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Contextual assessment of maintenance culture at Olkiluoto and Forsmark

Teemu Reiman and Pia Oedewald
VTT Industrial Systems

Carl Rollenhagen and Irene Eriksson
Mälardalen University

April 2004

Abstract

The study aims to characterise, assess and develop the organisational cultures of participating nuclear power companies' maintenance units. The assessment is made by the means of maintenance core task modelling that has already been started in previous studies. The theoretical core task model is used in evaluating the characteristics of the organisational culture. We aim to identify what are the strengths and weaknesses of the case organisation's culture in relation to its core task. The study also aims to validate the methodology for contextual assessment of organisational culture.

In addition to case specific results, the study acts as a benchmark between the participating companies and gives a chance to compare the different culture profiles between the companies. Similarities and differences between the organisational cultures at the maintenance units were identified. The purpose is not however to evaluate which organisation is better, but to raise issues that require attention at the organisations. When evaluative statements are made, the criteria are formed on the basis of the core task model: Even though the practices differ, from the perspective of the maintenance core task they might both be as effective.

Key words

Organisational culture, core task modelling, case studies, Forsmark, Olkiluoto

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NKS Secretariat
NKS-775
P.O. Box 49
DK - 4000 Roskilde, Denmark

Phone +45 4677 4045
Fax +45 4677 4046
www.nks.org
e-mail nks@nks.org

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Final Report

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1. Introduction

The aim of maintenance in power plants can be defined as that of guaranteeing the safe, reliable and cost-effective production of electricity. This includes preventive maintenance, condition monitoring, planned outages, modifications and different kinds of fault repairs. Preventive maintenance aims to prevent faults and keep the machinery running and in optimal condition in order to guarantee power generation. Corrective maintenance is needed in fault situations and in situations where non-critical machinery outside the program of preventive maintenance fails. Modifications can be done in order to enhance production or safety and replace older technology that is too expensive to upkeep, too inefficient or too unreliable to use. Proper working of the machinery and technology is critical to both plant safety and productivity.

According to Moubray (1992), maintenance issues in general have in the recent years received increasing attention, which stems from a "rapidly growing awareness of the extent to which equipment failure affects safety and the environment, a growing awareness of the connection between maintenance and product quality and increasing pressure to achieve high plant availability and to contain costs." (Moubray 1992, p. 1). The research and development programs have based mainly on technical and economic approaches. However, the maintenance activities require a lot of personnel and different kinds of knowledge and skills. Thus it can be claimed that the reliability and effectiveness of maintenance is largely dependent on the so-called human factors. What is needed is more knowledge of the requirements of the maintenance task and of workers' experiences of the daily challenges and the organisational solutions in maintenance work.

Maintenance is a complex activity in the sense of Vicente's (1999) definition of complex sociotechnical systems, characterised by many coupled subsystems, uncertainty in data available to workers, mediated interaction via various tools and potentially high hazards (Vicente 1999, p. 14-17; see also Perrow 1984). In addition to inherent complexities of maintenance, recent changes in society (changes in age structure and values towards work, utilisation of new technologies, deregulation of electricity markets, emphasis on outsourcing noncritical functions, etc.) have set new demands for the nuclear power production (see e.g. Wahlström et al. 2002). Current working practices, ideas, and conceptions might no longer be suitable in the new

environment. Rigid organisational structures can inhibit change and be detrimental to the effectiveness of maintenance.

We propose a cultural approach for studying and developing maintenance work. Cultural approach aims at investigating the principles that guides the behaviour of the organisation and its personnel. The value of cultural approach to maintenance work is that it enables a generic view of the social dynamics in a complex and diverse domain. Furthermore, one of the central features of any culture is that in order to maintain internal cohesion it forms routines, preconceptions and rules-of-thump, and hence it inherently resists change. When considering the challenges and pressures for change that the maintenance organisations are currently facing, understanding the impact of culture becomes crucial.

Organisational culture can be defined as "[a] pattern of shared assumptions that the group learned as it solved its problems of external adaptation and internal integration … [and is] taught to new members as a correct way to perceive, think, and feel in relation to those problems" (Schein 1985). According to Schein's theory, the deepest layer of organisational culture consists of shared tacit assumptions that have resulted from a joint learning process. These assumptions make an individual's life predictable and meaningful in organisational context. The assumptions, which are basically sub- and preconscious values and beliefs, concern organisation's strategy, goals, language, social interaction and leadership. The assumptions also consist of beliefs about the nature of knowledge and human nature and about the proper way to allocate rewards and status. Espoused values refer to conscious justifications to action. They predict what people will say in a variety of situations, but if they are not congruent with underlying assumptions, they do not necessarily predict what people will actually do in different situations. The surface level of culture consists of artefacts, which include the visible behaviour of the group and organisational processes, products and technology. These surface level phenomena are hard to decipher since they stem primarily from the subconscious assumptions and situational or individual variables. (Schein 1985.)

Various methods corresponding to the different paradigms of organisational research have been used in studies on organisational culture. Traditionally methods have been separated into qualitative and quantitative on the basis of the nature of the data they produce. There has been a

long debate on what approach is the most suitable one for studying organisational culture. For an overview of the debate see e.g. Rousseau (1990) and Martin (2002, p. 205).

Where quantitative research is traditionally research based on deductive reasoning that tests a theory, qualitative research typically represents ideography and a research direction based on inductive reasoning. By this is meant that the research does not strive to find generalising theories but to study the research subject in natural conditions and to understand its uniqueness. Qualitative research is thus more context-bound than quantitative research. No attempt is made to examine phenomena out of context; the objective is contextual understanding. Often a phenomenon that is a subject of interest for qualitative research is one in which the context is difficult or impossible to separate from the phenomenon itself. Culture is a good example of such a phenomenon (see e.g. Sackmann 1991).

We propose that the best way to study culture is to combine the methods (cf. Rousseau 1990), since we strive to understand the unique organisational culture in question and also compare the profiles of similar organisations. Also it is more economical to use quantitative measures in large organisations, when we want to give everybody an opportunity to give their opinion on the culture of their workplace. Also, anonymous surveys produce different kind of data than face-to-face interviews or collective seminars.

The term organisational culture refers here to the values, norms and underlying assumptions forming over time during the company history and affecting all the company’s activities (and being in turn affected by them). Organisational culture is a learned way of responding, or a solution, to the demands of the organisation's core task. The solution, however, is not final or unambiguous. Organizational culture includes the process of formation and reformation of the above-mentioned solution. This process of collective sense-making is the essence of an organizational culture (cf. Weick 1995). This also means that the organizational culture includes the dysfunctional solutions and discrepancies, as well as the attempts to solve or cover these (Oedewald & Reiman 2003b, p. 292). The temporary outcomes of this process at any given time can be described by static models, such as Cameron and Quinn's (1999) Competing Values Framework or Hackman's et al. (Hackman & Lawler 1971) Job Characteristic Model.

In order to categorise different organisational cultures, Cameron and Quinn (1988, 1999, see also Quinn & Rohrbaugh 1983) have proposed a framework called Competing Values Framework. The framework has been developed through empirical research on organisational effectiveness. According to their theory, organisations can be viewed along two dimensions (see Figure 1):

- focus on internal processes versus focus on external processes
- focus on control versus focus on flexibility.

Together these two dimensions form four quadrants from which four dominant culture types emerge. Each dominant culture represents a distinct set of organisational effectiveness indicators. They define what is seen as good, right, and appropriate. They represent the core values that guide action and decision making at the company. In a hierarchy-focused culture (Fig. 1), procedures govern what people do and stability, predictability and efficiency are considered as long-term concerns of the organisation. The market culture values productivity and competitiveness by strongly emphasising external positioning and control. The workplace is highly results-oriented. The clan culture values cohesion, participativeness, teamwork and commitment. The adhocracy culture has as a major goal the fostering of adaptability, flexibility and creativity. Readiness for change is advocated. (Cameron & Quinn 1999.)

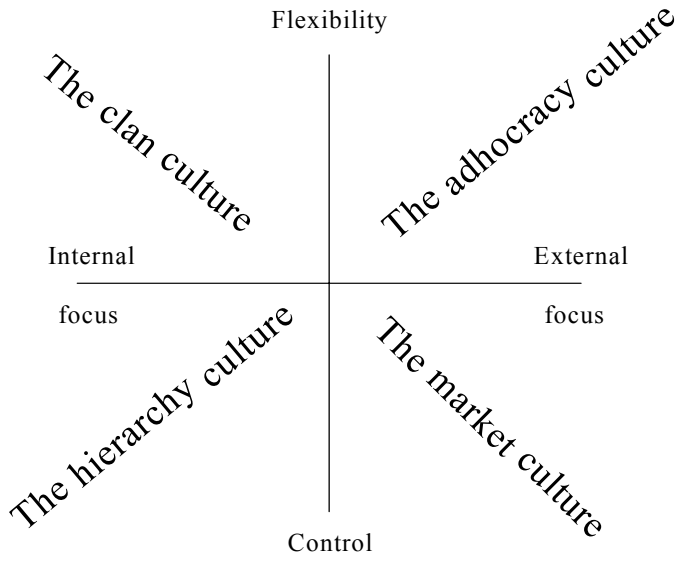

Figure 1. Cameron and Quinn's (1988, 1999) competing values framework

From the perspective of Schein's theory the cultural prototypes described with the help of the Cameron & Quinn's model are tacit assumptions that persons can take into account in different

situations and in so doing, further legitimate their existence (see also Giddens 1984, Reiman & Norros 2002).

The Contextual Assessment of Organisational Culture (CAOC) methodology has been developed in various research projects (see Reiman & Oedewald 2002b, submitted b). The methodology utilises two concepts, organisational culture and organisational core task (OCT). OCT refers to the shared motive of the activity of the organisation. It includes the critical demands and content of work that the organisation has to accomplish in order to be effective (Reiman & Oedewald submitted b, see also Norros & Nuutinen 2002). The core task concept can be used in assessing the central dimensions of the organisation's culture (see fig. 2). (see also Oedewald & Reiman 2003b.)

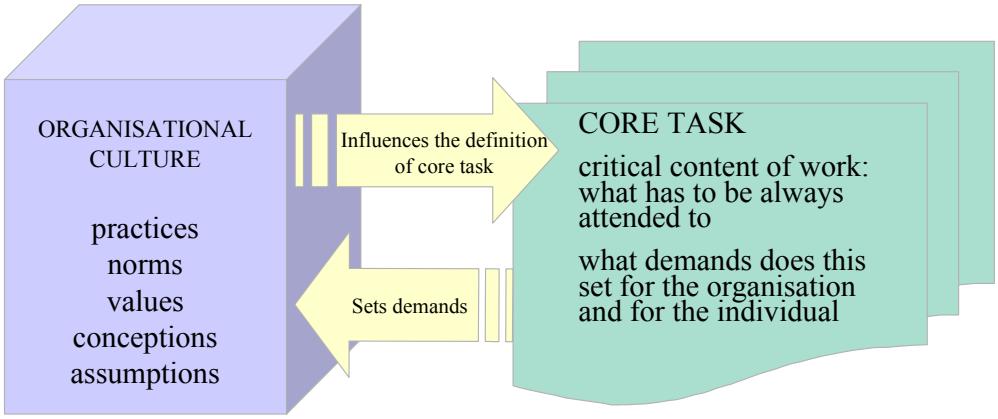

Figure 2. The central concepts of CAOC methodology, from Reiman and Oedewald (2002b)

Cultural perspective is interested in the meanings and generation of these meanings in a given organisation. Of special interest are the meanings that relate to the demands of the particular work. These meanings are also constructed in interaction with other members of the organisation. Cultural perspective thus emphasises collective and shared issues (and those issues that should be shared) over e.g. individual decision making. An individual always makes his/her decisions in a social context. The effect of this context can be so strong that the individual is not even aware of making a decision – choosing between alternative ways of acting. It is this context, which sets the possibilities and boundaries of action that is our main focus of interest. (Reiman & Oedewald submitted b).

When considering organisational culture, a starting point is that there might exist contradictions and different points of view within the organisation in question. Another premise is that these differences are not a priori "bad". The homogeneity of the culture as such is not a criterion for the good culture. The starting point of all evaluation is the demands of the work, i.e. the core task of the organisation. For example in safety-critical environments, different opinions can facilitate discussion and be adaptive in fulfilling the demands of safety and reliability.

This study aims to characterise, assess and develop the organisational cultures of participating nuclear power companies' maintenance units. The assessment is made by the means of maintenance core task modelling that has already been started in previous studies (see Oedewald & Reiman 2003b). The theoretical core task model is used in evaluating the characteristics of the organisational culture. We aim to identify what are the strengths and weaknesses of the case organisation's culture in relation to its core task. The study also aims to validate the methodology for contextual assessment of organisational culture.

In addition to case specific results, the study acts as a benchmark between the participating companies and gives a chance to compare the different culture profiles between the companies. Similarities and differences between the organisational cultures at the maintenance units were identified. The purpose is not however to evaluate which organisation is better, but to raise issues that require attention at the organisations. When evaluative statements are made, the criteria are formed on the basis of the core task model: Even though the practices differ, from the perspective of the maintenance core task they might both be as effective.

2. Methods

2.1 Research strategy

The research consisted of two case studies. Each case study concentrated on a single maintenance unit in a nuclear power plant, namely at Olkiluoto (Finland) and at Forsmark (Sweden). Each case study produced case-specific results, which can be used in initiating development activities at the corresponding plants. The case studies also provided generalisable information about maintenance as a work and about organisational culture as a concept.

Since organisational culture is a multidimensional phenomenon and unique to the organisation in question (Schein 1985), we utilised both qualitative and quantitative methods. In complex and distributed work such as maintenance, the survey method enables a general view of the organisation but also enables the identification of potential subcultures. Quantitative and qualitative methods are used in combination in all the three ways described by Hammersley (1996): triangulation (using data produced by different methods to validate each other), facilitation (one method produces hypotheses to be tested with another method) and complementarity (each method produces qualitatively different, complementary data about the same phenomenon).

To guarantee the valid comparison across the plants, the same data gathering methods were used in both case studies. Methods that were used in the study were organisational culture and core task questionnaire (CULTURE02), semi-structured interviews, document analysis, and working groups.

2.2 The case organisations

2.2.1 Olkiluoto maintenance

TVO's organisational structure was reformed in January 2003. The new organisation comprises five departments:

- operation responsible for the operation and maintenance of units OL1 and OL2
- project responsible for the construction of the fifth NPP in Finland
- engineering
- finance
- corporate resources (TVO 2003).

The case study concentrated on the two offices of the operation and maintenance department: Office of mechanical maintenance and the office of electrical and instrumentation maintenance. The offices consist of a number of groups with group manager, foremen and technicians. Group manager also attends to the duties of the foremen. At TVO a system of equipment responsibility areas was used to organise the work. The system means that the foreman or the group manager "owns" the particular equipment and plans e.g. the program of preventive maintenance and budget for the machinery. The owner of the equipment plans all the maintenance activities conducted for the corresponding equipment, irrespective of the type of maintenance (electrical,

mechanical, instrumentation) required. The owner utilises experts of the other fields in accomplishing this.

2.2.2 Forsmark maintenance

The maintenance function at FKA was in the aftermath of a major reorganisation at the time of the data collection. Even though the main phases of the organisational changes were already implemented many organisational issues were still under debate (the reorganisation had been initiated two years before the time of data collection). Before the reorganisation, maintenance activities were distributed so that each of the nuclear power stations had their own dedicated maintenance support-organisation. Within each station-specific maintenance organisation, control was previously exhibited in terms of a line organisation. In the new maintenance organisation, the previous specific maintenance functions were centralised into a single maintenance unit and a matrix organisation was introduced. Four “business areas” (Operative maintenance, Maintenance projects, Installation, Analysis and development) controlled and implemented operative maintenance projects that were ordered from the stations at the site (in a much more “business” flavour than previously was the case). Responsibility for the execution of various maintenance projects was, in the new organisation, separated from the responsibility for the maintenance resources (the matrix). As usually in matrix organisations the operative personnel had several “bosses”. A technician could conduct work to several business areas under the manager from that area. The line manager "sells" the technician to the particular business area that needs resources.

2.3 Description of the methods

2.3.1 CULTURE-questionnaire

The questionnaire consists of four different measuring instruments: measure of perceived values, measure of the psychological characteristics related to work, measure of the personnel's conceptions of the organisation's core task and measure of personnel's conception of the ideal values of the organisation. The questionnaire consists of about 100 likert-type questions and two open questions. Open questions are phrased as following: "What are the strengths of the maintenance activities at X" and "What are the weaknesses of the maintenance activities at X" (X being the plant in question). Questionnaire was piloted during the Finnish national FINNUS nuclear safety research program 1999-2002 (see Reiman & Oedewald submitted a).

Questionnaire was tailored and translated into Swedish in three meetings together with the entire research group (the authors).

Measures of workplace values (perceived and ideal), sections A and D

35 items, each rated on a six-point scale (from “completely disagree” to “completely agree”), were related to values typically manifested in organisations (e.g. “flexibility”, “economic efficiency”). Values were initially selected on the basis of Cameron and Quinn’s (1999) Competing Values Framework and the previous studies (Reiman & Norros 2002, Reiman & Oedewald submitted a), and they were further tailored together with the research group. Instruction was to mark how much the respondent felt that the given values were endorsed in the respondent's section. Respondents were also asked to select their ideal values in the final (D) section of the questionnaire, with the same 35 items and the same six-point scale.

Measure of personal conceptions of one's own work (B-section)

32 questions, each rated on a six-point scale, addressed the conceptions concerning one's own work and the organisation. Hackman et al. (Hackman & Lawler 1971, Hackman & Oldham 1975, 1979) have analysed a large number of jobs and identified the basic dimensions that should apply to any job. They identified five job dimensions (skill variety, task identity, task significance, autonomy, and feedback) and three underlying psychological states. According to Hackman et al. (Hackman & Oldham 1975, 1979), high job motivation and high quality of work performance can be acquired if the worker can achieve the following three psychological states:

- the work must be experienced as meaningful
- the worker must experience that he is personally responsible for the work outcome
- the worker must be able to determine how his efforts are coming out, what results are achieved and are they satisfactory

Questions were initially formed on the basis of the above mentioned theoretical model and the results of the previous organisational culture studies (Reiman & Norros 2002, Reiman & Oedewald submitted a). Pilot study also identified a fourth psychological "state", sense of control (Reiman & Oedewald submitted a). Questions measuring this concept were also included in the B-section.

Since no objective data about the characteristics of the respondents' jobs could be collected, it was plausible to measure directly the psychological states. Furthermore, Hackman and Lawler

(1971) emphasise that it is not the "objective" state of the job characteristics, which is essential to employee attitudes and behaviour but how they are perceived and experienced by the employees. Also, substantial support for the linkage between psychological states and job satisfaction exists, but not so much for the linkage between objective job characteristics and job satisfaction (see Fried & Ferris 1987).

In the pilot study at Loviisa NPP, three personal work related scales were identified: perception of the working climate, attitudes toward management and the personal development orientation (see Reiman & Oedewald submitted a). Questions related to these scales were included in the B-section of the questionnaire.

Measure of the maintenance core task (C-section)

23 items, each rated on a six-point scale, were related to the general demands of the maintenance work at a nuclear power plant. Questions were initially formed on the basis of interviews and workshops with maintenance experts from the pilot organisation (Loviisa NPP). Questions were tailored on the basis of the results from the pilot study (Oedewald & Reiman 2003b, Reiman & Oedewald submitted a). The maintenance core task model constructed in that study identifies three critical demands of the maintenance task: anticipating, reacting and reflecting / monitoring (see also Section 2.5 in this report). The measure aimed at grasping the features of the maintenance task that are common to the entire organisation in question.

Demographic information and covariates

Table 1. The demographic information and their scale of measurement

Variable	Scale	Categories
Age	Ordinal	5
Position	Nominal	5
Section	Nominal	varied
Tenure	Ratio	n.a.
Time in same job	Ratio	n.a.

Table 1 depicts the variables and their scale of measurement that were used in gathering the demographic information. In addition to the demographic information, several covariates were included in the survey. Generic satisfaction with one's work was measured with one question "I am generally satisfied with my work", with six point Likert-type scale. Generic job motivation was measured with one question "My work is motivating". Job stress was also measured with

one question: "My work is stressful". All three questions were included in the B-section of the survey.

2.3.2 Interviews

The participating researchers (authors) formed the interview questions in concert. Previous studies served as a background for the questions (see e.g. Oedewald & Reiman 2003b). The interview themes were as follows:

- Own job (the content, motivating and demanding features, nature of expertise, utilisation of tools, changes in work)
- Maintenance task (goals and critical demands)
- Organising of maintenance activities (pros and cons of current organisational structure, co-operation between different technical fields)
- Organisational culture (stories, climate, subcultures).

2.3.3 Work groups and seminars

Group working was conducted at TVO in order to further validate the model of the maintenance core task (see Section 2.5) and to present the raw results from e.g. the survey in order to attract the group's interpretations of the meaning of the results. The working group consisted of five members of a manager or an expert background. Seminars were used to present results to larger audience in the organisation in question and to stimulate discussion and the collective interpretation of the results.

2.4. Data collection and analysis

Survey

In Finland, each questionnaire was addressed directly to the personnel, and a sealable envelope, preaddressed to the research institute (VTT) accompanied the questionnaire. Respondents were assured that the responses would be dealt with confidentially and that the results could not be traced back to individual respondents. Information on the objectives of the research and methods to be used was given to personnel in a separate meeting.

In Sweden the questionnaires were distributed at 6 section meetings and completed individually by each participant in about 30 minutes. Ten questionnaires were sent by mail to the researcher by subjects not participating in the section meetings at the time of the first data collection.

84 responses were obtained from TVO (with response rate of 60%), and 132 responses from Forsmark (with response rate of 72 %). Missing values were replaced by mean scores, after making sure that the missing values were random and no respondent had more than 20 % missing in any section. One respondent did not fulfil this criterion on the section B, and hence this respondent's values were not replaced.

For purposes of comparison, tenure was divided into seven categories as shown in the Table 2.

Table 2. Plant and tenure crosstabulation

Plant * Tenure Crosstabulation

Count

		Tenure							Total
		under 6 years	6-10	11-15	16-20	21-25	26-30	over 30	
PLANT	Olkiluoto	5	2	6	18	33	14	6	84
	Forsmark	24	10	20	21	29	14	14	132
Total		29	12	26	39	62	28	20	216

Chi square test indicated that tenure in organisation was not randomly distributed (χ^2 (6)=19.3, p = .004). The Table 2 shows that Forsmark has more people with shorter tenure than Olkiluoto has. The age of the respondents was, however, randomly distributed (χ^2 was non-significant) in both plants.

Results of the pilot study (Reiman & Oedewald submitted a) were used in defining the hypothesised factor structure for the survey data. The data, being of the ordinal scale in nature, do not meet all the assumptions for parametric tests. Aggregated scores were used in the analyses whenever possible. Aggregated scores are closer to interval measurement than the original ordinal scale variables. Care was taken to use only methods that are known to be robust to the effects of non-normal distributions and measuring scales. (Hair et al., 1998.) Statistical functioning of the survey instrument is considered in more detail in Appendix A.

Interviews

At TVO twenty interviews were conducted, ten in fall 2002 and ten in spring 2003. At Forsmark, 12 interviews were conducted during the fall 2002 - spring 2003.

Interviews were transcribed and used on the one hand for the modelling of the core task and on the other hand for a grounded-theory (see Charmaz 1995) based analysis of the typical features of the organisational culture. Interviews were also used as an aid in the interpretation of the survey results.

Seminars

Presentation of the preliminary results at TVO took place in a work group consisting of maintenance experts and managers from the corresponding plant. The work group also provided information to researchers by offering interpretations about the findings and by offering hypotheses and suggestions for the further analysis of the research material.

Preliminary results were presented at a seminar at Olkiluoto. The seminar had approximately 60 participants from the different levels of the maintenance organisation.

Two development seminars were arranged at TVO. The seminars were identical in content and were held at the same place outside the plant area. Over thirty persons attended each seminar. Seminars were taped and the groupworking that took place there was partially videotaped. The results from the seminar were reported directly to the maintenance unit in a confidential Finnish language report (see also Reiman & Oedewald 2003).

At FKA a feedback seminar was arranged for the maintenance managers. About 20 people attended the seminar. Also two Swedish language reports which are aimed primarily for the plant are in progress; one report concentrates on the results of the case study and the other on the management of change in general (based partly on the results from this study).

2.5 Criteria for the assessment: the core task of maintenance

From the systemic perspective, it can be concluded that effective maintenance is about balancing between various critical demands (see Oedewald & Reiman 2003b). These demands have been termed anticipating, reacting, and monitoring and reflecting (see Fig. 3).

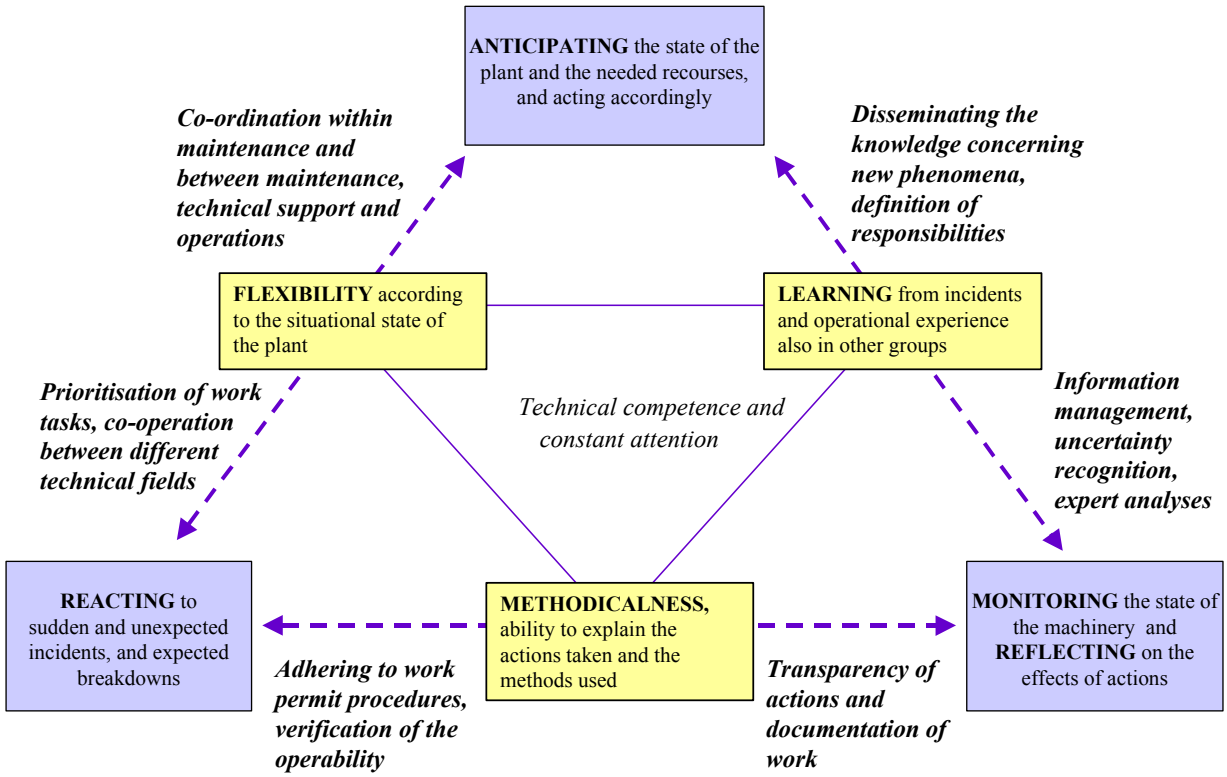

Figure 3. The model of the demands of the maintenance core task, adapted from Oedewald and Reiman (2003b)

In addition to the critical demands depicted in Figure 3, three instrumental demands, which facilitate the fulfilment of the critical demands, have been extracted. These instrumental demands are also shown in Figure 3 and they have been termed flexibility, methodicalness and learning.

Model also depicts maintenance as a knowledge creation and problem solving activity. The model thus brings the demands of the maintenance work closer to those of knowledge work. The knowledge creation is one of the main goals of the maintenance. A challenge to maintenance work is that there are multiple and parallel tasks in maintenance, some of which are independent and some which are dependent on one another, happening at the same time. Different tasks demand different types of coordination and cooperation. The central coordination requirement is to get all the different disciplines working together, parallel and in distributed tasks.

The model in Figure 3 is a general framework of the requirements of the maintenance work. The model is contextualised in the discussions with the maintenance personnel. The model stimulates discussion and brings out issues in one's own work that are not usually considered. This works as a starting point of the discussion on the demands of maintenance work. The

model is thus a tool of organisational assessment as well as the source of the criteria for an effective maintenance culture.

3. Results

3.1 Perceived workplace values

The data from A- and D-sections of the survey was factor analysed separately for both plants, since we were interested in the possible differences in the factor solutions and in the interrelations of individual values. Summated scales were formed on the basis of factor loadings. The mean scores for the summated scales of both the perceived and ideal value sections of the survey were calculated. See Appendix A for a more detailed description of the summated scales. The summated scales and their mean scores and the gap between the perceived and ideal values at TVO is presented in Figure 4.

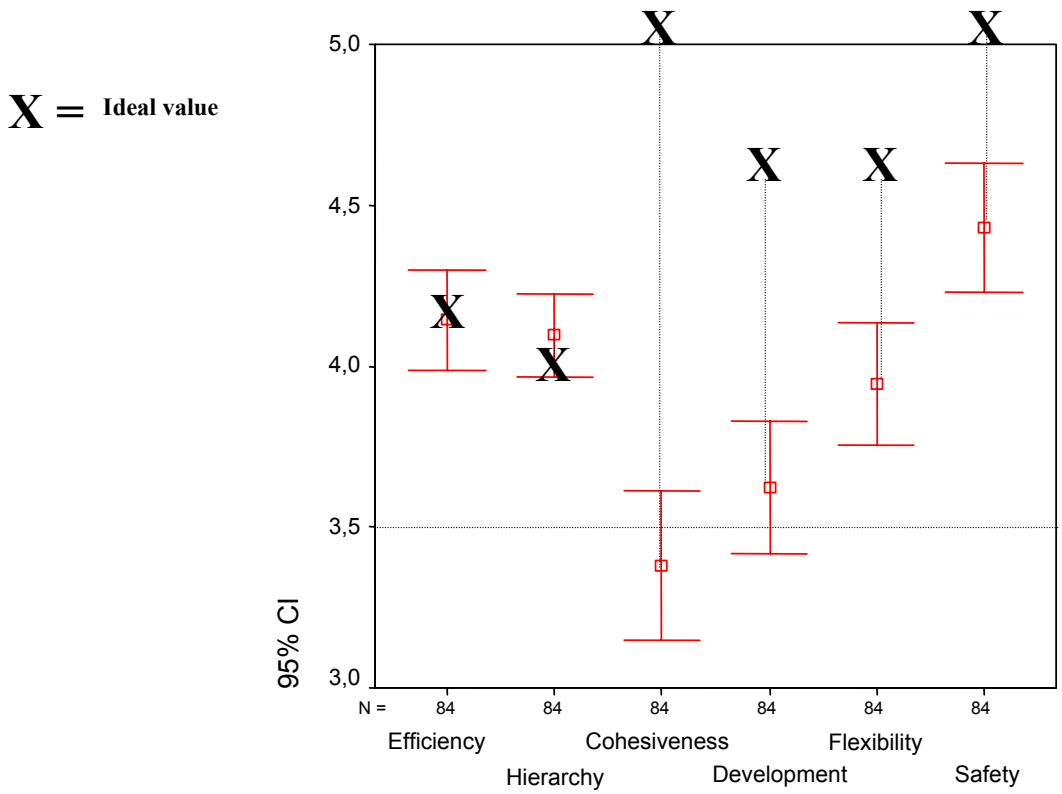

Figure 4. The gap between the perceived and the ideal values at TVO

The Figure 4 shows that the largest gap between the perceived and the ideal values is in the values related to cohesiveness (e.g. personnel wellbeing, co-operation). Also according to the

personnel, the change and development related issues should be valued more than they currently are.

The mean scores and the gap between perceived and ideal values at FKA is presented in Figure 5. As can be observed from the figure, the solution differed from the TVO's solution. At TVO hierarchy values formed their own factor, whereas at FKA safety, rule following and hierarchy are considered as being in the same cluster of values (facilitating the attainment of the same end-state). Efficiency at TVO includes the values of efficient work tasks and financial objectives, whereas at FKA financial values clearly separate from all the other values (see also Appendix A).

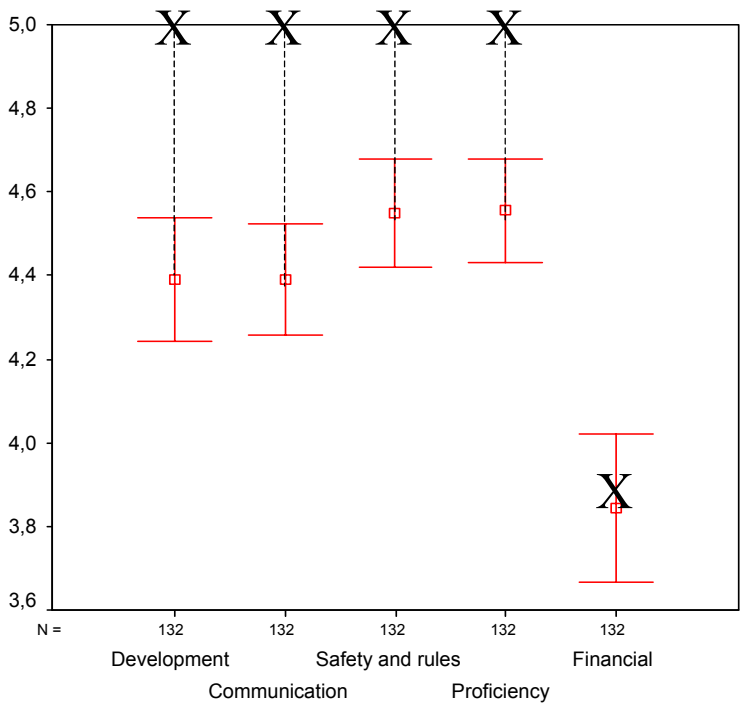

Figure 5. The gap between the perceived and the ideal values at FKA

When inspecting the individual value questions, the highest perceived workplace values were very similar at both TVO and FKA. Safety related values (e.g. avoidance of all risks, occupational safety) were experienced as being relatively highest of all values at both plants. At FKA "centralised decision making" was among the lowest perceived value scores, whereas at TVO it was quite high. In the ideal value section, also some differences were found. The relatively lowest ideal values were quite similar (mostly the economic values), except that at FKA "questioning old beliefs" was among the values receiving low scores, whereas at TVO one

of the lowest mean scores on the ideal values was on the value "questioning new ideas". The four relatively highest ideal values at FKA were "wellbeing of the personnel", "open communication", "avoidance of all risks", and "co-operation". At TVO the four highest ideal values were "proficiency at work", "occupational safety", "wellbeing of personnel", and "personnel development".

The difference in the results of the perceived workplace values can also stem from a different understanding of the value questions or the concept of "value" between Finland and Sweden. This possibility is considered further in the Discussion section of the report.

3.2 Conceptions of one's own work and the maintenance task

The one's own work –section was factor analysed with the combined data from both plants (see Appendix A). The mean scores for the summated scales of the section were calculated for both FKA and TVO. The summated scales and their mean scores are depicted in Figure 6.

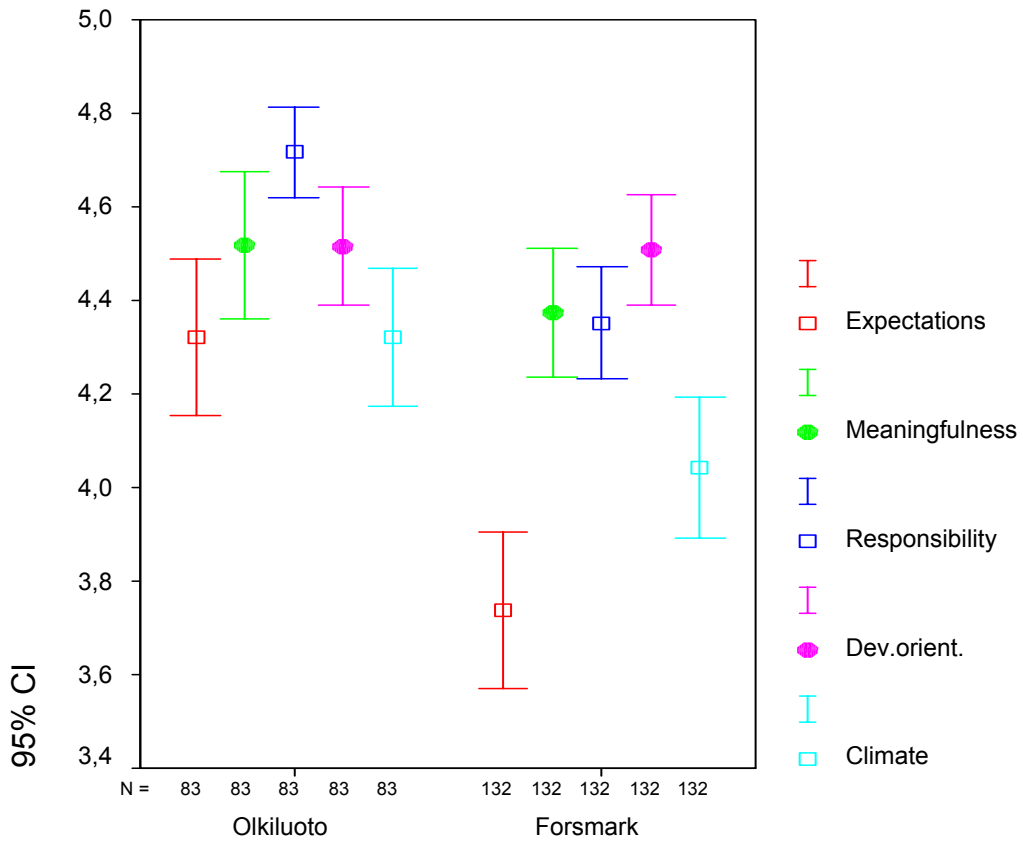

Figure 6. Conceptions of one's own work at TVO and FKA. Mean scores of the summated scales of the B-section of the survey.

From Figure 6 it can be noted that the meaningfulness of the work is perceived to be high at both plants. The knowledge of the expectations concerning one's work was judged as good at TVO and mediocre at FKA. The sense of personal responsibility and control over one's own work was high at both plants. Personal development orientation was also high at both TVO and FKA.

The interviewees were asked about what motivates them at their work. The answers varied in content between the plants. At FKA the personnel were motivated by new learning opportunities, technical problem solving, fault situations, and also by good colleagues and the social aspects of the job. At TVO the personnel felt more meaningfulness from the non-events, the smooth functioning of the plant, and of being "the best in the world", but also special situations, wage and the social climate motivated at TVO as they did at FKA.

At the interviews there was asked what where the most demanding aspects in the interviewees' jobs. From the grounded-theory based analysis of the interviews at TVO, the following categories emerged:

- **nothing special** (”I have to admit that I don't know”, ”I've been here for so long that nothing is anymore”, ”routine-like, normal work-work”) (4)
- **personnel relations** (4)
- **special situations** e.g. outage, modifications (4)
- the **achievement of certainty and the endurance of strain** (”so you don't start to rush”, ”safety requirements...that the work's done correctly”, ”fault repairs…gets you thinking”) (3)
- **other things related to the maintenance of expertise** e.g. language skills, deteriorating eyesight (3)
- **knowledge of the machinery** (”upgrades and modifications”, ”to know these machines”) (2)

At FKA the following categories emerged:

- **prioritising the tasks, the work load** (6)
- **seeing the goals, trust in the management** ("purpose of the reorganisation") (4)
- **social demands** (3)
- **technical competence** (2)

From the interviews and the survey results several indications were obtained that one of the problems at FKA was to allocate resources in a wise way and to know the current work load of the personnel. Especially managers had difficulties in arranging the work tasks, allocating the resources and planning the everyday activities. On the other hand, some of the personnel felt that the new matrix organisation did spread the work load more evenly than it had been spread in the previous organisation.

At TVO the feedback from supervisors was very exiguous. Feedback was considered as a mostly negative indication that something had been done poorly. Positive feedback was rare according to the personnel. On the one hand, the personnel emphasised that they themselves usually knew whether or not the particular job had been done well. On the other hand, some people felt that the culture is a bit problematic in that a high quality performance is taken for granted. This leads to the practice that high quality is taken as an assumption and positive feedback is not given, but poor quality immediately gets attention from the managers.

The results raised the question of whether there are differences in the perceptions of the core task of the maintenance. The core task section of the survey was inspected further. On the basis of the survey results, the sharing of knowledge as well as anticipation and planning were commonly seen as important requirements of the maintenance core task at both plants. The questions that suggested bypassing the bureaucracy in the name of efficiency were scored very low at both plants. On the other hand both plants also scored low on those questions that suggested that rules relieve of personal responsibility or that it is enough to just follow the instructions in unanticipated situations.

Significant differences between FKA and TVO were found in questions that concerned e.g. the ability to know the consequences of maintenance activities in advance, and the way of dealing with uncertainty. At TVO the personnel were more confident about the consequences of the various daily maintenance tasks. They also emphasised that if you are uncertain you should do nothing. Furthermore, they did not see a contradiction between economy and safety, as the personnel at Forsmark did.

The responses to questions concerning the role of rules and instructions also differed. At TVO the personnel did not see a need to interpret the rules, whereas at Forsmark where the personnel

perceived more uncertainty they also stated that rules have to be sometimes interpreted. At Forsmark understanding and learning the machinery was pointed out more strongly than at TVO. They emphasised that it is important to know the reasons behind the rules and that documentation routines contribute to learning in the maintenance work.

The results of the core task section thus suggest that knowledge sharing, planning and anticipation and personal proficiency are important requirements of the maintenance task in a NPP. However, TVO maintenance personnel experienced less uncertainty in the maintenance work or in the working environment. They approached the work more through routines than they did at Forsmark. There the uncertainties of the sociotechnical systems were more apparent and the personnel also emphasised maintenance work more as learning and a problem-solving task.

Also the interviews were inspected from the perspective of the core task. Interviewees brought up the following issues in response to the question "what is critical in achieving the core task of maintenance" (the number in brackets indicates how many persons raised the issue):

TVO:
- sufficient resources (8)
- overview and continuos improvement (6)
- appropriate routines and adhering to procedures (5)
- competence, to know the equipment (5)
- attitude (2)
- nothing, everything is under control (2)

FKA:
- attitudes of the personnel, engagement and flexibility (4)
- long term planning, clear goals, feedback (4)
- competence (2)
- money (1)

The results from the interviews supported the above-formed hypothesis that the core task perceptions differed between FKA and TVO maintenance units.

3.3 Conceptions of the organisation

The personnel were asked to characterise their culture at the interviews. At TVO the interviewees gave for example the following descriptions: "high in professional pride, a bit conservative due to the age structure and quite bureaucratic, but that has its own reasons", "well, it strives toward good goals, but it's a bit rooted and immovable", "responsible people, whether young or old", "when something happens, the guilty one has to be always found". The personnel had no trouble characterising their organisation, even though the characterisations were sometimes contradictory.

At FKA most of the respondents had difficulties responding to the question concerning the maintenance culture – it appears that the question was too broad and general to receive meaningful answers. From the responses to the other questions, a picture emerges that the current maintenance organisation evoked mixed feelings. Several interviewees complained about the matrix form and found it confusing. On the other hand, there were also signs that the new organisation had led to a broader scope of work tasks and to positive challenges in one's work. On the downside there were indications that the new maintenance organisation had led to negative changes in the perceived ownership for the technology – previously the maintenance organisation had been one for each of the three stations. In several of the interviews at FKA there were indications of a general cost pressure that affected the maintenance organisation: “it is talk about costs all the time” and "costs have got a too high focus”. On the other hand several of the respondents said that they were personally strong in their ambition to keep the plant in a state of high quality.

In the survey there was asked what were the strengths and weaknesses of the maintenance culture at the respondent's organisation. At TVO the personnel saw their strengths mainly in the know-how and experience of the workers (57 respondents out of 59 raised either know-how or experience as the major strength) and at the attitude and motivation (responsibility) of the personnel. Also the viability of the organisation (ability to react to problems, methodicalness, flexibility) was raised, as were good tools and procedures and the good condition of the plant. Central weaknesses were perceived to be in the age structure and inadequate attention on the problems of knowledge retention. Also leadership and personnel values of the organisation were felt as weak at TVO.

At FKA the need for the clarification of the new organisation was the most acute problem according to the respondents (30 persons out of 76 raised this issue explicitly). Also a lack of cooperation and the quality of leadership were raised as needing improvement. These can also partly stem from the reorganisation, though, as can the unclear division of labour that 10 persons raised as needing improvement. Only one person raised the age structure and the knowledge retention as problems needing more attention.

At FKA the majority of the employees spontaneously replied that the thing that worked best was the social aspect of the work and the fellowship in the work groups. Communication and cooperation within the work groups was experienced as working well. Couple of employees explicitly raised the safety thinking as a strength and a few emphasised managerial and leadership aspects. There were thus mixed feelings toward the management and the maintenance organisation in general.

3.4 Differences between organisational levels and age

The data was inspected from the perspective of differences between organisational levels and various age groups. Some notable differences were found, of which only the most significant ones are discussed here. Some of the findings (e.g. the finding that worker level was more critical to the organisation than the management level) corresponded with the Loviisa case study (Reiman & Oedewald submitted a).

At Olkiluoto the foremen scored significantly higher ($p < .05$) on job stress than the other workers did. They also felt that they "do not always have enough time to do their job carefully". This result was unique to TVO; at FKA managers felt most stressful and at the Loviisa case study (see Reiman & Oedewald submitted a, Oedewald & Reiman 2002) it was found that the maintenance experts felt the most stress. The differences between the technicians and the foremen in both plants were analysed further. MANOVA was conducted with task (technician or foreman) and plant as independent variables. No significant interaction effects were found, thus differences have to do more with plant-specific cultures than professional subcultures. Foremen's position and attitudes at TVO were thus inspected further. From the interviews it was noted that some foremen felt that they are not able to do work planning, work supervising and taking care of the system of equipment responsibility at the same time.

The age groups showed few statistically significant differences on the survey items of the either plant. This result differed from the results of the Loviisa case study (Reiman & Oedewald submitted a). Only at TVO did the younger employees differ from the older ones on several of the core task questions. The younger employees experienced much more certainty over the impact of maintenance activities than the older ones did.

4. Assessment of the maintenance cultures

4.1 Maintenance culture at Olkiluoto

Results from the TVO case study showed that the personnel are very committed to their tasks and they perceive their work as highly meaningful. Most of the workers are also very proud of their plant and their own proficiency. General job satisfaction was quite good. The low sense of control, the weak sense of solidarity and the perceived lack of positive feedback were experienced as the most negative aspects of the culture. The perceived lack of sufficient resources and the unequal distribution of labour were experienced as lowering the sense of control and causing work stress. The work itself was experienced as quite routine-like and the personnel had difficulties in identifying any challenging aspects in their own tasks.

At Olkiluoto NPP the personnel were able to perceive very well the relevance of their individual tasks and how their tasks contribute to the organisational goals. This can be considered as an achievement on the part of the management of TVO. The personnel at all levels and all tasks have a strong professional pride. This has both positive and negative consequences. When discussing the shared goals and co-operation, pride in one's own profession can contribute to an overemphasis of the importance of one's own tasks. In any case the feeling of professional pride and the sense of meaningfulness of one's own work is a very positive aspect of the TVO maintenance culture: know-how and responsibility are the central aspects that are emphasised in the artefacts (management talk, procedures etc.) of the culture. Nevertheless several employees feel that they do not get the respect and support from their superiors that they and their competence deserve. On the one hand responsibilities have clearly been dispensed downwards, but it is hoped that the management could more closely follow the developments in the field and be more clear in its definition of policies (e.g. concerning the distribution of responsibilities and

accountabilities). It seems that the process of the distribution of responsibility is unfinished: At the field there exists uncertainty about one's own and others' responsibilities and obligations.

"Responsibility" was an ambiguous concept for the personnel at TVO, even though responsibility was emphasised as the cornerstone of maintenance culture. More discussion on the meaning of responsibility is clearly needed. It should be specified, what the personnel actually mean by emphasising that the workers at Olkiluoto have a high sense of responsibility. What kind of activity is expected from a responsible worker? The problem of responsibility is enlarged by the fact that certainty, competence and the ability to know and do well are emphasised as being very high at TVO. On the one hand it is emphasised that in order to be responsible for something you have know it well and you have to be absolutely certain about it, but on the other hand the ability of the organisation to be certain is explained by the responsible and well-knowing personnel. The sense of responsibility should also include the process of thinking about the uncertainties connected to the different tasks and admitting that you cannot know everything.

Despite the obscurity of the concept of responsibility at TVO and the cultural emphasis on certainty, safety and carefulness were considered as values of utmost importance in the organisation. Cohesiveness values were perceived to be quite low, and improvements to them were wished for. Low cohesiveness is largely a result of the activity of the organisation and its other cultural features. For this reason cohesiveness cannot be treated and developed as a separate problem (e.g. by increasing shared parties and get-togethers), instead one has to intervene also to the problems in the organising of work and in the content of the work itself.

On the basis of the results it can be concluded that TVO has developed quite functional practices in order to respond to the critical demands of the maintenance task. The functioning of the organisation is however partly based on the long experience of the personnel, and the field workers do not necessarily appreciate all the official procedures and practices. They are not confident that the organisation is able to function when new personnel come in by large numbers. The personnel feel that many of the current information systems and technological solutions are designed for the newcomers, not to support the current way of working or the current workers as such. On the other hand, strong doubts exist whether these solutions are adequate enough to guarantee the functioning of the maintenance organisation in the future. For

these reasons the personnel feel that the forthcoming change of generation is a huge challenge. The field workers have a feeling that the management does not appreciate the seriousness of the problem, or else they do not appreciate the professional skills of the field workers by belittling the challenge of maintaining the competencies in the future. There also existed some doubts that the routine tasks will be more easily given to the newcomers than the more interesting and challenging tasks.

Currently the central malady at the TVO maintenance unit is the unequal distribution of labour. Tasks as such are not considered as meaningless, but tasks seem to pile up to some much more than to others. Another challenge is the nature of the foremen's work. The system of equipment responsibility also raised a lot of discussion. Many perceived the idea as such as good, but the system has acquired a bad reputation since the work is experienced as being extra to regular work. As an idea the system could work as a tool to share knowledge and facilitate co-operation: even though the individual has the accountability / responsibility for the particular device, the work should be shared activity, which means shared cross-disciplinary and cross-departmental responsibility for the particular device.

The information systems are not currently utilised at TVO as efficiently as they could be. Partly the reason may stem from a general resistance towards computers: the new electronic solutions are felt alien in an environment were personnel have gotten used to carrying out tasks without them or with much older systems. The information systems can furthermore be experienced as belittling the individual professional skills based on handicraft experience.

4.2. Maintenance culture at Forsmark

The maintenance function was undergoing a major reorganisation at the time of the data collection. Responsibility for the execution of various maintenance projects was, in the new organisation, separated from the responsibility for the maintenance resources (the matrix). As usually in matrix organisations the operative personnel had several “bosses” which tended to create confusion in responsibility issues.

The data collected from FKA in the present study should be perceived in the context of the reorganisation. It is thus very possible that the responses to the value-questions, intending to measure more stable aspects of the culture, also in fact measure what should more accurately be

described as the "climate" of the maintenance organisation (i.e. a much more superficial and fluctuating aspect than what is normally assumed by the concept "culture"). The reader should thus bear this overall context in mind when interpreting some of the specific findings obtained for Forsmark.

Looking into the mean values obtained as a basic for rank ordering the individual values judged in the A-section we can see that both at TVO and at FKA, safety related values are among the ones that are at the top of the ranking list. Moreover, at Forsmark, and judging from the rank ordering of the means for perceived values, *communication, co-operation and trust are all judged high*. In the previous maintenance organisation, the respective maintenance groups had a clear sense of belonging and ownership. Maintenance culture(s) was, then, associated with specific stations, which also presumably created a set of different maintenance cultures. In the new organisation, people can be assumed to protect some of the previous values that belonged to the previous cultures. And among these values the communication and interpersonal values can be assumed to be salient since the previous organisation had a structure that supported these.

In the interviews there were also indications that some employees in the new organisation experienced concern about the possible negative changes in the ownership, identity and communication. Since people now belong to a much larger unit – a unit that serves all of the stations, and also conducted in a matrix, with the generic pros- and cons characterising such an organisational arrangement, it is not surprising that communication values is estimated as very high since it is such values that are at stake in trying to cope with the new organisation.

The values of economy and cost effectiveness scored among the lowest at Forsmark. Together with information received from the interviews, we interpret this finding in the following sense: Many persons in the maintenance organisation are reacting to an increasing focus at economy. This can explain why economy values are put low on the list (in comparison with other values). Also in the interviews there were many signs of that the personnel interpreted the striving for economic effectiveness in a negative way.

Matrix organisations are usually, both in theory and praxis, associated with some difficulties regarding clear responsibilities and communication. Judging from the mean values for the items of the B-section in comparison with the corresponding mean scores from Olkiluoto, there are

several significant differences of interest. Definitions of goals, roles and responsibilities appear to be experienced as more clearly defined at TVO than at Forsmark – and this is also a consequence of the confusion experienced in the matrix organisation as we interpret this data. Judging from the other items in the B-section, it also appears that FKA experiences more trouble in finding and identifying resources when needed – something that was also mentioned in several of the interviews and (paradoxically) partly a result of the new organisation.

Taken together, item analysis of the B-section points to a conclusion that the structural aspects were of much concern. Since no baseline was obtained (before and after the reorganisation) these indication are, however, difficult to interpret. The observations could also be an indication that there are more general and stable differences in praxis and perception of structural aspects among the Swedish and the Finnish maintenance organisations.

Both interviews and the result of the responses to items in the B-section indicate, that the working climate, by large, is judged as good when perceived in the small group context but that there were strong signs that the confusion with the organisational structure arrangements did effect working climate negatively in a larger sense. In the questionnaires the respondents were given room to write comments regarding areas of improvement in the organisation. The most frequent category of comments was about the need to "clarify" the maintenance organisation. Also comments were made on the negative effects of the organisational change on climate, personnel wellbeing and trust in management.

In conclusion, we think that one of the most interesting generic aspects of the Forsmark data concerns structure and communication in interaction with organisational forms. One hypothesis is that the previous plant-specific organisation model supported ownership and communication practices of a sort that were not fully compatible with the demands of the new organisation. When the organisation changed to a much larger maintenance unit, new practices and structures had to be developed that did not match the previous more informal, smaller and communicative culture -orientation.

It is, however, important not to interpret the comments above as an indication of an overall only negative impression regarding the reorganisation. Many people also expressed positive consequences from the reorganisation – for example, the learning experiences that were made

possible from working at all three sites. Feelings were, thus, very mixed about the new arrangements. In the interviews several comments were made about the good competence and the well-grounded experience that could be associated with the maintenance personnel. Many people also commented on that the actual work (micro processes) had not changed so much in spite of the reorganisation but that much energy was devoted to “clarification” of how the macro processes should be implemented in the new organisation.

In Spring 2003 there was a change in the maintenance organisation. The matrix type was left in favour of a more traditional line organisation but still keeping the centralisation aspect.

5. Discussion

The aim of this project was to characterise, assess and develop the organisational cultures of participating nuclear power companies' maintenance units. Case studies were carried out at Forsmark NPP in Sweden and at Olkiluoto NPP in Finland. Both quantitative and qualitative methods were used. The same data gathering methods were used in both case studies. In addition to the case specific results, the study acted as a benchmark between the participating maintenance units. Similarities and differences between the organisational cultures at the maintenance units were identified. The purpose was not however to evaluate which organisation is better, but to raise issues that require attention at the organisations. When evaluation was made, the criteria were formed on the basis of the core task model: Even though the practices differed, from the perspective of the maintenance core task they might both be as effective.

5.1 The main findings of the case studies

The maintenance units at Olkiluoto and Forsmark had quite different organisational cultures, but they also shared a set of dimensions that are considered below. Common to both the plants was that at a general level the goals of the maintenance task were very clear; maintenance is a prerequisite for the reliable production of electricity. The personnel at both plants saw their work as highly important and meaningful, even though the plants differed significantly on how the personnel saw their work contributing to the overall goals of the organisation. Implications were found that the source of the meaningfulness of one's work varied between the plants.

Results from TVO show that the personnel were very committed to their tasks and they perceive their work as highly meaningful. Most of the workers are also very proud of their plant and of their own proficiency. Overall job satisfaction was quite good. The low sense of control, the weak sense of solidarity and the perceived lack of positive feedback were experienced as the most negative aspects of the culture. The lack of sufficient resources and the unequal distribution of labour were experienced as lowering the sense of control and causing work stress.

At TVO the maintenance work itself was experienced as quite routine-like and the personnel had difficulties in identifying any challenging aspects in their own tasks. It was pointed out that the plant is well functioning and everybody has sufficient competence to get along with his or her daily tasks. Special situations such as the outages and large modification projects were seen as demanding and motivating. At FKA the prioritising of tasks and the managing of lately increased workload were seen as demanding.

At FKA the economic aspects were more salient as aspects that affect the maintenance than at TVO. The need for the clarification of the new organisation at FKA was the most acute problem according to the personnel. On the other hand, there were also signs that the new organisation has led to increased challenges and learning opportunities and a broader scope of the work tasks. On the downside there were indications of that the new maintenance organisation had led to negative changes in the perceived ownership for the technology

Knowledge sharing, planning and anticipation and personal proficiency were considered as important requirements of the maintenance task in both units. However, at TVO the maintenance personnel experienced less inherent uncertainty in the maintenance task itself. They approached the work more through routines than they did at Forsmark. At FKA the uncertainties of the sociotechnical systems were more apparent and the personnel also emphasised the maintenance work more as a learning and a problem solving task.

An overview of the plant condition and long term planning were emphasised at both plants. However, at FKA some implications were found that many saw this as a task of the planning engineers. Some of the technicians were more or less waiting for things to happen, aka reacting. Some people at both plants nevertheless pointed out that maintaining an overview of the state of the plant should be included in the maintenance task of all the personnel: Maintenance workers

are the critical source of information concerning the current (and future) state of the plant and the needed recourses.

Results of the study gave implications that at least some of the maintenance personnel felt their status as being lower than that of other departments, and that their work was not appreciated as much as it should be. Also status and power differences were found inside the maintenance organisations, between e.g. different technical disciplines. Also some implications were found that at FKA the personnel did not feel so much as belonging to the plant organisation as the personnel at TVO did. On the other hand, the identification at TVO was to the firm, not to the maintenance organisation per se. The questions of commitment, identification, status and power issues in high reliability organisations require further attention and research.

5.2 Challenges to maintenance activity in the future

The case studies gave plenty of implications that the content of the individual jobs is gradually changing in maintenance work. The results also implied that there exists a clear danger that the routine tasks and the more challenging tasks will be systematically given to different people. The worst case scenario is that the challenging tasks are given to the people who will not accept routine work. Conducting routine tasks is as important for the development of expertise as is the carrying out of the more challenging and unique tasks. Every employee should have the opportunity to do both in an appropriate proportion. The importance of these questions are emphasised by the coming generation change, and by the new forms of organising work (such as the increased use of subcontractors for special tasks).

As already stated, maintenance work appears to produce a feeling of meaningfulness when there are technical problems to solve with safety significance and time pressure. If in the future the technology becomes more reliable for example due the operational experience and upgrades, then the job motivation is searched from other sources. However some interest in the technology and the machines themselves should remain. There also exists a danger that routine tasks and more challenging tasks will be systematically given to different people. This is a threat to expertise, since maintaining expertise and competence requires that each individual is able to do both routine and non-routine tasks is his / her job.

New information technology is clearly changing the nature of maintenance work. Current focus on strategic optimisation and new information technology threatens the traditional conception of proficiency (based on handicraft skills and experience) among the personnel. In principle the personnel usually understand the reasons for optimisation, but they do not want to see the machinery as merely numbers on a computer screen / data base, but as concrete objects to work and play with. This means that new technological solutions are not utilised as effectively as they could be. A challenge for both the training and socialisation of newcomers is on the one hand to maintain the practical handicraft competence and on the other hand to teach the use of the information tools and their meaning for the personnel's daily work and maintenance in general.

Long tenures and the high middle age of the personnel are one of the current characteristic features of the nuclear industry. At the same time a change of generation will happen during the forthcoming years. Long tenure or experience as such does not guarantee competence (cf. Klemola & Norros 1997). New technology sets new requirements, which means that some of the old habits have to be unlearned. The longer the habits have been in use, the harder the change. Long tenure can also lead to routinisation. Experience is then no longer a benefit, but can actually be a source of errors when the work and its outcomes are not actively reflected upon. Crucial issue in terms of the generation change is, what should the newcomers learn, the old working practices and the old culture or something new? Should the change of generation also mean a change of the organisational culture? What are the aspects worth maintaining in the existing cultures and what are the aspects that should be changed?

5.3 Features of work in complex organisations

The present study contains many interesting observations about two maintenance organisations in two different Nordic countries. The data could be interpreted from several perspectives. A first major concern is to what extent these data really say something specific about maintenance cultures or if they better should be interpreted as general observation about *work* in complex organisations, regardless if it is maintenance, operation etc. Taking the latter point of departure, the structure obtained from the factor analysis of the B-section, is of great interest as we see it. As a hypothesis we propose that work activities and their context, with a generalisation from the present data, could be characterised in at least the following important general dimensions:

- Meaningfulness
- Communication climate

- Experienced control
- Structure

Meaningfulness and control could be considered as end-states and structure and communication climate more as goals. This distinctions is not a clear-cut however, the dimensions are complex and they affect each other. Experienced control for example is dependent on the meaningfulness, but also on the communication climate and structure.

Meaningfulness is a complex cognitive variable presumably resulting from several other more specific factors, such as the content and variation of the tasks and the feeling that the task is important and leads to personal development (see also Hackman & Oldham 1980). Meaningfulness as a dimension was in the present study found to exhibit high significant positive correlation's with job motivation and job satisfaction (which both may be assumed to be output variables resulting from more specific factors). Maintenance tasks appear to produce a feeling of meaningfulness especially in terms of the problem identification and problem solving characteristics of the technical work. In fact, an interesting comment from one of the interviews was that the work was perceived as most exciting in terms of the "problems that occurred in the technology". This is a paradox in the sense that one of the goals for maintenance is to avoid problems and keep the technology running without experience of problems. If one assumes that the technology in the future can be made more reliable and less problems will occur, then this could be a challenge for the task to withhold "meaningfulness" in the sense of the joy felt by fixing problems. As one of our respondents remarked "it is more interesting when things happen and you have to solve problems in contrast to ordinary more boring maintenance tasks". To maintain the feeling of meaningful task in maintenance, in lack of concrete problem solving, one source of this feeling could be development of the maintenance task in terms of a more abstract work content (such as new maintenance strategies).

Good communication climate as a dimension of the work context was also found to correlate positively with motivation and well being. Communication practices appear, however, to be more and more abstract and in some sense also less of a face-to-face nature. Introduction of complex and large matrix organisations, such as in the case of Forsmark, also makes it difficult to structure the communication. In fact, the more "matrix" used, the more communication seems to be important to support then functioning of the matrix. To some extent this increased need

seem to counteract the efficiency benefits looked for in the matrix arrangement. The communication practices were highly salient values in terms of the scores received from Forsmark and we think this can be explained partly as an effect of previous smaller individual site specific maintenance cultures that supported these values.

Structure is a general term with many meanings. In this context we define structure as the degree to which people feel that goals, tasks and responsibilities are well defined. Judging from specific correlation's among some of the items measuring what we here call structure it was found that structure correlated positively with safety related items (in the B-section). This is perhaps an expected but nevertheless interesting observation that evokes general issues about how structure and flexibility interact in safety related activities

It is interesting to speculate to what extent these general dimensions are affected by different management innovations and how they correlate to various structural arrangements (matrix organisations, line organisations etc). Different organisational changes probably affect different dimensions. It could it meaningful to inspect these dimensions when doing organisational changes, and especially when conducting risk analyses before these changes are made. This area needs more research. It can be hypothesised that outsourcing for example could affect the meaningfulness and communication climate in the company.

5.4 Theoretical and methodological issues

Major methodological finding concerned the question of measuring organisational culture in turbulent organisations. It was found that it is hard to know what you are actually measuring, or are you measuring the same thing in both organisation (even though using the same methods). On the other hand, organisational changes can bring into surface features of the culture that have been in contradiction, but have not surfaced due to functioning daily routines and implicit knowledge of how to get by in the particular social-technical organisation (Oedewald & Reiman 2003a).

The timeline of the measurement also affects the results: It can be hypothesised that too short timeline leads to results that tackle with issues of climate more than culture. On the other hand, too long timeline can obscure the results in that the culture has changed, climate has fluctuated constantly and the results reflect different conditions of the organisation during the time of

measurement. A challenge for cultural research is in balancing the timeline of measurement and in taking into account the influence of climate on the results.

Cameron and Quinn's (1999) Competing Values Framework was originally used as the measurement model for the cultural research conducted in maintenance (Reiman & Oedewald submitted a). The pilot study gave implications that the four cultural types identified by Cameron and Quinn do not adequately describe the cultural dynamics in a complex sociotechnical system such as a nuclear power plant. This study illustrated that data from both FKA and TVO produced unique value structures, which also differed from the structure identified at the pilot study in Loviisa NPP maintenance (Reiman & Oedewald submitted a). Thus, the Competing Values Model needs to be refined to fit studies conducted at complex sociotechnical systems. The criteria for effectiveness in complex sociotechnical systems are in some respects different from traditional non-safety critical organisations. The model nevertheless offers a promising starting point, especially when inspecting changes in organisational structures.

It was found that the conception of "values" between Finland and Sweden might differ. Our results imply that in Finland the personnel respond more on the basis of what the manager seems to value, and consider that as an implication of the organisational values. Swedish personnel respond more on the basis of the prevailing conceptions and the consensus at their own organisational level. This difference in understanding the concept of values as measured in the survey affected the results in a great degree. On the other hand, the use of multiple methods guaranteed that one difference in the national cultures does not affect the results of the entire study.

Maintenance activities require a lot of personnel as well as economic resources compared to other functions of the power plants. The competence consists of different technical fields but requires also strategic understanding as well as practical handicraft skills. Due to the diversity of maintenance work and competence requirements it can be stated that focusing on single tasks (e.g. electric installations), special situations (e.g. outages) or to single psychological problem (e.g. memory overload) has only a small effect on the overall functioning of the plant. A cultural perspective aims at investigating the principles that guides the behaviour of the organisation and its personnel. Cultural perspective thus emphasises collective and shared issues (and those issues

that should be shared) over e.g. individual decision making. An individual always makes his/her decisions in a social context. This can be so strong that the individual is not even aware of making a decision – choosing between alternative ways of acting. It is this context, which sets the possibilities and boundaries of activity that is the main focus of interest in cultural research.

In addition to the social context, the assessment of organisational culture should take the task that the organisation is trying to accomplish into account. Cultural assessment is always an intervention to the organisation in question. The analysis of the core task provides a tool to reflect the current working practices and to facilitate the development of new ones. In terms of development, it is important to examine working practices as social phenomena and take the organisation's culture into account (Reiman & Oedewald 2002a).

The results of this study also show differences in power relations and subcultural relations among the maintenance organisations. The challenges in safety critical organisations should perhaps be approached from the perspective of critical theory and power conflicts. This aspect has not received much attention in the safety culture tradition which emphasises the integration aspects of organisation culture.

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Appendix A: Functioning of the survey instrument

Perceptions of values, A- and D-sections

A- and D-sections were analysed separately for both the plants, since the factor structure as such tells about how the personnel perceive different values and their interrelations.

TVO sample. D-section (the ideal values) of the survey was analysed by factor analysis. Five variables were removed from the analysis. Six factor solution was selected on the basis of the scree plot. The initial solution was rotated by Equamax method. Six-factor solution explained 54 % of the total variance of the questions.
Summated scales were formed from both the A- and D-sections and they were named as follows:
1. Efficiency (e.g. cost effectiveness, goal setting, efficient work tasks)
2. Hierarchy (e.g. rule following, centralised decision making, determined leading)
3. Cohesiveness (e.g. wellbeing of personnel, cooperation)
4. Development (e.g. openness for new ideas, continuous development)
5. Flexibility (flexibility, initiative)
6. Safety (occupational safety, learning, carefulness)

FKA sample. A-section of the survey was analysed by factor analysis. Three variables were removed from the analysis. Initial solution was rotated by Varimax method. Eigen values over one produced seven factors. The solution explained 66 % of the total variance of the questions. Summated scales were formed from the first five factors and they were named as follows (five factors explained 60 % of the total variance of the questions):
1. Development (e.g. continuous development, co-operation, wellbeing of personnel)
2. Communication and feedback (e.g. feedback, well-defined tasks)
3. Safety and rules (e.g. rule following, occupational safety, carefulness)
4. Proficiency and individual responsibility (e.g. proficiency at work, individual responsibility)
5. Financial values (financial objectives, cost-effectiveness)

One's own work -section for TVO and FKA

B-section of the entire sample was factor analysed by principal components solution and summated scales were formed on the basis of the factor loadings. Rotation method was Varimax. A five-factor solution was obtained on the basis of eigenvalues over one. Four variables were removed from the analysis on the basis of the low communalities.

Summated scales were formed and they were named as follows:
1. Knowledge of expectations concerning one's own work (e.g. I have a clear picture of my responsibilities, I know on what basis my work is assessed)
2. Meaningfulness (e.g. I feel that the work I am doing is important, My job tasks are varied)
3. Sense of personal responsibility and control (e.g. I can cope with my tasks, I make sure that my tasks lead to the desired outcomes)
4. Development orientation (e.g. I actively develop my skills, I generally enjoy challenges in my work)
5. Communication and climate (e.g. My superior gives me constructive feedback, The working climate in my group is good)

Functioning of the instrument

Internal consistency of the measures was inspected by calculating a reliability coefficient (Cronbach's alpha, see e.g. Chiselli et al. 1981) for every summated scale (see Table 1). The table also depicts the number of variables included in each summated scale and their mean scores.

Table 1. The number of variables, mean scores and reliability coefficients (Cronbach's alpha) of the summated scales

	Variables	Mean score	Reliability coefficient
VALUES, TVO			
1. Efficiency	6	4,14	.72
2. Hierarchy	7	4,10	.68
3. Cohesiveness	5	3,38	.90
4. Development	4	3,62	.82
5. Flexibility	5	3,95	.79
6. Safety	3	4,43	.79
VALUES, FKA			
1. Development	9	4,39	.91
2. Communication and feedback	6	4,39	.83
3. Safety and rules	7	4,55	.85
4. Proficiency	5	4,56	.82
5. Financial	2	3,84	.75
OWN WORK			
1. Knowledge of expectations	5	3,96	.87
2. Meaningfulness	4	4,43	.79
3. Sense of personal responsibility	6	4,49	.75
4. Development orientation	4	4,51	.68
5. Communication and climate	4	4,15	.72
IDEAL VALUES, TVO			
1. Efficiency	6	4,19	.80
2. Hierarchy	7	3,98	.73
3. Cohesiveness	5	5,10	.61
4. Development	4	4,62	.65
5. Flexibility	5	4,59	.67
6. Safety	3	5,11	.61
IDEAL VALUES, FKA			
1. Development	9	5,09	.83
2. Communication and feedback	6	5,02	.78
3. Safety and rules	7	5,05	.78
4. Proficiency	5	4,99	.66
5. Financial	2	3,87	.84

Reliabilities (coefficient alphas) of the value instrument ranged from 0.68 to 0.91 (see Table 3), of the own job instrument from 0.68 to 0.87 and of the ideal values from 0.61 to 0.84. Twenty of the 27 measures obtained alphas over 0.7, which is generally considered an acceptable level for reliable interpretations (see Hair et al. 1998) also across the case studies. It should be noted that the sample sizes varied between the instruments: TVO value instruments had a sample size of 84, Own work instrument had a sample size of 215 and FKA the perceived and ideal value instruments had a sample sizes of 132 and 130, respectively.

What is interesting about the value solution for TVO is that reliabilities are higher in A-section even though they were formed on the basis of the loadings of D-section. The solutions of both plants also differ from that found at the Loviisa case study (see Reiman & Oedewald submitted a, Oedewald & Reiman 2002).

Another interesting finding was that proficiency-value had to be removed from the analysis of the TVO sample since it formed its own factor. The proficiency value variable correlated highly with safety scale however.

Linear univariate differences between plants on the own work summated scales were inspected with ANOVA. Knowledge of expectations ($F(1,213)=21.6$ $p < .001$), sense of personal responsibility ($F(1,213)=18.2$ $p < .001$) and communication & climate ($F(1,213)=6.2$ $p < .05$) had statistically significant differences. In all the scales, TVO had a higher score than FKA. Meaningfulness of work on the other hand did not show statistically significant differences and was high at both plants.

Correlation of the summated scales to control variables were also calculated separately for both plants. Table 2 depicts the correlation matrix for Olkiluoto and Table 3 for Forsmark.

Table 2. Correlations at Olkiluoto

VALUES	Age	Tenure	Same task	Job satisfaction	Job motivation	Work stress
Efficiency	0,070	0,144	-0,099	0,358***	0,355***	-0,022
Hierarchy	-0,170	-0,131	-0,192	0,350***	0,253*	0,052
Collectiveness	-0,029	0,034	-0,323**	0,514***	0,559***	0,064
Development	0,129	0,183	-0,019	0,540***	0,495***	0,035
Flexibility	-0,068	0,023	-0,186	0,500***	0,410***	0,049
Safety	-0,026	0,002	-0,203	0,340**	0,407***	-0,016
OWN WORK						
Knowledge of expectations	0,096	0,140	0,078	0,492***	0,494***	0,194
Meaningfulness	0,174	0,244*	-0,113	0,548***	0,724***	0,167
Sense of pers. resp	-0,084	-0,034	0,043	0,257*	0,271*	-0,101
Development orientation	0,085	-0,029	-0,203	0,389***	0,410***	0,244*
Communication and climate	-0,187	-0,076	-0,351**	0,481***	0,385***	-0,153
IDEAL VALUES						
Efficiency	0,039	0,085	-0,083	0,268*	0,415***	-0,034
Hierarchy	-0,129	-0,032	-0,038	0,054	0,018	-0,159
Collectiveness	-0,007	0,010	0,023	-0,097	-0,150	0,005
Development	-0,181	-0,108	-0,052	0,012	0,021	-0,113
Flexibility	0,093	0,088	-0,104	0,144	0,112	-0,055
Safety	0,061	0,135	0,048	0,024	0,022	-0,050

Table 3. Correlations at Forsmark

VALUES	Age	Tenure	Same task	Job satisfaction	Job motivation	Work stress
Development	0,111	0,138	0,045	0,265**	0,387***	0,000
Communication	0,009	0,063	0,020	0,218*	0,280***	0,065
Safety and rules	0,048	0,158	0,025	0,162	0,213**	0,064
Proficiency	-0,120	0,026	-0,101	0,269**	0,413***	-0,021
Financial	0,137	0,119	0,061	0,081	0,199*	0,114
OWN WORK						
Knowledge of expectations	0,237**	0,230**	0,078	0,540***	0,523***	0,167
Meaningfulness	-0,065	-0,013	-0,058	0,600***	0,774***	0,217*
Sense of pers. resp	0,048	0,017	0,073	0,580***	0,503***	-0,148
Development orientation	-0,220*	-0,106	-0,148	0,459***	0,514***	0,083
Communication and climate	0,029	0,063	0,027	0,563***	0,534***	-0,050
IDEAL VALUES						
Development	-0,132	-0,129	-0,043	0,277***	0,406***	-0,018
Communication	-0,204*	-0,115	-0,125	0,250**	0,356***	0,037
Safety and rules	0,049	0,043	0,118	0,318***	0,354***	0,049
Proficiency	-0,056	0,023	0,048	0,262**	0,388***	-0,013
Financial	0,149	0,117	0,019	0,247**	0,318***	0,128

Some differences in correlation coefficients could be found. For example at TVO age does not correlate positively with knowledge of expectations, as it does at FKA, and at TVO age does not correlate negatively with development orientation as it does at FKA. Instead at TVO stress correlates positively with development orientation whereas at FKA work stress correlates positively with the meaningfulness of the work. Furthermore at TVO tenure correlates positively with the meaningfulness, whereas at FKA tenure correlates positively with the knowledge of the expectations concerning one's own work.

No interaction effects between plant and age were found. Age has thus similar effect on both plants. When considering the whole sample, age created statistically significant differences on:
- values of efficiency $F(4,205)=3.6$, $p=.007$), with age group 36 – 45 scoring lower
- knowledge of results ($F(4,204)=3.6$, $p=.007$), with older people scoring higher
- development orientation $F(4,204)=2.6$, $p=.035$), with older people scoring lower

- ideal value of cohesiveness $F(4,204)=3.4$, $p=.010$), with people under 25 scoring significantly higher
- ideal value of change $F(4,204)=2.8$, $p=.028$), with older people scoring lower
- ideal value of safety $F(4,204)=3.4$, $p=.011$), with age group 36 – 45 scoring lower

The value structures and the corresponding figures for FKA and TVO show plenty of differences. The relation between the value items was inspected with multidimensional scaling method, by Euclidean distance measure. From TVO sample the values of centralised decision making and questioning new ideas were removed since they were outliers (were clearly separated from all the other values). Centralised decision making and Questioning new ideas both loaded highly positive on the vertical dimension, and almost nil on the horizontal dimension. The results of MDS of TVO sample is presented in Figure 1. Notice the difference in scales between the horizontal and vertical dimensions.

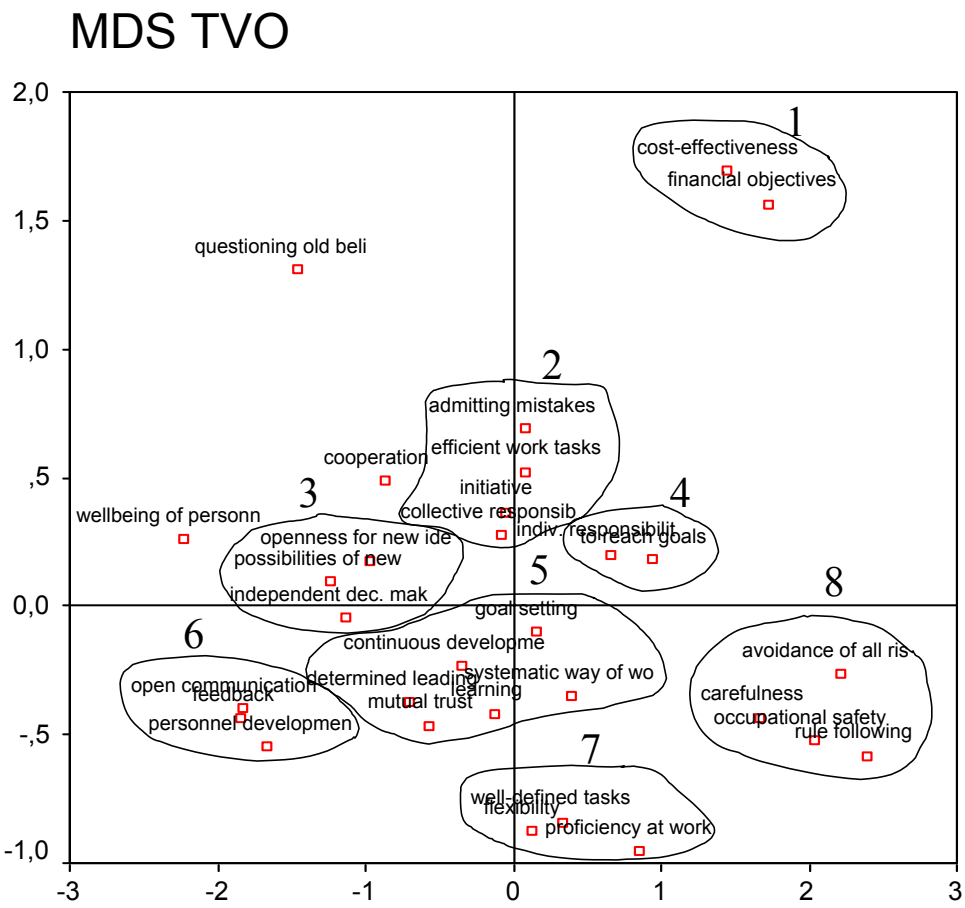

Figure 1. The spatial map produced by multidimensional scaling of the value instrument of the TVO sample with 8 identified clusters.

At TVO financial values separate clearly from all the other values (see cluster 1 in Figure 1). The second cluster consists of values related to initiative on the one hand and collective responsibility and admitting mistakes on the other hand. The third cluster includes the values related to innovation and change. The fourth cluster includes two values: individual responsibility and goal achievement. The fifth cluster includes values related to systematic ways of acting and shared goals. The sixth cluster includes communication and personnel development values. The seventh cluster consists of the proficiency, flexibility and well-defined tasks values, whereas the eight cluster includes values connected to safety and rule-following. Despite the eight cluster, the two dimensions separate all the values on two conceptually meaningful axis: The horizontal dimension separates values related to wellbeing of personnel and communication from values related to task goals (safety, rule following, cost-effectiveness). This dimension resembles Cameron and Quinn's (1999) control – flexibility dimension. The vertical dimension separates proficiency and safety values from financial values. The second dimension resembles Cameron and Quinn's internal – external dimension.

From the FKA sample centralised decision making and determined leading were removed since they were outliers. Notice the difference in scales between the horizontal and vertical dimensions.

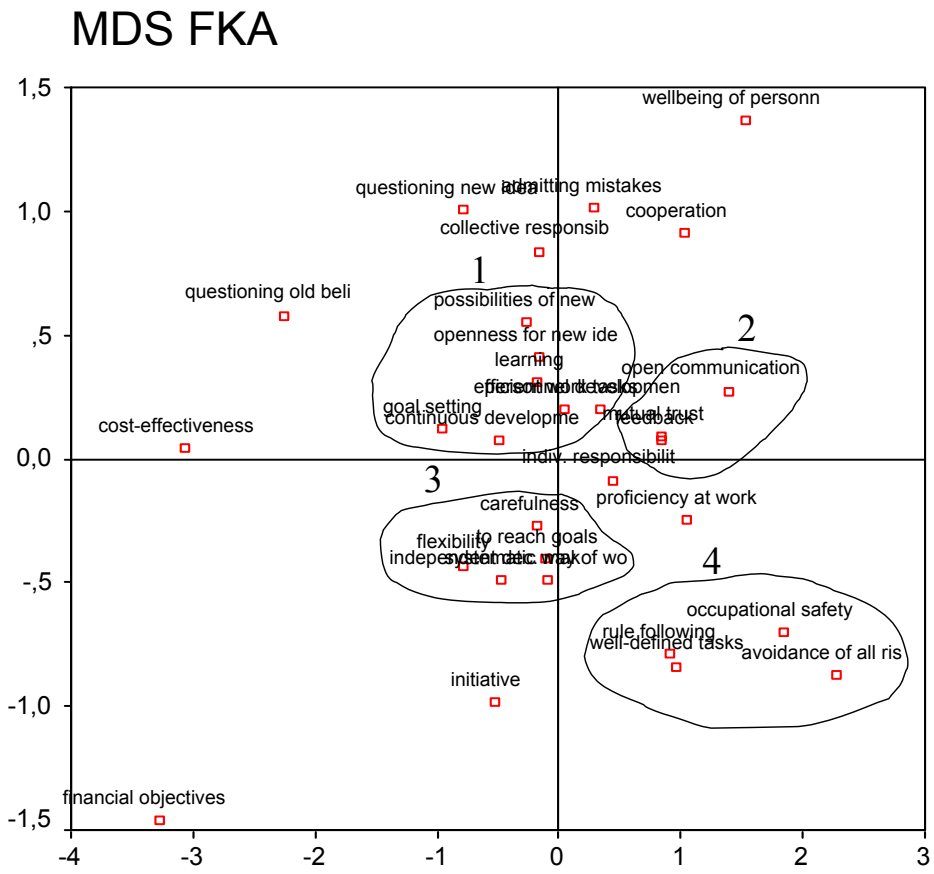

Figure 2. The spatial map produced by multidimensional scaling of the value instrument of the FKA sample with 4 identified clusters.

Horizontal dimension separates financial values from safety, wellbeing and communication values. This dimension corresponds to Cameron and Quinn's (1999) internal – external dimension. The vertical dimension separates financial and safety objectives from the objectives related to the wellbeing of personnel.

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Author(s)	Teemu Reiman*, Pia Oedewald*, Carl Rollenhagen** & Irene Eriksson**
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Abstract

The study aims to characterise, assess and develop the organisational cultures of participating nuclear power companies' maintenance units. The assessment is made by the means of maintenance core task modelling that has already been started in previous studies. The theoretical core task model is used in evaluating the characteristics of the organisational culture. We aim to identify what are the strengths and weaknesses of the case organisation's culture in relation to its core task. The study also aims to validate the methodology for contextual assessment of organisational culture.

In addition to case specific results, the study acts as a benchmark between the participating companies and gives a chance to compare the different culture profiles between the companies. Similarities and differences between the organisational cultures at the maintenance units were identified. The purpose is not however to evaluate which organisation is better, but to raise issues that require attention at the organisations. When evaluative statements are made, the criteria are formed on the basis of the core task model: Even though the practices differ, from the perspective of the maintenance core task they might both be as effective.

Key words: Organisational culture, core task modelling, case studies, Forsmark, Olkiluoto

Available on request from the NKS Secretariat, P.O.Box 49, DK-4000 Roskilde, Denmark.
Phone (+45) 4677 4045, fax (+45) 4677 4046, e-mail nks@nks.org, www.nks.org