Press.

Brown, J. & Duguid, P. (1998). Organisational Learning and Communities of Practice: Toward a Unified View of Working, Learning and Innovation. Organization Science, 2, pp. 40–57.

Bruner, J. & Hastes, H. (1987). Making Sense. London: Methuen.

Brunsson, N. (1982). The Irrationality of Action and Action Rationality; Decisions, Ideologies and Organisational Actions. Journal of Management Studies, Vol. 19, pp. 29–44.

Caroll, J. (1998). Safety culture as an ongoing process: cultural surveys as opportunities for enquiry and change. Work and Stress, 12, pp. 255–271.

Carroll, J.S. (1998). Organizational learning activities in high-hazard industries: The logics underlying self-analysis. Journal of Management Studies, Vol. 35, No. 6, pp. 699–717.

Carroll, J.S. & Hatakenaka, S. (2001). Developing a safety conscious work environment at Millstone nuclear power station. In: B. Wilpert & N. Itoigawa (Eds.). Safety Culture in Nuclear Power Operations. Taylor & Francis, London.

Chevalier, F. & Segalla, M. (1996). Organizational behaviour and change in Europe. Sage Publications.

Cohen, M.D., March, J.G. & Olsen, J.P. (1972). A garbage can model of organisational choice. Administrative Science Quarterly, Vol. 17, pp. 1–25.

Cox, S. & Cox, T. (1991). The structure of employee attitudes to safety: A European example. Work and Stress, 5, pp. 93–106.

Cox, S. & Flin, R. (1998). Safety culture: Philosophers stone or a man of straw? Work & Stress, Vol. 12, No. 3, pp. 189–201.

Cox, S.J. & Cheyne, A.J.T. (2000). Assessing safety culture in offshore environments. Safety Science, 34, pp. 111–129.

Cyert, R. & March, J. (1963). A Behavioural Theory of the Firm. Englewood Cliffs, NJ: Prentice Hall.

Czarniawska-Joerges, B. (1992). Exploring Complex Organisations: A Cultural Perspective. Newbury Park: Sage.

Davenport, T.H. & Prusak, L. (1998). Working Knowledge: How Organisations Manage What They Know. Boston: Harvard Business School Press.

Davoudian, K., Wu, J.-S. & Apostolakis, G. (1994). Incorporating organizational factors into risk assessments through the analysis of work processes. Reliability Engineering and System Safety, Vol. 45, pp. 85–105.

Davoudian, K., Wu, J.-S. & Apostolakis, G. (1994). The work process analysis method (WPAM). Reliability Engineering and System Safety, Vol. 45, pp. 107–125.

Denison, D.R. (1996). What is the difference between organisational culture and organizational climate. A native's point of view on a decade of paradigm wars? Academy of Management Review, 21, pp. 619–654.

DiBella, A.J., Nevis, E.C. & Gould, J.M. (1996). Understanding organizational learning capability. Journal of Management Studies, Vol. 33, No. 3, pp. 361–379.

Dixon, N. (1999). The Organisational Learning Cycle: How We Can Learn Collectively (2nd Ed.). Gower: Hampshire.

Edmondson, A.C. (2003). Speaking up in the operating room: How team leaders promote learning in interdisciplinary action teams. Journal of Management Studies, Vol. 40, No. 6, September, pp. 1419–1452.

Espejo, R., Schuhman, W., Schwaninger, M. & Biello, U. (1996). Organizational transformation and learning. John Wiley&Sons.

Esterby-Smith, M., Crossan, M. & Nicolini, D. (2000). Organizational learning: Debates past, present and future. Journal of Management Studies, Vol. 36, No. 6, pp. 783–796.

Fahlbruch, B. & Wilpert, B. (1997). Event analysis as problem solving process. In: A.R. Hale, B. Wilpert & M. Freitag (Eds.). After the Event: From Accident to Organisational Learning. Oxford: Elsevier. Pp. 113–130.

Fahlbruch, B., Miller, R. & Wilpert, B. (1998). Sicherheit durch Organisationales Lernen. A T W – Internationale Zeitschrift für Kernenergie, 43, pp. 699–703.

Fahlbruch, B. & Wilpert, B. (2002). Goals, claims, and difficulties of safety interventions. In: B. Wilpert & B. Fahlbruch (Eds.). System Safety. Challenges and Pitfalls of Intervention. Oxford: Elsevier Science. Pp. 7–15.

Furuta, K., Sasou, K., Kubota, R., Ujita, H., Shuto, Y. & Yagi, E. (2000). Human factor analysis of JCO criticality accident. Cognition, Technology & Work, Vol. 2, pp. 182–203.

Gherardi, S. Nicolini, D. & Odella, F. (1998). Toward a Social Understanding of How People Learn in Organisations: The Notion of Situated Curriculum. Management Learning, 29, pp. 273–98.

Gherardi, S. & Nicolini, D. (2001). The Sociological Foundations of Organisational Learning. In: M. Dierkes, A. Berthoin Antal, J. Child & I. Nonaka (Eds.). Handbook of Organisational Learning and Knowledge. Oxford: Oxford University Press.

Gibbs, G. (1988). Learning by Doing: A Guide to Teaching and Learning Methods. London: Further Education Unit.

Gill, K.S & Darling, F. (1996). Partnership; its contribution to outage success. Nuclear Engineering International, Vol. 41, No. 508, pp. 38–40.

Grabowski, M. & Roberts, K.H. (1996). Human and organizational errors in large scale systems. IEEE Transactions on Systems, Man and Cybernetics-Part A: Systems and Humans, Vol. 26, No. 1, pp. 2–16.

Grote, G. & Kunzler, C. (2000). Diagnosis of safety culture in safety management audits. Safety Science, 34, pp. 131–150.

Hafeez, K., Zhang, Y.B. & Malek, N. (2002). Core competence for sustainable competitive advantage: A structured methodology for identifying core competence. IEEE Trans. on Engineering Management, Vol. 49, No. 1, February, pp. 28–35.

Hale, A., Wilpert, B. & Freitag, M. (Eds.). (1997). After the Event: From Accident to Organisational Learning. Oxford: Elsevier.

Harris, M. & Raviv, A. (2002). Organization design. Management Science, Vol. 48, No. 7, July, pp. 852–865.

Haunschild, P.R. & Rhee, M. (2004). The role of volition in organizational learning: The case of automative product recall. Management Science, Vol. 50, pp. 1545–1560.

Heacock, D. (1999). How Virginia Power plans to succeed in a deregulated market. Nuclear Engineering International, Vol. 44, No. 534, pp. 36–37.

Hickson, D.J., Butler, R.J., Cray, D., Maory, G.R. & Wilson, D.C. (1986). Top Decisions: Strategic Decision-Making in Organisations. Basil Blackwell: Oxford.

Hofstede, G. (1997). Cultures and organizations; software of the mind. McGraw-Hill.

Honey, P. & Mumford, A. (1988). The Manual of Learning Opportunities. Maidenhead: P. Honey & A. Mumford.

Huber, G. (1991). Organisational Learning: The Contributing Process and the Literatures. Organization Science, 2, pp. 88–115.

IAEA. (1991). Safety Culture, INSAG-4. International Atomic Energy Agency, May, Vienna.

IAEA. (1994). 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, May, Vienna.

IAEA. (1997). Organizational factors influencing human performance in nuclear power plants. IAEA-TECDOC-943, May.

IAEA. (1997). Procedures for self-assessment of operational safety, TECDOC-954.

IAEA. (1998). Nuclear power plant organization and staffing for improved performance: lessons learned. International Atomic Energy Agency, IAEA-TECDOC-1052.

IAEA. (1999). Management of operational safety in nuclear power plants, INSAG-13. International Atomic Energy Agency, Vienna.

IAEA. (1999). Self-assessment of operational safety for nuclear power plants, TECDOC-1125.

IAEA. (1999). Evaluating and improving nuclear power plant operating performance, IAEA-TECDOC-1098. International Atomic Energy Agency, Vienna.

IAEA. (2000). Regulatory control of the use of contractors by operating organizations. Peer discussions on regulatory practices (IAEA-PDRP-5). Vienna: International Atomic Energy Agency.

IAEA. (2000). Operational Safety Performance Indicators for Nuclear Power Plants, TECDOC-1141.

IAEA. (2001). The Operating Organization for Nuclear Power Plants, Safety Guide, NS-G-2.4. International Atomic Energy Commission, Vienna.

IAEA. (2001). Managing change in nuclear utilities, IAEA-TECDOC-1226. International Atomic Energy Agency, Vienna.

IAEA. (2002). Review of methodologies for analysis of safety incidents at NPPs, TECDOC-1278.

IAEA. (2002). Self-assessment of safety culture in nuclear installations, TECDOC-1321.

IAEA. (2002). Developing an economic performance system to enhance nuclear power plant competitiveness, IAEA-Technical Report Series-406. International Atomic Energy Agency, Vienna.

IAEA. (2002). Safety culture in nuclear installations; guidance for use in the enhancement of safety culture, TECDOC-1329. International Atomic Energy Agency, May, Vienna.

IAEA. (2002). Key practical issues in strengthening safety culture, a report by the International Nuclear Safety Advisory Group, INSAG-15. International Atomic Energy Agency, Vienna.

IAEA. (2003). Maintaining Knowledge, Training and Infrastructure for Research and Development in Nuclear Safety, INSAG-16.

IAEA. (2003). Managing Change in the Nuclear Industry: The Effects on Safety, INSAG-18.

Isaacs, W. (1993). Taking flight: Dialogue, collective thinking, and organisational learning. Organizational Dynamics, 21, (3), pp. 24–39.

Isaacs, W. (1999). Dialogue and the art of thinking together: A pioneering approach to communication in business and in life. Garden City, NY: Doubleday.

Itoigawa, N., Fahlbruch, B. & Wilpert, B. (Eds.). (2004). Emerging Demands for the Safety of Nuclear Power Operations. Bacon Rouge, FL: CRC Press.

Jacobs, R. & Haber, S. (1994). Organizational processes and nuclear power plant safety. Reliability Engineering and System Safety, Vol. 45, pp. 75–83.

James, L.R. & Jones, A.P. (1974). Organisational climate: a review of theory and research. Psychological Bulletin, 81, (12), pp. 1096–1112.

Jensen, B. & Rothwell, G. (1998). Transaction costs, regulation, and subcontracting at nuclear power plants. Journal of Economic Behavior & Organization, Vol. 36, Issue 3, pp. 369–381.

Kim, D. (1993). The link between individual and organizational learning. Sloan Management Review, Fall, pp. 37–50.

La Porte, T.R. & Consolini, P.M. (1991). Working in Practice but not in Theory. Journal of Public Administration Research and Theory, 1, pp. 19–47.

Lannes, W.J. & Logan, J.W. (2004). A technique for assessing and organization's ability to change. IEEE Trans. on Engin. Management, Vol. 51, pp. 483–488.

Lave, J. & Wenger, E. (1991). Situated Learning: Legitimate Peripheral Participation. Cambridge: Cambridge University Press.

Levitt, B. & March, J. (1988). 'Organisational Learning.' Annual Review of Sociology, 14, pp. 319–40.

Llory, M.A. (1992). Human reliability and human factors in complex organizations: epistemological and critical analysis: Practical avenues to action. Reliability Engineering and System Safety, Vol. 38, pp. 109–117.

March, J. & Olson, J. (1976). Ambiguity and Choice in Organizations. Bergen: Universitetsforlaget.

Martin de Holan, P. & Phillips, N. (2004). Remembrance of things past? The dynamics of organisational forgetting. Management Science, Vol. 50, pp. 1603–1613.

Miller, R. & Wilpert, B. (1997). SOL – Sicherheit durch Organisationales Lernen. Ereignisanalyse in der verfahrenstechnischen Industrie. In: VDI-Gesellschaft Systementwicklung und Projektgestaltung (Ed.). Zuverlässige Technik ist planbar. Düsseldorf: VDI-Verlag. Pp. 163–171.

Miner, A. & Mezias, S. (1996). Ugly Duckling No More. Pasts and Futures of Organisational Learning Research. Organisational Science, 7, (1), pp. 88–99.

Mintzberg, H. (1973). The Nature of Managerial Work. New York: Harper and Row.

Moigeon, B. & Edmondson, A. (1996). Organisational Learning and Competitive Advantage. London: Sage.

Morgan, G. (1986). Images of organizations. Beverley Hills: Sage.

Mumford, A. (1992). The Pursuit of Change. Management Decisions. Individual and Organizational Learning, Vol. 30, Iss. 6, pp. 143–148.

Nevis, E.C., DiBella, A.J. & Gould, J.M. (1995). Understanding organizations as learning systems. Sloan Management Review, Winter, pp. 73–85.

Nickerson, J.A. & Zenger, T.R. (2002). Being efficiently fickle: A dynamic theory of organisational choice. Organization Science, Vol. 13, No. 5, September–October, pp. 547–566.

Nonaka, I. & Takeuchi, H. (1995). The knowledge creating company, Oxford University Press.

Nonaka, I. & Konno, N. (1998). The Concept of *ba*: Building a foundation for Knowledge Creation. California Management Review, 40(3), pp. 40–54.

OECD/NEA. (1999). The role of the nuclear regulator in promoting and evaluating safety culture. Organisation for Economic Co-operation and Development, June, Paris.

OECD/NEA. (1999). Identification and assessment of organisational factors related to the safety of NPPs, Vol. 1 & Vol. 2, NEA/CSNI/R898)17.

OECD/NEA. (2002). Regulatory aspects of management of change, summary and conclusions, NEA/CSNI/R(2002)20, Nuclear Energy Agency.

OECD/NEA. (2000). Nuclear Power Plant Life Management in a Changing Business World. Workshop Proceedings, Washington DC, United States, 26–27 June 2000. Issy-les-Moulineaux: OECD Nuclear Energy Agency.

Ortega, J. (2001). Job rotation as a learning mechanism. Management Science, Vol. 47, No. 10, October, pp. 1361–1370.

Pautzke, G. (1989). Die Evolution der organisatorischen Wissensbasis. Bausteine zu einer Theorie des organisationalen Lernens. Herrsching: B. Kirsch.

Pawlowsky, P. (2001). The Treatment of Organisational Learning in Management Science. In: M. Dierkes, A. Berthoin Antal, J. Child. & I. Nonaka (Eds.). Handbook of Organisational Learning and Knowledge. Oxford: Oxford University Press.

Perrow, C. (1999). Normal Accidents. Princeton, New Jersey. Princeton University Press.

Quinn, R.E. & Rohrbaugh, J. (1998). A spatial model of effectiveness criteria: Toward a competing values approach to organizational analysis. Management Science, 29, pp. 363–377.

Reason, J. (1998). Managing the risk of organizational accidents, Brookfield, VT: Ashgate Publishing Company.

Roberts, K.H. (1993). New Challenges to Understanding Organizations. New York: Mac Millan.

Rochlin, G.I. & von Meier, A. (1994). Nuclear power operations: A cross-cultural perspective. Ann. Rev. Energy Environ., 19, pp. 153–187.

Schein, E.H. (1992). Organisational culture and leadership (2nd. ed.) San Francisco: Josssey Bass.

Shrivastava, P. (1983). A typology of organizational learning systems. Journal of Management Studies, 20, (1), pp. 7–28.

Simon, H.A. (1976). Administrative behaviour. New York: Macmillan.

Simon, H.A. (1986). Decision Making and Problem Solving. Report of the Research Briefing Panel on Decision Making and Problem Solving by National Academy of Sciences. Washington, DC: National Academy Press. Available on the public-website: http://dieoff.org/

Sorensen, J.N. (2002). Safety culture: a survey of the state-of-the-art. Reliability Engineering and System Safety, Vol. 76, pp. 189–204.

Sorenson, O. (2003). Interdependence and adaptability: Organizational learning and the long-term effect of integration. Management Science, Vol. 49, No. 4, April, pp. 446–463.

Stata, R. (1989). Organizational Learning – The Key to Management Innovation. Sloan Management Review, 30/3, pp. 63–74.

Steinfeld, M. (2002). Organisationales Lernen und umweltbezogene Lernprozesse. Arbeitsbericht INTUS Konsortium. Universität Stuttgart.

Streitz, N.A. (1987). Subjektive Wissensrepräsentationen als Determinanten kognitiver Prozesse. Sankt Augustin.

Stubbart, C. (1989). Managerial Cognition: A missing link in Strategic Management Research. Journal of Management Studies, 26:4, July.

Trompenaars, F. & Hampden-Turner, C. (1998). Riding the waves of culture; understanding cultural diversity in global business. McGraw-Hill.

Tsuokas, H. & Chia, R. (2002). On organizational becoming: Rethinking organizational change. Organization Science, Vol. 13, No. 5, September–October, pp. 567–582.

Walsh, J.P. (1995). Managerial and Organisational Cognition: Notes from a Trio Down Memory Lane. Organization Science, Vol. 6. No. 3, pp. 280–321.

WANO. (1999). Performance objectives and criteria, Revision 2, March.

Weick, K. (1979). The Social Psychology of Organising (2nd Ed.) Reading Mass.

Weick, K.E. (1995). Sensemaking in Organisations. Sage: California.

Weil, R. & Apostolakis, G. (2001). A methodology for the priorization of operating experience in nuclear power plants. Reliability Engineering and System Safety, Vol. 74, pp. 23–42.

Williams, A.P.O. (2001). A belief-focused process model of organizational learning. Journal of Management Studies, Vol. 38, No. 1, pp. 67–85.

Wilpert, B. Management as risk factor in high hazard systems. In: P.J.D. Drenth, P.L. Koopman & B. Wilpert (Eds.). Organizational Decision-Making under Different Economic and Political Conditions. Amsterdam: North-Holland. Pp. 71–78.

Wilpert, B. (1999). Organizational Factors in Nuclear Safety. In: S. Kondo & K. Furuta (eds.). PSAM5 – Probabilistic Safety Assessment and Management, Vol. 2. Tokyo: Universal Academy Press. Pp. 1251–1265.

Wilpert, B. (1999). Sicherheit durch organisationales Lernen – Das SOL-Verfahren. Jahrestagung Kerntechnik '99, Fachsitzung Der Faktor Mensch im Betrieb von Kernkraftwerken. Bonn: INFORUM. Pp. 79–89.

Wilpert, B. (2001). The relevance of safety culture for nuclear power operations. In: B. Wilpert & N. Itoigawa (Eds.). Safety Culture in Nuclear Power Operations. London: Taylor & Francis. Pp. 5–18.

Wilpert, B. & Fahlbruch, B. (Eds.). (2002). System Safety. Challenges and Pitfalls of Intervention. Oxford: Elsevier Science.

Wilpert, B., Fahlbruch, B. & Miller, R. (1996). Problems of implementing a systemic approach to safety management. In: A.F. Özok & G. Salvendy (Eds.). Advances in Applied Ergonomics. West Lafayette: USA Publishing Corporation. Pp. 143–146.

Wilpert, B., Fahlbruch, B., Miller, R., Baggen, R. & Gans, A. (1999). Interorganizational development in the German nuclear safety system. In: J. Misumi, B. Wilpert & R. Miller (Eds.). Nuclear Safety: A Human Factors Perspective. London: Taylor & Francis.

Wilpert, B. & Itoigawa, N. (Eds.). (2001). Safety Culture in Nuclear Power Operations. London: Taylor & Francis.

Wilpert, B. & Klumb, P. (1993). Social dynamics, organization and management: Factors contributing to systems safety. In: B. Wilpert & T. Qvale (Eds.). Reliability and Safety in Hazardous Work Systems. Hove: Lawrence Erlbaum.

Zammuto, R.F., Gifford, B. & Goodman, E.A. (2000). Managerial Ideologies, Organization Culture, and the Outcomes of Innovation: A Competing Values Perspective. In: N. Ashkanasy, C. Wilderom & M. Peterson (Eds.). The handbook of Organisational Culture and Climate. Thousand Oaks, CA: Sage Publications. Pp. 263–280.

Appendix A: Partners in the LearnSafe project

The following organisations have participated in the LearnSafe project. Contact information can be found at the web-site http://www.vtt.fi/virtual/learnsafe/.

PROJECT CO-ORDINATOR

Technical Research Centre of Finland (VTT), VTT Industrial systems, Espoo, Finland

CONTRACTORS:

Berlin University of Technology (TUB), FSS Research Center Systems Safety, Berlin, Germany

Lancaster University (ULANC), the Management School, Lancaster, UK

The Research Centre for Energy, Environment and Technology (Ciemat), Madrid, Spain

SwedPower AB (SWP), Stockholm, Sweden

ASSISTANT CONTRACTORS:

Asociación Española de la Industria Eléctrica (UNESA), Madrid, Spain

World Organisation for Nuclear Operators (WANO), Paris, France

Teollisuuden Voima Oy (TVO), Olkiluoto, Finland

Forsmark Kraftgrupp AB (FKA), Östhammar, Sweden

E.ON Kernkraft GmbH, Kernkraft Grafenrheinfeld (KKG), Grafenrheinfeld, Germany

Kernkraftwerk Krümmel GmbH (KKK), Geesthacht, Germany

British Nuclear Fuels plc (BNFL), Warrington, UK

OKG Aktiebolag (OKG), Oskarshamn, Sweden

Ringhals AB (Ringhals), Väröbacka, Sweden

Appendix B: The LearnSafe final seminar

The Final Seminar of LearnSafe was held at the Technical Research Centre of Finland on 28th–29th April 2004 in Espoo, Finland. During the first day the LearnSafe team presented results and findings from the project. The second day was devoted to comments from the nuclear power plants that had participated in the project and two individuals, who had been invited to present their views on the project and its results. The seminar was concluded in a panel discussion. A total of 46 persons from 5 countries participated in the seminar. In an optional programme before the start of the seminar the participants had an opportunity to hear presentations on the fifth reactor to be constructed in Finland by the TVO Company. The presentations and other material from the seminar can be found on the web-site http://www.vtt.fi/virtual/learnsafe/.

Presentations at the seminar

Overview of the LearnSafe project, Björn Wahlström, VTT (FIN)

Challenges seen by the nuclear industry, Sue Cox, ULANC (GB)

What can we learn from the collected data, Bethan Jones, ULANC (GB), Jari Kettunen, VTT (FIN)

Characteristics of learning organisations, Bernhard Wilpert, TUB (DE)

Hindrances for organizational learning, R. Martinez & Jose M. Prieto, Complutense University, Madrid (ES)

An attempt for a synthesis, Björn Wahlström, VTT (FIN)

Nuclear power in Europe; some personal reflections, Björn Wahlström, VTT (FIN), based on material from Mr. Loris Rossi, European Commission

Challenges in maintaining 60 years of operation, Antti Piirto, TVO (FIN)

A stable life of change, Leif Johansson, Ringhals AB (SE)

RENAT Project. A Generational Turnover, Jose M. Zamarrón, Almaraz-Trillo nuclear power plants (ES)

Our experience from LearnSafe, Knut Mume, KKK (DE)

Creating a Learning Organisation, Ray Hughes, BNFL Magnox (GB)

Hazards & Safety; What is new?, Armand Colas, WANO

The importance of organizational learning for safety. A regulatory perspective, Jose Villadoniga, CSN (ES)

An outsiders view, the LearnSafe project from an academic perspective, Erik Hollnagel, University of Linköping (SE)

Panel discussion

"What next?", chair Magnus von Bonsdorff (FI), panel members Karl-Fredrik Ingemarsson, Vattenfall (SE), Marja-Leena Järvinen, STUK, (FI), Rauno Mokka, TVO (FI), Tellervo Taipale TVO (FI)

Appendix C: Reports and presentations that can be downloaded from the LearnSafe web-site

In addition to the presentations at the LearnSafe final seminar (cf. Annex B) the following reports and presentations have been placed in the open domain for the benefit of all organisations and individuals that are interested in nuclear safety, organisational factors, safety management and learning organisations. By an agreement the LearnSafe web-site will be maintained at least to the end of June 2006, which means that additional reports may be included at later instants. Additional information on LearnSafe together with the reports sited below can be found at the web-site http://www.vtt.fi/virtual/learnsafe/.

Olle Andersson, Carl Rollenhagen (2002). The MTO Concept and Organisational Learning at Forsmark NPP, Sweden, PLEM – LearnSafe – X005.

Sue Cox, Bethan Jones, Helen Rycraft (2002). Behavioural Approaches to Safety Management within Reactor Plants – a Preliminary Study, PLEM – LearnSafe – X004.

Sue Cox, Bethan Jones (2003). 'LEARNSAFE' Learning Organisations for Nuclear Safety, PLEM – LearnSafe – X006.

Bethan Jones (2003). Theoretical approaches to organisational learning, PLEM – LearnSafe – P002.

Bethan Jones, Sue Cox, Helen Rycraft (2004). Assessing Employee Attitudes towards Behavioural Approaches to Safety Management within UK Reactor Plants, PLEM – LearnSafe – X010.

Jari Kettunen, Bethan Jones, Teemu Reiman (2004). Assessing Challenges to Nuclear Power Plant Management in Five European Countries: Methods, Results and Lessons Learned, PLEM – LearnSafe – X011.

Carl Rollenhagen (2002). Safety management of nuclear power plants: Values and balance of attention, PLEM – LearnSafe – P001.

Carl Rollenhagen (2003). Safety Management as Problem - identification and Problem – solving, PLEM – LearnSafe – P004.

Björn Wahlström, Bernhard Wilpert, Sue Cox, Rosario Solá, Carl Rollenhagen (2002). Learning Organizations for Nuclear Safety, PLEM – LearnSafe – X001.

Björn Wahlström (2002). Challenges in the nuclear industry as seen by senior managers and safety experts, PLEM – LearnSafe – X002.

Björn Wahlström, Carl Rollenhagen (2003). Reflections on organisational structures in nuclear power plants, PLEM – LearnSafe – P003.

B. Wahlström, B. Wilpert, S. Cox, R. Solá, C. Rollenhagen, M. Ibanez, Y. Canaff, M. Friberg, O. Andersson, R. Scheuring, P. Gerdes, H. Rycraft, E. Dunge, K. Egnér (2003). Learning organisations for nuclear safety (LearnSafe), PLEM – LearnSafe – X007.

Björn Wahlström (2003). Risk Informed Approaches for Plant Life Management: Regulatory and Industry Perspectives, PLEM – LearnSafe – X008.

Björn Wahlström (2004). Organisational learning; a path to safety and efficiency, PLEM – LearnSafe – X009.

Björn Wahlström, Carl Rollenhagen (2004). Issues of safety culture; reflections from the LearnSafe project, PLEM – LearnSafe – X012.

Björn Wahlström (2005). Reflections on regulatory oversight, PLEM – LearnSafe – W013.

Björn Wahlström, Jari Kettunen, Olle Andersson, Markku Friberg (2005). A discussion of core competencies, PLEM– LearnSafe – P007.

Bernhard Wilpert (2004). Characteristics of learning organizations, PLEM – LearnSafe – P005.

Appendix D: Members of the LearnSafe team

The following persons from the five main partners have collectively contributed to the collection and analysis of data and thus to the results of the LearnSafe project.

VTT Industrial Systems (http://www.vtt.fi/tuo/indexe.htm)

Jari Kettunen	VTT Industrial Systems POB 1301 Tekniikantie 12 FIN-02044 VTT (Espoo)	phone +358 20 72266784 fax +358 20 7226752 jari.kettunen@vtt.fi
Teemu Reiman	VTT Industrial Systems POB 1301 Tekniikantie 12 FIN-02044 VTT (Espoo)	phone +358 20 7226775 fax +358 20 7226752 teemu.reiman@vtt.fi
Björn Wahlström	VTT Industrial Systems POB 1301 Tekniikantie 12 FIN-02044 VTT (Espoo)	phone +358 20 7226400 fax +358 20 7226752 bjorn.wahlstrom@vtt.fi http://www.bewas.fi/bgw.html

Berlin University of Technology (http://www.tu-berlin.de/)

Juliane Jung	Technische Universität Berlin Inst. of Psychology & Arb.Wissenschaften Marchstrasse 12, DE-10587 Berlin	phone fax Juliane.Jung@gp.tu-berlin.de
Hans Maimer	Technische Universität Berlin Inst. of Psychology & Arb.Wissenschaften Marchstrasse 12, DE-10587 Berlin	phone +49 30 31426885 fax +49 30 31425274 hans.maimer@tu-berlin.de
Bernhard Wilpert	Technische Universität Berlin Inst. of Psychology & Arb.Wissenschaften Marchstrasse 12, DE-10587 Berlin	phone +49 30 31422915 fax +49 30 31425434 Bernhard.Wilpert@tu-berlin.de http://www.tu-berlin.de/~aopsych/personen/home-bw.htm

Lancaster University Management School (http://www.lums.lancs.ac.uk)

Sue Cox	Lancaster University The Management School Bailrigg LA1 4YW Lancaster	phone +44 1524 593998 fax +44 1524 594720 s.cox@lancaster.ac.uk
Bethan Jones	Lancaster University The Management School Bailrigg LA1 4YW Lancaster	phone +44 1524 594495 fax +44 1524 594720 b.jones4@lancaster.ac.uk

CIEMAT (http://www.ciemat.es/eng/)

Rosario Martinez Arias	Catedratico de Unversitad Facultad de Psicologia Somosaguas ES-28223 Madrid	phone fax rmnez.arias@psi.ucm.es
José M. Prieto	Catedratico de Unversitad Facultad de Psicologia Somosaguas ES-28223 Madrid	phone +34 91 3943236 fax +34 91 3943189 jmprieto@psi.ucm.es
Rosario Sola	Universitat Autónoma de Barcelona Casa de la Convalescència C/ San Antonio María Claret 171 Barcelona 08041	phone +34 93 4335088 fax roser.sola@fundacio.uab.es

SwedPower AB (http://www.swedpower.se/swpwwwsite/index_ns.htm)

Carl Rollenhagen	SwedPower AB POB 527 Jämtlandsgatan 99 SE-16216 Stockholm	phone +46 8 7395360 fax +46 8 7396226 carl.rollenhagen@swedpower.com

Published by

Series title, number and report code of publication

VTT Research Notes 2287
VTT–TIED–2287

Author(s)
Wahlström, Björn, Kettunen, Jari, Reiman, Teemu, Wilpert, Bernhard, Maimer, Hans, Jung, Juliane, Cox, Sue, Jones, Bethan, Sola, Rosario, Prieto, José M., Martinez Arias, Rosario & Rollenhagen, Carl

Title

LearnSafe
Learning organisations for nuclear safety

Abstract

The nuclear power industry is currently undergoing a period of major change, which has brought with it a number of challenges. These changes have forced the nuclear power plants to initiate their own processes of change in order to adapt to the new situation. This adaptation must not compromise safety at any time, but during a rapid process of change there is a danger that minor problems may trigger a chain of events leading to a degraded safety. Organisational learning has been identified as an important component in ensuring the continued safety and efficiency of nuclear organisations. In response to these challenges a project LearnSafe "Learning organisations for nuclear safety" was set up and funded by the European Community under the 5th Euratom Framework Programme. The present report gives an account of the LearnSafe project and its major results.

Keywords
nuclear safety, organisational factors, safety management, earning organisations, culture, management of change, human factors, safety culture

Activity unit
VTT Industrial Systems, Tekniikantie 12, P.O.Box 1301, FI–02044 VTT, Finland

ISBN			Project number
951–38–6538–X (soft back ed.) 951–38–6539–8 (URL: http://www.vtt.fi/inf/pdf/)			C4SU00201
Date March 2005	Language English	Pages 58 p. + app. 7 p.	Price B
Name of project Learning organisations for nuclear safety		Commissioned by European Community, the 5th Euratom Frameword Programme 1998–2002	
Series title and ISSN VTT Tiedotteita – Research Notes 1235–0605 (soft back edition) 1455–0865 (URL: http://www.vtt.fi/inf/pdf/)		Sold by VTT Information Service P.O.Box 2000, FI–02044 VTT, Finland Phone internat. +358 20 722 4404 Fax +358 20 722 4374	

VTT INDUSTRIAL SYSTEMS

VTT TIEDOTTEITA – RESEARCH NOTES

2140 Reiman, Teemu & Oedewald, Pia. The assessment of organisational culture. A methodological study. 2002. 42 p.

2148 Aaltonen, Pertti, Bojinov, Martin, Helin, Mika, Kinnunen, Petri, Laitinen, Timo, Muttilainen, Erkki, Mäkelä, Kari, Reinvall, Anneli, Saario, Timo & Toivonen, Aki. Facts and views on the role of anionic impurities, crack tip chemistry and oxide films in environmentally assisted cracking. 2002. 68 p. + app. 21 p.

2149 Hemilä, Jukka. Information technologies for value network integration. 2002. 97 p. + app. 1 p.

2172 Tonteri, Hannele, Vatanen, Saija, Lahtinen, Reima & Kuuva, Markku. Life cycle thinking in the design for environment aware work machines. 2003. 32 p.

2178 Andersson, Peter, Tamminen, Jaana & Sandström, Carl-Erik. Piston ring tribology. A literature survey. 2002. 105 p.

2184 Kondelin, Kalle & Karhela, Tommi. Gallery Markup and Query Language Specification. 2003. 111 p.

2240 Jarimo, Toni. Innovation Incentives in Enterprise Networks. A Game Theoretic Approach. 2004. 63 p. + app. 3 p.

2265 Alanen, Jarmo, Hietikko, Marita & Malm, Timo. Safety of Digital Communications in Machines. 2004. 93 p. + app. 1 p.

2277 Kondelin, Kalle, Karhela, Tommi & Laakso, Pasi. Service framework specification for process plant lifecycle. 2004. 123 p.

2287 Wahlström, Björn, Kettunen, Jari, Reiman, Teemu, Wilpert, Bernhard, Maimer, Hans, Jung, Juliane, Cox, Sue, Jones, Bethan, Sola, Rosario, Prieto, José M., Martinez Arias, Rosario & Rollenhagen, Carl. LearnSafe. Learning organisations for nuclear safety. 2005. 58 p. + app. 7 p.

VTT PUBLICATIONS

507 Rosqvist, Tony. On the use of expert judgement in the qualification of risk assessment. 2003. 48 p. + app. 82 p.

510 Kauppi, Ilkka. Intermediate Language for Mobile Robots. A link between the high-level planner and low-level services in robots. 2003. 143 p.

516 Määttä, Timo. Virtual environments in machinery safety analysis. 2003. 170 p. + app. 16 p.

522 Jokinen, Tommi. Novel ways of using Nd:YAG laser for welding thick section austenitic stainless steel. 2004. 120 p. + app. 12 p.

531 Toivonen, Aki. Stress corrosion crack growth rate measurement in high temperature water using small precracked bend specimens. 2004. 206 p. + app. 9 p.

532 Moilanen, Pekka. Pneumatic servo-controlled material testing device capable of operating at high temperature water and irradiation conditions. 2004. 154 p.

546 Norros, Leena. Acting under uncertainty. The core-task analysis in ecological study of work. 2004. 241 p.

547 Hänninen, Saara & Rytkönen, Jorma. Oil transportation and terminal development in the Gulf of Finland. 2004. 141 p. + app. 6 p.

Tätä julkaisua myy	Denna publikation säljsav	This publication is available from
VTT TIETOPALVELU PL 2000 02044 VTT Puh. 020 722 4404 Faksi 020 722 4374	VTT INFORMATIONSTJÄNST PB 2000 02044 VTT Tel. 020 722 4404 Fax 020 722 4374	VTT INFORMATION SERVICE P.O.Box 2000 FI–02044 VTT, Finland Phone internat. + 358 20 722 4404 Fax + 358 20 7226 4374

ISBN 951-38-6538-X (soft back ed.) ISBN 951-38-6539-8 (URL: http://www.vtt.fi/inf/pdf/)
ISSN 1235-0605 (soft back ed.) ISSN 1455-0865 (URL: http://www.vtt.fi/inf/pdf/)