

Organisational challenges associated with design and implementation of technology in re-design projects in the nuclear domain

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Abstract. A complex socio-technical system needs to optimize on safety when designing the human-machine systems. The purpose of this study was to learn about organisational challenges in redesign projects in the nuclear domain. Interview results showed that stakeholders had focus on either technology driven or human factors driven design. A conclusion was that all project members need knowledge and understanding of human factors aspects; these need to be highlighted both in planning and during the whole iterative design process, where also operator involvement is crucial. If organisational challenges can be solved the resilience of the nuclear power domain may improve.

Keywords. Design project, nuclear control, organizational challenges, human factors

1. Introduction

Socio-technical systems are often defined as complex systems and characterised by interactions between humans and technology. A complex system produces unexpected events, positive as well as negative. Brehmer (1992) argues that complexity cannot be defined independently of the task to be performed in relation to a system; goal conflicts may exist between different interdependent subsystems. According to Perrow (1999) it is normal for complex systems to produce incidents and accidents. High demands on safety are important for complex systems. To optimise human interactions within the system, the technology must be designed and implemented with care.

A nuclear power plant is one example of a complex socio-technical system, which is characterised by high demands on safety and regulation. Today nuclear power plants in Sweden and elsewhere are being modified. Since the goal of safety has a very high priority, the design process must proceed with great caution. It is therefore of utmost importance to understand the goal conflicts or challenges that may exist when modifying a complex system.

It is also of importance to apply a system perspective on modifications in nuclear power plants and not only focus on separate components and their relation to other components. Modification of a nuclear power plant may also, in some cases, be regarded as a more or less complex project where many stakeholders are involved, with different background, safety philosophy, and knowledge about safety, sometimes also with different cultural background and different languages. Goal conflicts should be expected when the complexity of a modification process increases.

The first step to an improvement of the modification process is thus to understand the goal conflicts that may exist on an organizational level and after that develop coping methods to minimize or eliminate these goal conflicts. In order to avoid negative consequences as much as possible and optimise the interaction between operators and technology the design processes in the nuclear power industry must be given sufficient attention.

Design in this case refers to the process of designing an artefact or the end result of a design process. When design is about the end result of a design process, human factors guidelines exist and can be used to guide the design process. International regulator guidelines exist (EPRI-1008122), with a focus on Human Factors guidelines at different phases in the design process.

When design is about the process or activity of designing some artefact the central problem to address is how to make sure that the design process will lead to high quality and safety of the end product. The planning and management of the design process becomes critical (Trueman, 1998).

In order to identify organizational challenges and goal conflicts associated with the planning and management of modification/design activities in the nuclear industry the Nordic Nuclear Safety Research (NKS) financed a project 2011 regarding 'Improving the design processes in the nuclear domain' run by VTT Technical research Centre of Finland (Macchi et al. 2013; 2014). The NKS project had a focus on design from a safety culture and resilient engineering perspective, and was structured in three phases.

The first phase of the project was a literature review and interviews with experts from the nuclear domain in Finland and Sweden. The challenges and goal conflicts of collaboration and communication were addressed. The second phase the project aimed at deepening the understanding of challenges and opportunities. In the third phase of the project the aim was to test and evaluate the results found in the earlier phases.

The aim of the study presented in this paper was to study organisational challenges with design and implementation of technology in projects focusing on redesign of existing control room functions in nuclear power plants in Sweden. The result from this study was included in phase three of the larger NKS project.

2. Methods

The case studies dealt with organisational challenges associated with design and implementation activities in projects focusing especially on redesign of existing control room functions in nuclear power plants.

In-depth interviews were made with two representatives from nuclear power plant organisations and three representatives from design organisations. Out of these three representatives were human factors engineering specialists, one was safety controller and one was project leader with electrical engineering background. The respondents had been working in the domain between 5-20 years and had been involved in several design projects.

Before the interviews took place, each respondent was asked to choose a design project to discuss and relate to during the actual interview. The project should be safety related, include several stakeholders with various background and interests, include both technical as well as human factors issues and relate to control room functions. The respondent should preferably have participated in the project from start to end.

The actual interview followed a predetermined interview scheme but the questions were adapted depending on the topics discussed and complemented by other questions for deepening the understating of some specific aspects. The scope of the interview was first to

get a background of the respondent and then a brief overview picture of the actual design project chosen. This was then followed by a deeper design process story discussion from the respondent's perspective, where obstacles or problems hindering the execution of the design projects should be highlighted.

The respondents from the nuclear plant organisations were interviewed at their work place, and the respondents from design organisations were interviewed in phone meetings. All interviews were transcribed and analysed. The results were also discussed between the researchers in the large Finish/Swedish project and analysed from safety culture and resilience engineering perspectives.

2.1 Organizational challenges

Five organizational challenges found as a result of phase 1 and 2 in the NKS project (Macchi et al., 2013) regarding goal conflicts of collaboration and communication in nuclear design projects were also addressed in the interviews. These challenges were:

1. Safety is not always the first and most important guiding value in the design process;
2. Understanding the context where the designed end-product will be utilized may be difficult for the designers and this may lead to dysfunctional designs;
3. Organisations do not always share the same safety philosophies and understand safety requirements in the same way;
4. Coordinating activities may be difficult between organizations that work according to different logics and understandings;
5. Distributing responsibilities and balancing roles between different stakeholders.

3. Results

In the interviews one larger design project was discussed involving many stakeholders with duration of more than five years. Two respondents had been involved in this project. The other three respondents discussed one design project each with duration of 1-2 years.

From the design stories a number of problems were highlighted regarding organizational challenges, hindering the execution of the project, due to involvement of different stakeholders. The problems were categorized in the following groups: cultural differences, design focus, time & budget constraints, documentation, and human factors knowledge.

Dealing with cross-national *cultural differences* exists in larger projects where many different stakeholders are involved, such as in-house engineers, consultancy companies, suppliers and subcontractors. Language barriers may occur, which can increase uncertainty to some degree. Also introduction of new companies increases uncertainty in the process.

Stakeholders often have different *design focus*, either technology driven or human factors driven design. The classification of a design problem as either a pure technical or a human factors problem was sometimes not optimal. Human factors aspects were now and then neglected or played down.

Problems also encountered were *time & budget constraints*. The time needed to implement an iterative design process was not always enough. Iterations of design proposals were hardly ever made and operators as test subjects seldom included. The planning phase of a design work was often performed under time pressure and human factors aspects were seldom highlighted at that stage due to lack of involvement of human factors specialists in the planning.

All needed written *documentation* to fulfil the requirements from power companies and authorities were also experienced as a time consuming challenge affecting the project

outcome. Some stakeholders were not always used to do such thorough paper work that is needed in the nuclear domain.

The knowledge of the importance of taking the *human factors aspects* into consideration in the designs varied between different stakeholders. Human factors knowledge was reported to come in too late in the design process, and sometimes also too late to make a difference in the design proposals.

3.1 Results organizational challenges

A further analysis of the results showed that the organizational challenges regarding goal conflicts of collaboration and communication (Macchi et al., 2013) exist to some extent in all the design projects discussed.

1. *Safety*: All stakeholders are aware of the importance of safety when working in the nuclear domain, but suppliers/sub-suppliers have different opinions concerning safety requirements than in-house engineers and human factors consultants.

2. *Understanding the context*: To which extent the involved stakeholders have an understanding of the demands from the context such as layouts and requirements in the nuclear industry on the end-product seems to vary. To understand and make sense of the effects when introducing a new design in an existing system was pointed out as a problem. The possible side effects of new systems may often be hard to predict in advance.

3. *Safety requirements*: Following guidelines were regarded as a problem, and human factors considerations were sometimes not included from the start of a project. The administrative burden, i.e. the need to provide all documents needed, may also slow down the design process for people not working inside the nuclear industry. The interaction with regulators was relatively successful since established routines exist. Overconfidence in established rules may create problems.

4. *Coordinating activities*: Coordination of activities involves a challenge to get an overall picture of the design process and to understand connections between different parts of the project. To correctly monitor the progress was harder in large projects where different tasks are coupled. There is a risk that different stakeholders are doing their job without any knowledge of the progress of other stakeholders. The coordination of activities could be more or less lost, which may lead to tensions between involved stakeholders.

5. *Distributing responsibilities and balancing roles*: Balancing different roles and clearly define responsibilities between involved stakeholders is especially problematic in a large project. It could sometimes be hard to know who is responsible for a project and who has the authority to decide the progress of the work. A challenge is when defining the responsibilities between the operating organization and their demands on a product and the sellers' expectations. Also the distribution of responsibilities and focus of the regulators and the design organization respectively could sometimes cause problems.

4. Discussion and Conclusion

The aim of this study was to discuss organizational challenges in terms of problems and hinders in design projects focusing on control room functions in the nuclear power domain in Sweden. The organizational challenges identified in this study were in line with previous results reported for modification activities in the nuclear industry (Macchi et al., 2013) and are probably generic for most design projects in complex socio-technical systems.

The interview results provided strong support for the importance of coordination and collaboration, especially in large complex projects with several stakeholders including suppliers and sub-suppliers, in-house experts and human factors consultants. In the case studies it was possible to identify how different perspectives on design had an impact on

the process. A pure technical perspective may ignore the human factors aspects and lead to unwanted consequences. A pure human factors perspective may also have a negative impact on the design results. When modifications in complex systems are made, a systemic perspective may be used. Engineering experts as well as human factors experts are both needed to optimize the process, from beginning to end, including the planning phase.

The results also showed that in design processes with special focus on control room design, the stakeholders might have different opinions regarding technical and human factors aspects as well as safety issues. It is crucial to create a common understanding of safety conditions and operational requirements for all stakeholders involved in the decision making. A recommendation is that all people involved in control room designs should have basic knowledge in human factors and human (operator) machine interaction issues.

A design process involves both rational and creative approaches to a real-life problem. To develop a safe and functional design in the nuclear power domain, designers need to balance between innovation and fulfilling specific requirements for the domain and from the authorities. Thus, to better manage safety culture in design activities, the nuclear power companies, engineering companies and design supply chains need to develop a shared understanding on these perspectives.

4.1 Concluding recommendations

To summarize the following recommendations, are thought for improving the design process in re-design projects with multiple interdisciplinary stakeholders with conflicting goals, under time and financial pressures where safety is crucial. The recommendations are based on the interviews made in this study and also supported by the results found in the NKS project (Macchi et al., 2013; 2014).

- Develop a safety culture, keep a systemic perspective, increase the transparency and reduce the complexity in the design process
- Create a common understanding of safety conditions and operational requirements for all stakeholders in the design process
- All people involved in the design process and in the decision making should have at least basic knowledge in human factors and safety issues.
- Use a multidisciplinary team to manage the design process and establish good practices to clearly define roles and responsibilities
- Monitor the development and status of the design process continuously for all stakeholders and improve communication and coordination of activities
- Emphasize the human factors role in the design process and involve human factors expertise in stages, including negotiation and planning
- Allocate time for design iterations and involve operators in the evaluations

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