

System modeling with the DISC framework: evidence from safety-critical domains

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Abstract. The objective of this paper is to illustrate the development and application of the Design for Integrated Safety Culture (DISC) framework for system modeling by evaluating organizational potential for safety in nuclear and healthcare domains. The DISC framework includes criteria for good safety culture and a description of functions that the organization needs to implement in order to orient the organization toward the criteria. Three case studies will be used to illustrate the utilization of the DISC framework in practice.

Keywords: Safety culture, modeling, system safety, evaluation

1. Introduction

The ability of an organization to monitor its current state, anticipate possible deviations, react to expected or unexpected disturbances, and learn from weak signals and past incidents is critical for success [1, 10]. Safety culture is a concept that can be used to denote the organizational capability to manage internal and external variability.

There is need for system modeling (and a model of the system) when developing and evaluating safety (culture) in complex systems. This is due to the fact that evaluation and development of complex socio-technical systems is always driven by a theory of how the organization functions and what are its key constituent elements and their interaction. In order to be able to develop and validate organizational safety culture evaluations, this model needs to be made explicit. It includes assumptions about the nature of reality and ways of gaining knowledge of that reality (ontology and epistemology). These ontological and epistemological premises form the basis of methodological choices, including what methods to use, how to use them, and how to infer results from data and judge their validity. The objective of this paper is to illustrate the development and application of the Design for Integrated Safety Culture (DISC) framework

for system modeling by evaluating organizational potential for safety in nuclear and healthcare domains.

The DISC framework has been developed at VTT Technical Research Centre of Finland [3, 7]. The framework is meant to be used as a tool for aiding development of safety culture, including evaluation of the current level of safety culture. The paper will describe the premises of the framework and present results from its application in nuclear and health care case studies.

2. Basic Premises of Organizational Evaluation

2.1. The DISC framework

The DISC framework is based on a systems view on organizations. According to this view, organizations are (complex adaptive) systems and as such certain basic requirements can be set for being able to control them [based on 4, 6]:

1. The organization has a clearly define objective
2. There is a willingness among the personnel and management to keep the organization in line with its objective
3. The personnel and management is able to observe the current status and condition of the

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- system (including its alignment with the objective) and act on it
4. There is a model of the system that describes the internal dynamics of its functioning and it is updated as the system changes
 5. Management is able and willing to use the model of the system to proactively anticipate how the organization changes in time and how the organization responds to certain actions and control measures at the same time as they acknowledge the inherent limitations of all models
 6. The organization can be influenced and steered toward the objective or maintained in its current direction by carrying out certain activities and executing certain control measures

Following these principles, the management of organizational safety logically requires that a) safety is part of the objective of the organization and that b) people are willing and able to spend effort in operating the system in a safe manner. 1) Safety thus has to be a genuine value in the organization and an integral part of the core task (see section 2.3). 2) Willingness stems from safety motivation and perceived responsibility for safety. 3) Understanding the requirements of the core task of the organization and the inherent hazards of the given sociotechnical system are needed in order to be able to act in the system and observe the status of the system. 4) Understanding of what is safety and how safety is created is a necessary precondition for understanding system dynamics in a safety-critical organization. 5) Mindfulness is needed to anticipate the consequences of actions and potential risks. Finally, 6) the work has to be controllable in order to preserve the manageability of the system. In terms of evaluating the organizational capability for safety, the previous list of requirements can be used as criteria for good safety potential. Thus, safety culture is described in the DISC framework as the organizational potential for safety.

In the DISC framework, precondition for fulfilling the six criteria is that the organization appropriately performs certain key control functions. The functions depict the activities and measures that an organization with good safety culture, i.e. with good potential for safety, needs to carry out.



Fig. 1. The DISC framework consists of ten control functions (outer layer) and six criteria (inner layer).

The 10 key control functions are described as follows:

Work conditions management: structuring the work in terms of the constraints and requirements it puts on the workers: management of the physical conditions (e.g. workspace, lighting), the structural means necessary for carrying out the work (e.g. tools, instructions) as well as human resources.

Work process management: how cooperation and communication as well as information flow are managed in the organization.

Safety management and leadership: how safety considerations are included in management decision making. This function involves gathering feedback and information, making expectations clear, communicating on safety issues and ensuring that management is up to date on the way work is conducted in the field.

Supervisory support for safety: supervisors organizing the work in the immediate work environment in such a manner that it can be safely accomplished, providing positive feedback on the safety-conscious behavior of the personnel, treating subordinates fairly, and monitoring the subordinates' coping skills, stress, fatigue levels and skills.

Proactive safety development: utilizing both experience and leading safety indicators, as well as continuous development of practices, and constant vigilance for weak signals. This function deals with how learning takes place and it supports the ability of the organization to recognize the boundaries of safe performance.

Hazard control: how known hazards are prevented from causing harm. This function deals with the provision and implementation of barriers (e.g. quality assurance, back-up systems, checklists and physical barriers) to prevent unwanted human and technical variance.

Competence management: how the competence needs are identified and how the skills and knowledge of the personnel are developed and maintained. This function also includes the training and socialization of newcomers and transfer of knowledge from the experienced personnel to newcomers.

Change management: handling of changes in organizational structures, practices and technology; planning, implementation, as well as follow up on changes already implemented. Change management should also take into account incremental changes in the organization.

Management of third parties: how contractors and leased employees are selected and trained in safety-related issues, and how their know-how in the field of interest is ensured. This function also concerns the practices to facilitate organizational learning from contractors as well as contractors' own learning.

2.2. System modeling

The model of the sociotechnical system that we have utilized in our studies has been previously described in [5] and subsequently revised based on further empirical and theoretical work. Fig 2 illustrates the key elements of an organization, and the notion of safety is integrated in all these elements:

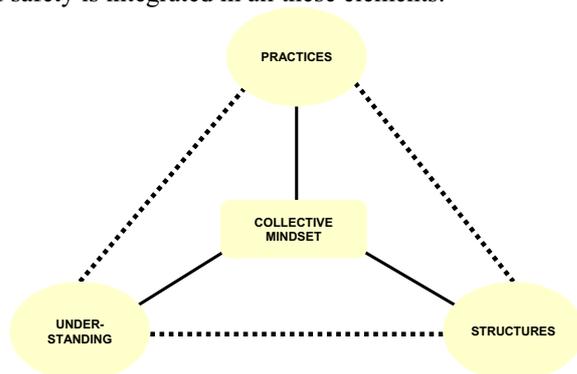


Fig. 2. Elements of an organization.

According to Fig. 2, four interrelated elements of an organization can be separated; structures, practices, collective mindset, and understanding. 'Understanding' (or 'conceptions') refers to the personnel's knowledge, skills and abilities that are connected to

the work and its hazards. It refers to the more or less shared ways of thinking about safety and risks in the organization. This element looks at the organization from the point of view of information and competence, whether it is individuals, teams or some specific department that have it. Thus, despite being an element of the organization not all of its contents need to be shared by all. It is a matter of practices and structures how the individual competence is utilized. 'Structures' are related to the artefacts of the organization including tools, information systems, management system, formal roles and accountabilities and physical work spaces. 'Practices' include more or less enduring patterns of action at the organization.

'Collective mindset' (or the social texture of the organization) refers to norms, values, climate, social identity and other such emergent organizational phenomena.

The elements are closely interlinked and their contents influence each other. Thus, they can be considered as complementary perspectives to an organization.

The model depicted in Fig 2 is descriptive and thus it does not take a stance on what is good or bad for safety. Thus, the model needs to be complemented with a safety management framework depicting what activities, systems and structures the organization needs in order to achieve good potential for safety.

2.3. Contextual evaluation

Another important issue to consider is the context where the organization operates, the type of work that it carries out and the technology that it utilizes. These are presented by the concept of organizational core task (OCT). OCT denotes the shared objective or purpose of organizational activity (e.g. in the nuclear domain guaranteeing safe and efficient production of electricity by light boiling water nuclear reactor). The physical object of the work activity (e.g. particular power plant, manufacturing plant, offshore platform), the objective of the work, and the society and environment (e.g. deregulated electricity market, harsh winter weather) set constraints and requirements for the fulfilment of the organizational core task. Different industrial domains have different outside influences, e.g. the laws set different constraints on the organization and the economic pressures vary.

The contents of the work, the nature of the hazards involved in their daily activities, the basic education of the personnel and the role for the overall safety in the company differs. The core task of the organiza-

tion sets demands (constraints and requirements) for the activity and should be kept in mind when making evaluations of the organizational solutions or performance. The organizational core task has three main dimensions [5]:

- objective of work
- characteristics of the object of work
- external influences

Further, the inherent hazards of the work are defined by the organizational core task. These in turn are interpreted within the organization where the appropriate means to overcome the hazards are defined and carried out (cf. Fig 2 and the elements of an organization).

In practice, when evaluating an organization, each function depicted in the DISC model should be inspected in light of its contribution to the six criteria by looking at a) how the function manifests in organizational structures and processes, b) how the function is carried out in practice, c) what kind of understanding and conceptions are connected to the function and d) how the function is interpreted in the social community. These four viewpoints correspond to the four elements depicted in Fig 2.

From the various sources of evidence we can make conclusions about each element (e.g. clarity, sharedness, strength, consistency) and also about the relation between the elements (congruence). Also the direction where the organization is heading is evaluated based on the finding concerning the elements, their content and interrelations. The six criteria are then used for evaluation whether the direction is in line with the requirements for a good safety culture.

For example, it is interesting to note if understanding, structures and practices are aligned with each other, and if not, in what direction they are shaping each other. In a best case scenario there are clear structures built on good understanding of safety and this understanding is prevalent also among the personnel; practices are still based on older and deficient understanding but there are indications that the practices are slowly developing. A worse situation would be incongruence where the official structures are not clear enough, the understanding is not shared enough and the mindset does not support acting according to official systems. In that case an improvement in one or even two elements is unlikely to contribute to overall system improvement.

As Fig 3 illustrates the DISC framework is utilized in guiding the data analysis. Data about organizational practices, structures, collective mindset and understanding is collected with various methods. An

evaluation of the fulfilment of the criteria depicted in the DISC framework is made by assessing how the ten functions manifest in the given organization.

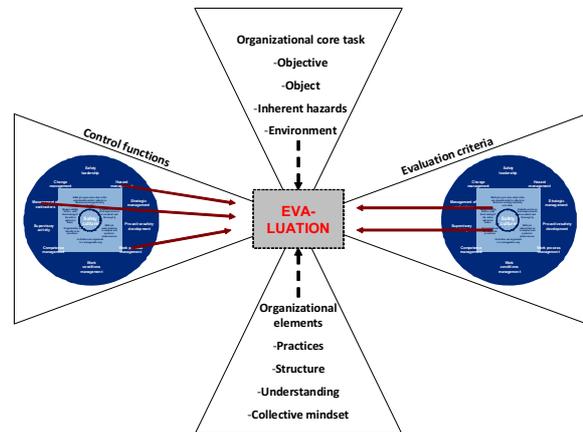


Fig. 3. The DISC framework provided the control functions and the evaluation criteria to the evaluation process

As Fig 3 implies, the DISC framework is utilized in defining key areas of interest that guide the data analysis. An evaluation of the fulfilment of the criteria depicted in the DISC framework is made by collecting data about the organization and its core task. We have outlined four elements of an organization from which data can be collected.

3. Case Studies

Three case studies will be used to illustrate the utilization of the DISC framework. The aim of presenting three different applications of DISC is to show how the framework can be used in modelling systems with a different organizational core task and different manifestation of the ten required control functions. In this section the case studies, their original goals and methods of data collection will be briefly presented.

3.1. Case A: Nordic nuclear power plant unit

The objective of the first case study was to conduct an organizational safety evaluation of a nuclear power plant unit A. The unit belonged to a Nordic nuclear power plant with several reactors. Data collection took place during spring 2010. Data was collected with twelve semi-structured interviews, document analysis and the TUKU safety culture survey [8]. Also a feedback seminar was arranged. The data

collection and main results have previously been presented in more detail in Oedewald et al. [3].

3.2. Case B: Central hospital

The second case study consisted of the evaluation of the organizational prerequisites for patient safety at a Finnish central hospital B. Data collection took place between January 2011 and April 2011.

TUKU safety culture survey (n=553), feedback seminars, reports of patient safety incidents and summary reports on patient safety and quality at the hospital units were utilized as methods. We also had at our disposal data from a previous TUKU measurement carried out at the same hospital in 2008. Further sources of data were ten personnel interviews carried out during the first TUKU measurement.

3.3. Case C: Human performance development department at a Nordic nuclear power plant

The third case study consisted of a longitudinal development project in a department C working with human factors and competence issues in a Nordic nuclear power plant. The project lasted for three years between 2008-2010. The department had been established one year prior to the study. Its goal had been defined as contributing to development of human and organizational aspects including safety culture and competence issues at the power plant.

Two researchers participated in several internal meetings of the department C, interviewed all of its employees either face to face or via email, interviewed several key people from other departments who regularly deal with department C, arranged two seminars and analyzed other material such as internal documents and bi-annual safety culture survey.

The overall goal of the case study C was to clarify how to choose and justify human performance and safety culture related development initiatives and evaluate their impact on safety culture and plant performance. We were interested in how the department C was organized, what kind of competence and knowledge they had in terms of nuclear safety, how other departments perceived C, and how the department were able to contribute to nuclear safety.

3.4. Note on the methods of data gathering

In all the case studies interviews have been utilized at least to a certain degree. The interviews were semi-structured and focused on the interviewees

work, his/her perceptions of the core task of the organization, its hazards and the contribution that the work (s)he is doing has on the core task. We are also interested in how the interviewees see the concept of safety culture and its manifestation in their own organization.

TUKU survey has been developed in studies in healthcare [8] and nuclear domains [3, 5], and currently two versions exist for these specific domains. The underlying measured dimensions are the same, only the framing of individual questions differs. The measurement model corresponds closely with the functions described in Fig. 2. In addition, the survey has individual level measures of people's safety motivation, sense of responsibility, mindfulness, sense of control and safety worry. Finally, the survey has an open question: "What are the most significant development areas in your organization? All this gives evidence on how the employees experience their work, its official structures and practices. The survey is limited in providing information about the understanding element (see Fig. 2) however.

4. Results from the case studies

In this paper we will focus on cases B and C, since case A has already been described in detail in Oedewald et al. [3]. However, results from all the cases will briefly be tackled below.

4.1. Case A: NPP unit

There were plenty of safety development activities ongoing at the NPP unit at the time of the evaluation. These activities were strongly supported by management and seen as important for safety. The evaluation showed, however, that the activities contributed mainly to creating a mindset supporting safety-consciousness in general, rather than to improve understanding of safety and to create the organisational preconditions (structures and processes) for safety. Many initiatives were based on a rather linear view on safety and focused heavily on human performance on an individual level. Further, human performance issues were not integrated with organisational and technological issues. There were so many development projects and activities ongoing that the normal everyday work was in danger of being overlooked. Their proactive safety development function manifested as a safety mindset and several development practices but was not supported by ade-

quate understanding or organizational structures. The development practices were also not perfectly in line with the everyday practices of operating the power plant.

The evaluation concluded that in order to improve their safety potential, the organisation needs to refocus its development activities to be more in line with each other and more strongly oriented towards improving understanding and making everyday work more manageable. The DISC criteria helped in pointing out the focus of the current development activities and in clarifying how they were not creating an adequate systemic understanding of nuclear safety.

4.2. Case B: Central hospital

Similar to the case A, the central hospital B had had several development activities ongoing for the past couple of years. This manifestation of the proactive safety development function incorporated creating a mindset supporting safety, developing safe practices, improving understanding of patient safety as well as constructing structures (e.g. incident reporting system, checklists) that facilitate safety.

The biggest challenges of the organisation were associated with competence management and change management. At the same time the current competence of the personnel was considered good. This result was taken as an indication of possibly worsening situation in future if changes will not be managed adequately and training and recruitment activities will not be sufficient.

The Table 1 shows examples of the various sources of evidence regarding the four elements that was gathered in this case study. As can be seen from the table, the study utilized qualitatively very different types of data sources. The table also indicates that as in all research, for some elements we were able to gather more evidence (in this case, structures, understanding mindset) than for the others (in this case, practices was the least covered element). These limitations in data need to be taken into account when making conclusions about the safety potential of the organization.

4.3. Case C: Department in a NPP

The importance of the C department and its task seemed to be widely acknowledged at organization. The department had worked in several areas of human and organizational performance in parallel. This has been good in a sense of gaining momentum and

recognition in the organization. The department contributed to some degree to almost all ten control functions identified in DISC. A major challenge was the fact that C was not able to gain as much recourse as planned in the first place. Because of this the intensity of the activities had suffered and workers were sometimes overburdened.

At the same time, the department struggled with balancing non-independent support role with an independent standard setting role. When it was noted at the plant that department C is able to help the line organization, the suggested targets for development and activities were plentiful. While this confirmed the need for the work that C was carrying out, it also made that work fragmented and reactive.

The department also suffered from a lack of definition to some basic concepts. This led to separation of 'competence' issues from 'safety culture' issues despite clear parallels between both. Thus, their work was systematic but fragmented at the same time, pulling the department and the rest of the organization in multiple directions.

Another obstacle for having an influence on the plant level is the fact that there are signals of C getting excluded from organizational activities that affect the trade-off between production and safety goals, intentionally or unintentionally. There is a risk that the C department has to compensate for budget cuts and non-optimal decisions made elsewhere by focusing on improving human performance when more appropriate response from safety point of view would be a technological change, increase in resources or redesign of work processes [cf. 9].

At the time of the evaluation, many of the activities carried out by C were beginning to root in the normal practices of organization. Certain working practices have changed, new concepts have been adopted, vast number of employees has been trained and material has been produced on human performance issues, and so on. Thus, the line organization knows C, and they know to ask for help with certain human factors related issues. A future challenge for the department is to develop its own practices, structures and understanding in parallel in order to deliver a consistent message to the power plant. Currently, a shared mindset of development orientation and development practices were more advanced than their conception of safety or their structures that would support and guide the activities.

Table 1
Examples of types of evidence gathered in the central hospital case study

ELEMENT / DATA SOURCE	Evidence from formal descriptions / statements	Evidence from the TUKU survey	Evidence from internal analyses	Ev. from observation of work and social conduct	Evidence from the artefacts	Overall conclusions
Structures and processes	Patient safety policy and plan have been written. Collection and analysis of incident data a major part of patient safety development. 'Quality and patient safety' reports done by all units annually. A quality manager with patient safety as one responsibility area had been appointed as well as a safety manager for all the other areas of safety and security.	Hospital facilities were perceived as adequate and supporting communication. Systematic patient safety management was experienced as significantly improved during the past three years. Work conditions were experienced as good. Personnel were critical toward competence management activities as well as change management. Especially recruiting and retaining competent personnel was experienced as being a challenge.	Safety reports had criticism towards working conditions.	N.A.	Old hospital buildings. Web-based confidential voluntary incident reporting system Haipro.	Responsibilities for safety development were clear. The organization was consistently driving its safety work toward systemic direction. Work conditions were perceived inconsistently. Doctors had more positive view on them than nurses.
Practices	There are no strict procedures for guiding practices. For certain tasks checklists have been created.	Communication and cooperation between units was experienced as requiring improvement. Units that experienced their supervisory activity positively also reported more near misses into the Haipro system.		NO DATA	-	
Understanding	Patient safety policy and plan include comprehensive safety related measures covering all the functions described in the DISC framework.	Patient safety worry had increased during the last three years when lot of development initiatives have been carried out	Competence of the personnel was experienced as high. Safety understanding was not considered as requiring special knowledge from "normal" expertise. Normal expertise was considered as requiring multidisciplinary cooperation and communication.	NO DATA	Categories in the reporting system were based on Reason's theory of organizational accidents.	Shared understanding of the need for reporting and learning from events. Understanding of patient safety has been widening due to development work and increased utilization of the Haipro reporting system.
Mindset, norms and climate	N.A.	Safety motivation was good and people were committed to their work. Especially nurses experienced high workload and stress. On the average stress had decreased during the past three years. Many experienced worry about the level of patient safety at the hospital		Open and communicative climate in seminars. Personnel and management expressed an interest in the results and in developing patient safety. A general feeling that not enough doctors were committed prevailed at the seminars.	N.A.	

5. Summarizing the evaluation results

After providing a rich description of the empirical findings the evaluation results can be summarized according to the six criteria. Table 2 presents an example of a summary table. Only in case A was an explicit summary provided to the case organization. In the hospital case B, the evaluation focused on both

the necessary control functions and the criteria. The case C had a focus on how the department contributes to the functions and the overall criteria on a plant level. However, the summary table would look rather different for each case. For example, systemic safety understanding would receive a higher score in the hospital case compared to the two other cases. On the other hand, in all cases safety was valued rather good

– patient safety in case B and nuclear safety in cases A and C. Similarly, understanding of the core task and its inherent hazards was rather good in all the cases. Mindfulness of the practices would have received a highest score in department C. Further, all the organizations had problems in the manageability of their activities.

Table 2

An example of how the evaluation results can be summarized.

Fulfillment of the criterion	Excellent	Very good	Rather good	Rather poor	Unacceptable
1. Safety is genuinely valued	X				
2. Responsibility is taken		X			
3. Safety is understood as systemic				X	
4. Core task and its hazards are understood		X			
5. Mindfulness of practices			X		
6. Manageability of the activities				X	

There is an inherent hierarchy in the criteria that make it impossible for an organization to score high on the last criteria (manageability of the organization) if the previous objectives have not been met. Also, the first criteria, safety as a genuine value, does not yet take a stance on how safety is defined and is the organization truly able to achieve the value. In the imaginary example in Table 2 the organization scores low on safety understanding and thus when combined with, e.g., a high workload and stress, the long term steering of the organization (its manageability) is not good from the perspective of developing and maintaining a good safety potential.

6. Conclusions

The purpose of the current paper was to provide evidence on how modelling organizational safety potential can be performed with the DISC framework.

Two other concepts were introduced that should be incorporated with the DISC framework: ‘model of an organization’ and ‘organizational core task’. The model of an organization provided the elements

where the control functions should manifest. The concept of organizational core task in turn reminded that safety is dependent on the inherent hazards of the system and on what the system is trying to achieve.

The evidence from the three case studies illustrated the importance of orchestrating the key control functions and understanding their relations with the six criteria for managing the safety potential of the organization. For this, a modelling of organizational elements is needed together with an account of the organizational core task.

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