Maintenance Core Task and Maintenance Culture

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***Abstract*—The aim of the study reported here was to develop a methodology for modeling the maintenance core task and assessing the maintenance culture. The case study was carried out at the Loviisa nuclear power plant in Finland. Maintenance task, its goals, critical demands and the demands for the actual organisation of the maintenance were conceptualised by core task analysis. The organisational culture of maintenance department was inspected by interviews, observation, survey and workgroups. The core task model was used to assess the safety and efficiency of the maintenance culture. Results show three critical demands and three instrumental demands to be controlled in all levels of the organisation. The culture must support this. Implications of these functions for development of organisational culture are discussed.**

***Index Terms*—Human factors, Maintenance, Modeling, Personnel, Psychology, Technology social factors.**

I. Introduction

THE aim of maintenance in power plants is to guarantee the safe, reliable and cost-effective production of electricity. This includes preventive maintenance, planned outages and repairs. It is clear that proper working of the machinery and technology is critical to both plant safety and productivity. Nevertheless, maintenance as an activity has not been studied much. Maintenance has been researched mainly from the human error point of view, which is an important but in many respects a limited perspective. Maintenance task as itself has not been in focus, elsewhere than in purely strategic level. [16]

Maintenance is a complex activity in a sense of Vicente's definition of complex sociotechnical systems [31]. In addition to inherent complexities of maintenance, the changes in the environment put pressures on developing maintenance activities. One of the biggest challenges identified in many different fields is the ageing of technology, e.g. in aviation see [30]. A related change is the ageing of personnel, which also affects many different industries. The change of generation at the plants sets tensions for maintaining and developing adequate competencies. New technologies and new ways of organising and structuring work also have an effect on maintenance. Deregulation has set new challenges for the whole nuclear industry [1]. Economical pressures are sure to reflect also to working practices and strategies at the management level, but also at the worker level. A related interest in the nuclear field is that of identifying the essential activities of maintenance and the special know-how needed inside the house. Recruitment and commitment of new personnel is also an issue of continual relevance in the nuclear field, maybe even more so in the future depending on the political climate towards the use of nuclear power. [27], [16]

The growing interest of industry and researchers towards maintenance related human factors as seen for example in aviation and nuclear industry has resulted in many different interventions and advances [8], [27], [30]. Gramopadhye [8] states in his review of aviation maintenance human factors research that most airlines have human factors programs including incident analysis systems, personnel training, and information technology solutions to enhance the reliability of maintenance activities. Also personnel management systems such as maintenance resource management (MRM) or crew resource management (CRM) are in use. [8], [30]

Because maintenance is a complex sociotechnical practice and it can be organised and practised in many different ways, we propose that it is not possible to find the one best solution to promote safety and reliability of maintenance activities. Mathilde Bourrier who has studied organisational reliability in nuclear power plants during the annual outages points out that "Organisational reliability is neither an attribute, nor an attitude that can be imposed solely from outside. Rather, it is a result of a complex compromise between resource allocation and actors' strategies *within* the organisation." [2]. She concludes that organisational reliability should be investigated and seen as a property of the social systems embedded in reliability-seeking organisations. She also states that the social construction of reliability can best be analysed trough a systemic analysis.

Our Contextual Assessment of Organisational Culture (CAOC) methodology applies two basic concepts, *core task* and *organisational culture*, to capture the systemic and complex nature of maintenance work. According to Edgar Schein's [28], [29] theory, organisational culture is defined as "A pattern of shared basic assumptions that the group learned as it solved its problems of external adaptation and internal integration, that has worked well enough to be considered valid and, therefore, to be taught to new members as a correct way to

This work was supported in part by the Ministry of Trade and Industry of Finland, Nuclear Safety Authority of Finland (STUK), VTT and Fortum Power and Heat.

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perceive, think and feel in relation to those problems." [28, p. 12, italics altered].

The concept *core task* means the essential result-critical content of a particular work that has to be fulfilled in all situations in order to maintain an appropriate interaction with the environment [15]. The core task includes those operational demands that have to be fulfilled so that the objectives of the whole organisation can be achieved. [25], [15] The core-task concept and analytical approach have been developed by VTT in earlier studies [11], [13]-[15], [23]-[25]. For its theoretical background, see e.g. [6], [7], [12] and [19]. The core task analysis (CTA) provides a tool to reflect the current working practices and to facilitate the development of new ones [15], [25].

We agree on Vicente's [31] definition of an effective sociotechnical system: According to Vicente, an effective sociotechnical system is safe, productive and healthy. Therefore we do not limit ourselves only to safety related aspects of organisations' practices. Instead of using the term safety culture we use term organisational culture. We define *organisational culture* to be the organisation's learned way of responding to the different demands of its core task [25]. 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 it resists change. When considering the challenges and pressures for change that the maintenance organisations are currently facing, understanding the impact of culture comes crucial. Changes in the environment set pressures for the requirements of the maintenance, its core task.

In 2001 VTT's Human factors group started a two-year research project which had the following objectives:

- to model the maintenance core task from the perspective of demands that it sets to organisation and
- to characterise the organisational culture of the target organisation in order to
- assess how the culture supports perceiving and fulfilling the demands of the core task.

In this paper, the contextual assessment of organisational culture methodology is presented through a case study of nuclear power plant maintenance. The model of maintenance core task is presented along with the description of the case study on the basis of which the model was generated (see also Oedewald & Reiman [17], and Reiman & Oedewald [26]). Practical examples of the use of core task model for assessing and developing maintenance work are given.

II. METHODS

A. Case Organisation and Research Strategy

The case study was carried out at Loviisa nuclear power plant in Finland. Maintenance activities of the two reactor units are conducted by maintenance department with almost 200 permanent employees. At the beginning of the project in 2001 maintenance activities were organised into mechanical, electrical, instrumentation and construction maintenance, technical design, planning and coordination and quality control sections. During the study the maintenance functions were reorganised into five sections.

Contextual assessment of organisational culture (CAOC) – methodology [25] was applied in the case study. Maintenance task, its goals, critical demands and the demands for the actual organisation of the maintenance were conceptualised by core task analysis. The organisational culture of maintenance department was inspected by interviews, observation, survey and workgroups. The core task model was used to assess the safety and efficiency of the maintenance culture.

The case study employed an iterative and multimethod research strategy based on method triangulation [5], [32]. The primary means of data gathering were as follows:

23 semistructured interviews were conducted. The interviewees were of different hierarchical levels and functions of the maintenance department, including the head of the maintenance department. Interviews were taped and later transcribed.

Organisational culture and core task survey (CULTURE) was administered. The survey consisted of four different measuring instruments: measure of values, measure of practices, measure of the core task and measure of the psychological characteristics related to work. Total sample size was 135 yielding a response rate of over 70 percent of personnel. Questionnaire was based on our previous studies [22], [23], and Cameron and Quinn's competing values model [3], [21], [4]. Measure of the psychological characteristics related to work was based on Hackman and Oldham's theory [9]. Questions were also tailored on the basis of interviews and document analysis. The core task instrument of the questionnaire was constructed on the basis of the preliminary core task model.

Documented group working and seminars were conducted during the whole research project. Working group consisted of maintenance experts from the management level. Seminars had attendants from all the levels and functions of the maintenance department.

The data was used both to model the core task and to characterise the case organisation's cultural profile. The methodology sets specific requirements for the validity and reliability of the interpretations. This is discussed in the concluding section and also in Oedewald and Reiman [17], [18].

B. Preliminary Core Task Model

A preliminary model of maintenance core task was based on a literature review [16] and on the results of the interviews, group work modeling and the CULTURE-survey. Interview questions addressed the goals of the maintenance, the critical demands of the goals and demanding features and situations in interviewees' own jobs.

In the core task analysis we first define the object and goal of activity. The objective of maintenance was seen as maintaining the operational reliability and the economical value of the installation so that power production can continue as long as planned. After defining the object of activity, we then defined the critical demands set by the object of activity and the constraints and possibilities connected to it. In this case the aim was to model maintenance task in a generic level in order to

conceptualise common demands to the whole organisation. Figure 1 presents the three critical demands to be controlled in all levels of the organisation.

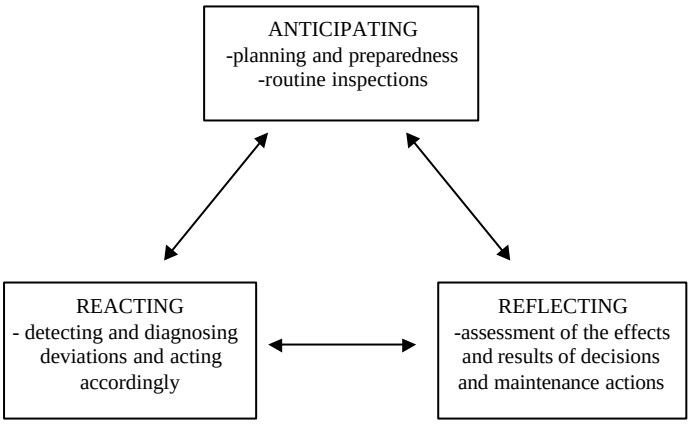

Fig. 1. First stage of core task analysis: critical demands of the maintenance task.

Anticipating refers to an intention to predict the state of the plant and the effects of actions, as well as to plan the needed actions and recourses in advance. Anticipation is central to obtaining reliable and economical operations. It is connected to the way of using the power plant, with one planned outage a year. Machinery that is imperative to production must be maintained during the annual outage. Because of the complexity of the system, also all the other works have to be carefully planned in advance. Example of the manifestation of the demand for anticipation in foreman's work could be that of the mornings' work allocation meeting or the program of preventive maintenance. In nuclear installations also safety-criticalness (both nuclear and occupational safety) emphasises the need for anticipation. For similar ideas, see e.g. [2].

Reacting to unexpected conditions is the obvious function of maintenance. Also the safety-critical nature of nuclear power plant maintenance requires efficient reaction to deviations. In spite of anticipating and planning, unexpected things may happen. This requires reacting. Example of the manifestation of the demand for reacting is fault repair work or detection of deviations.

Reflecting refers to a demand arising from the inherent uncertainties of highly complex systems, see e.g. [20], [31] and the hence mediated and uncertain nature of knowledge concerning the object of activity. Reflectivity means critical reviewing of the effectiveness and results of one's actions. Reflectivity includes challenging the existing conceptions and working practices which are embedded in the culture of the workplace. [6] An example of the manifestation of the demand for reflecting is the use of failure data bases before and after making fault repairs. Reflecting is needed to ensure that actions taken are appropriate and also to create knowledge for anticipation purposes. Changes in the field, and for example ageing phenomena of the plant put more emphasis on reflection.

We used the preliminary core task model for two purposes. First, it was used as a starting point in investigation of the maintenance department's culture. It provided a tool to focus on functionally relevant aspects of culture. Second, it also formed a basis for the next stage of core task analysis; specifying psychological demands for maintenance working practices.

III. RESULTS

A. Criteria for Assessing Culture: The Core Task Model

In analysis of the interview material the definitions of constraints and requirements of maintenance task were extracted from the data. Also conceptions of the criteria and goals for the fulfilment of the core task and the definitions of the object of work were extracted. In group working the same themes were discussed and definitions that were agreed upon by the group were written down.

Confirmatory factor analysis was conducted for the survey's core task instrument. Further analyses of the survey data were made on the basis of results from interviews and group working. Three summated scales were formed from the core task section. The scales measured whether or not the respondents considered them to be requirements of the core task. The first scale was termed *uncertainty awareness*, the second *coordination and cooperation* and the third *passive rule following*. For a more detailed description of the survey instrument and the results obtained by it, see [26].

Figure 2 presents the core task model that was conceptualised.

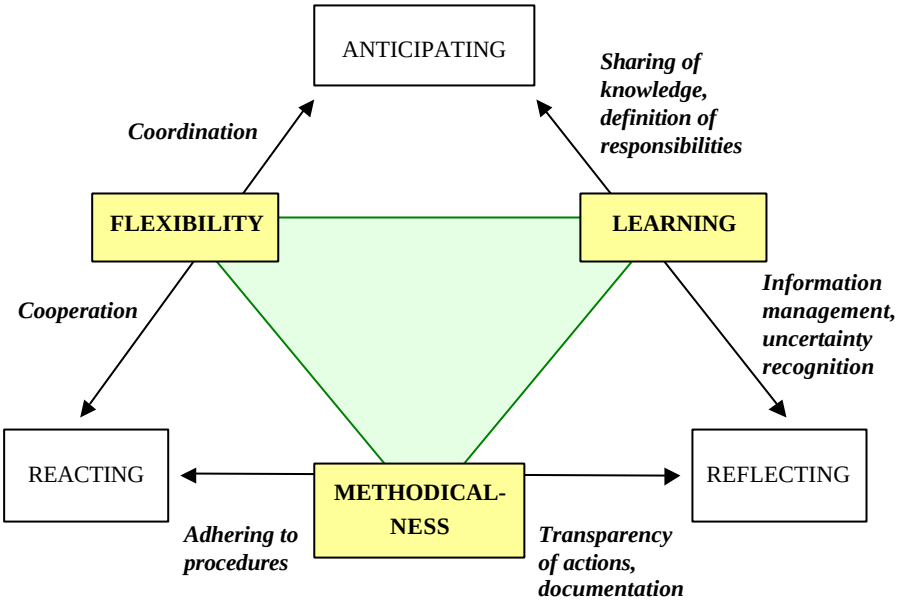

Fig. 2. The core task model: critical demands and requirements of the maintenance task.

In figure 2 there are depicted three kinds of demands: the *critical demands* (on the corners on the triangle), *instrumental demands* for the critical demands (between each core demand), and *demands for the working practices* (in italics, outside the triangle).

The instrumental demand that is associated with balancing between anticipating and reacting is that of *flexibility*. Example of the manifestation of the demand for flexibility is coordinating time tables for jobs that require different areas of expertise or coordinating resources in a case of a machine failure.

Fulfilling the requirements of reacting and reflecting requires *methodicalness* of actions. This means following the procedures and documenting the results of actions. Only then can they be later analysed and reflected upon. Example of the manifestation of the demand for systematicalness is fulfilling and updating the maintenance history database.

In order to *learn* from actions, *knowledge sharing and uncertainty awareness* are required. An example of the manifestation of the demand for learning could be changing the procedures on the basis of feedback or changing the program of preventive maintenance on the basis of maintenance history.

Flexible balancing between anticipation and reaction makes possible the formulation of shared goals and criteria for plant condition. If certain criteria are not met one is required to react on it. By reacting to novel situations and reflecting on the effects of action one is creating information about the object of activity. In the learning process, e.g. by comparing information to previous experiences and by sharing it with others, the information is generalised into knowledge concerning the current state of plant. The process thus provides an overview that can be utilised in anticipation.

The three critical demands depicted in figure 2 can be conceptualised as different *operational functions* in the maintenance department. It can be hypothesised, though, that this perspective is very limited in a complex system like the nuclear power plant maintenance. The uncertainties and complexities inherent in the object of activity demand that all the employees take into account all the demands in their daily tasks.

The plausibility and credibility (components of validity in qualitative research, see [10]) of the core task model was inspected by presenting the model to mechanics and foremen in three workshops. After presentation every participant thought up examples of the six demands (see figure 2) in their own daily tasks. Almost everybody found out at least one concrete example to every demand. They could also identify tasks that did not seem to belong to any of the categories. These tasks were in most cases felt to be unnecessary or aim at different goals than that of fulfilling the demands of the core task. The model can therefore be claimed to have at least pragmatic value as an instrument in reflecting upon one's work.

Although examples of the manifestation of demands in own jobs were quite easy to find, the interpretation of the demands differed, and hence the jobs selected to represent particular demand varied in type.

B. Differences in the cultural manifestation of instrumental demands

The three instrumental demands depicted in figure 2 (flexibility, methodicalness and learning) manifest themselves in the case organisation's culture in different ways. Differences could be found in workers' conceptions the object of learning, of the source of need for flexibility, and in reasons for methodicalness.

On the basis of further analysis of the survey instrument's core task section it was found out that uncertainty was conceptualised among the respondents
- as technical uncertainty inherent in the complex system or
- as social uncertainty formed as a learned aspect of the culture.

It can be hypothesised that orientation where uncertainty and unexpected incidents are interpreted as features of the social organisation is detrimental to development of expertise. In that case, learning is focused on the ways of coping with the perceived uncertain culture, not on the means of coping with the uncertain technical system. From the perspective of the core task, learning is more effective the more it focuses on the object of activity itself, see e.g. [6], [7].

Flexibility was also conceptualised in two different ways. Some people comprised the need for flexibility as arising from the unanticipated activity of other agents in the system. Other people meant by flexibility the complex nature of the technical system and a need to coordinate activities with other groups in order to react appropriately. The people who emphasised the unanticipated activity of others did not perceive so strongly the demands for anticipation in their own work. They emphasised the need to adjust activities on the basis of, for example, obscure work orders or on the basis of contradicting requirements from the different levels of the organisation.

On the basis of the survey results, methodicalness was found out to mean passive rule following to others and more active documentation and adherence to procedures to others. In the passive conception the demand for reflectivity was conceived of as being someone else's responsibility.

It can be hypothesised that these different ways of conceptualising the demands for work may be adaptive in a way of getting by in the organisation's culture, at least in the short term. Still, they can be unadaptive from the perspective of fulfilling the requirements of the core task. It can be further hypothesised that the different ways of conceptualising the core task demands stem from different basic assumptions, which are embedded in the culture in question.

C. Identifying the basic assumptions behind the cultural manifestations

In analysis of the interview data and group working sessions concerning core task demands in one's own job we identified following tensions:
- situational judgement vs. generally applicable rules
- certainty vs. uncertainty about the impacts of activities
- specialisation vs. maintaining overview.

The tension between situational judgement and generally applicable rules is manifested e.g. in concrete repair situations where the work broadens so that it is no longer clear if the work is defined in the work order. The question is whether it is acceptable to make a personal judgement and finalise the work, or should it be interrupted until the new work order is given. Correspondingly the dilemma of certainty vs. uncertainty is faced when performing a task for a first time. If the espoused norm forbids you to conduct activities if you are not sure how to do it, how can you ever achieve certainty. The third tension, specialisation vs. maintaining overview, is confronted when considering the role of expertise: what is the best strategy to ensure the reliability of work, to go into details in some areas or to obtain general understanding of the interdependencies.

Most of the interviewees brought up these themes when discussing one's own job, but in distinctive ways. Some interviewees pointed out that there are different and conflicting ways of handling demanding situations. Other interviewees seemed to prefer one or the other way of thinking about these dilemmas, which they did not question. We consider these findings to reflect the inherent complexity and uncertainties in fulfilling the demands of the core task. As Bourrier [2] states workers develop different strategies in order to be able to act in the environment. We think that the strategies to coping with the tensions on the other hand manifest the way people have learned to perceive, think and feel about these issues [28]. Thus they provide an opportunity to reveal the underlying, core task-related basic assumptions of the given culture.

IV. DISCUSSION

The purpose of this paper was to give an example of the practical application of the Contextual Assessment of Organisational Culture (CAOC) methodology [25] in developmental work. Methodology consists of an iterative process of core task modelling, organisational culture research and organisational assessment. The context in question was that of the maintenance work, but the methodology has also been applied to, e.g. regulatory work [23], [24].

Aim of the CAOC-research is to assess the culture, not only to describe the culture. According to our premises, assessment must be made contextually without exploiting universal and generic criteria for culture. Due to its contextual and participative nature, the methodology acts as an intervention to the culture of the target organisation. The aim of the research is, therefore, not only to assess the given culture, but also to give the personnel new concepts and new tools for reflecting on their organisation, their jobs and on appropriate working practices. This necessitates clarifying also the meanings given to various activities and the dynamics connected with their formation. [25] When analysing assumptions critical to the core task, preliminary results show that there exists basic assumptions concerning the reliability of human decision-making and the role of written rules. In addition basic assumptions relating to predictability of the environment and nature of expertise are hypothesised. The analysis of possible differences in basic assumptions is in progress [17]. Also further analysis aims to clarify the relationship between the organisational practices and the different basic assumptions prevalent in the organisation. [17]

Challenging issue in sense of validity and reliability of the research is the use of research material for two different analytical purposes, namely to model the core task and to characterise the case organisation's culture. This endangers the research into circular reasoning. This paper concentrated on the core task model and its use in development work. The main challenge is to separate those aspects of the core task model which are characteristics of the case organisation's culture and those aspects which can be generalised as core demands of any maintenance activity.

Follow-up research based on the CAOC-methodology and the core task model presented in this paper is aimed at two objectives: Firstly, developmental work with the Loviisa nuclear power plant's maintenance personnel will continue. This is an essential part of the methodology and provides data also on the practical usefulness of the core task modelling and cultural approach to developmental work. Secondly, an international research project has been started which attempts to validate the maintenance core task model and the CULTURE-survey. This project also acts as a benchmark and comparison between different maintenance cultures. This is an important step since one case study as such offers only limited generalisable information.

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