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Safety culture and subcontractor network governance in a complex safety critical project

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ABSTRACT

In safety critical industries many activities are currently carried out by subcontractor networks. Nevertheless, there are few studies where the core dimensions of resilience would have been studied in safety critical network activities. This paper claims that engineering resilience into a system is largely about steering the development of culture of the system towards better ability to anticipate, monitor, respond and learn. Thus, safety culture literature has relevance in resilience engineering field. This paper analyzes practical and theoretical challenges in applying the concept of safety culture in a complex, dynamic network of subcontractors involved in the construction of a new nuclear power plant in Finland, Olkiluoto 3. The concept of safety culture is in focus since it is widely used in nuclear industry and bridges the scientific and practical interests. This paper approaches subcontractor networks as complex systems. However, the management model of the Olkiluoto 3 project is to a large degree a traditional top-down hierarchy, which creates a mismatch between the management approach and the characteristics of the system to be managed. New insights were drawn from network governance studies.

1. Introduction

In safety critical industries, such as nuclear power, oil and aviation industry, the operating companies are expected to establish a systematic way of managing safety of their activities. However, many activities in those domains are not carried out by the operating company itself but by a *network* of actors consisting of e.g. subcontractor companies and their workers. Camarinha-Matos et al. [8] describe collaborative networks as consisting of a variety of entities (organizations and people) that are largely autonomous, geographically distributed, and heterogeneous in terms of their operating environment, culture, social capital and goals, but that collaborate to better achieve common or compatible goals, thus jointly generating value. In general, large projects involve great complexity and uncertainty, multiple stakeholders and ambiguity [5,19].

In nuclear power industry subcontractor networks are used, for example in maintenance activities, modernizations projects and in design and construction of new nuclear plants. The activities carried out by subcontractor companies may involve both occupational risks to the personnel and overall system safety effects. The challenges of preventing occupational injuries of subcontractor workers may be different from those of managing the activities in a subcontractor network in such a way the overall system safety is created and maintained. While the role of contractors have been analyzed in major accident investigations, e.g. Challenger space shuttle explosion [78,63], Deepwater Horizon oil rig accident [4] and Fukushima Daiichi nuclear power plant accident [74], scientific research concerning subcontractors and safety is largely focused on occupational safety (see e.g. [40,36,81]) with few exceptions (e.g. [54,14,43]). A recent study discussed how problems related to quality assurance, coordination and communication in early phases of a large project cascaded and manifested in the construction phase of the project. The authors discussed the problematic fragmentation of tasks and responsibilities (e.g. outsourcing and multinational workers, who speak different languages) and indicated that the emerging accident risks were largely attributed to deficiencies and deviations from other organisational units: different units were blaming each other, top management and the builder [1]. Recent studies on the governance of Olkiluoto 3 nuclear power plant project indicated how the responsibility and risk were transferred to project actors, who were not capable of carrying them properly [64,65]. There is a need to better understand the links between management and coordination of the activities in a subcontractor network and the overall system safety.

Resilience Engineering approach emphasizes that system safety cannot be viewed as absence of unwanted outcomes but rather it should be viewed as an emergent property of the system which allows the system to succeed in varying conditions [31]. System safety can be enhanced by increasing resilience of the system i.e. “the intrinsic ability of a system to adjust its functioning prior to, during, or

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following changes and disturbances so that it can sustain required operations under both expected and unexpected conditions" [ibid, p. xxxvi]. Resilience is characterized by four abilities: the ability to anticipate developments, the ability to monitor the environment and the system, the ability to respond to disruptions, and the ability to learn from experience [32]. However, achieving these abilities, or engineering them into a system which is a dynamic network of heterogeneous subcontractors is a challenge.

We argue that engineering resilience into the complex socio-technical system is largely about steering the development of the culture (i.e. the structures and practices, values, attitudes, knowledge and understanding in the organization) in order to facilitate the organization's ability to anticipate, respond, monitor and learn. This is a practical challenge for example in nuclear new build projects which are vast and complex undertakings in terms of number of companies, disciplines and nationalities involved [44,21,35]. What should safety management system or safety culture improvement program be like in an "organization", which is actually a dynamic network of actors from different companies?

The objective of this paper is to describe and analyze practical and theoretical challenges in applying the concept of safety culture in a complex, dynamic network of subcontractors involved in the construction of a new nuclear power plant in Finland, Olkiluoto 3. As such, the study contributes to advancing the development of systemic safety management and safety culture approaches, which can be utilized in contexts, where activities are largely dependent on external organizations and not solely on the operating company. Furthermore, we discuss the effects of the network management approach on safety culture development in practice. Although many empirical studies on resilience focus on so called "upward resilience" [83] and analyze how resilience is created by the local adjustments in the sharp-end activities, the "downward resilience" is important because the context and structure of the system either foster resilience or induce pressure towards resilient operations [76]. Network management can be viewed as downward resilience giving macro level directions and solutions to handle trade-offs. The scientific novelty of this paper lies in the integration of safety culture literature, network governance ideas and complex systems thinking which may open new avenues for more practical applications of resilience engineering.

2. Theoretical perspectives

During the past two decades safety science has increasingly utilized complex systems theory ideas to explain why activities evolve out of control and disasters happen. Safety critical organizations have been viewed as complex socio-technical systems [55–58,79] and the activities are often characterized as involving uncertainties, multiple conflicting goals, non-linear action-outcome effects and dynamic self-adaptation which makes them challenging to control. At the same time, organizational and social psychology constructs gained prominence as concepts to explain suboptimal organizational decision making or work performance in complex systems. Social mechanisms such as normalization of deviance [78] or local optimization of working practices [69] may cause unanticipated safety effects in certain circumstances. A central message of the complex system approaches for safety work has been that safety cannot be created by decomposing the system into components which will then be improved one by one. Instead, we should strive for approaches which allow us to understand the dynamics of the system behavior and develop system capabilities for coping with varying conditions [15,32,42,39]. Resilience Engineering provides an anchor point for scholars reaching at this aim.

Camarinha-Matos et al. [7] emphasize that networks cannot be managed like a single organization because partners are independent with own internal aims and processes. The concept of *polycentric control* or *governance* is used in the Resilience Engineering literature to denominate the need of navigating interdependencies in networked systems. Polycentric control refers to multiple formally independent decision-making unit existence in a network, which simultaneously operate at differing levels of the system [47,84]. Each unit has sufficient autonomy and power to make decisions and take action within its specific domain of competence, and partially responsible for achieving a shared goal [2,6,48,49].

Although network studies have shown that large networks of organizations cannot be centrally controlled the safety management literature has few applications that take this into account. Many of the practical concepts and models used for improving system safety embed an implicit assumption that the activity is carried out by one organization, or rather, that the organization which is carrying out the activity corresponds to one company. This is reflected for example in *safety management system* literature, where management system is usually seen as a company specific system, although there have been some discussions since 1990s on safety management *in* systems [27]. Safety management systems became popular in 1980s, when accident investigations in various domains pointed towards management inability to control the risks of the operations as a major contributor to accidents. Consequently, safety authorities changed the focus of regulatory oversight from technical risks to management and thus begun to require documented or even certified safety management systems from the operator companies [28]. In safety management studies, the analysis can focus on "activity or company" [28] or different levels of the system: group level, facility level or at corporate level [80] but studies on multi-company safety management systems are scarce.

The same company focus is relevant also for the concept of *safety culture*. The concept has its origins in organizational culture concept in 1980s, which aimed at explaining the success of companies [81,67,51]. The frequently appearing notions in safety culture literature, for example, "top management commitment", "open communication", "organizational learning" and "levels of organization" (e.g. [13,26,70]) imply that safety culture models have been developed to grasp a culture of a coherent unit. Conceptual studies on safety culture seldom discuss explicitly the unit of analysis issues, although Guldenmund [26] touched the topic in his famous paper of the concept of safety culture by saying that "the issue of the level of aggregation has not received the attention it warrants" (see also [12]). Silbey [68] points out that "One is hard pressed to find a reference to power, group interests, conflict, or inequality in the literature promoting safety culture. This may be the most striking feature of this field." Also Antonsen [2,3] highlighted that safety culture studies seem to embody a harmonious view of the organization to be analyzed.

Although the concept of safety culture is subject to many scientific controversies (e.g. [16,61,68]) it has become more visible in the nuclear industry requirements and practices during the past couple of years. Safety culture is usually used in a normative sense, i.e. some aspects of culture are viewed as beneficial and some as detrimental for safety (e.g. [33,34,45]). It seems fair to say that research has identified certain generic characteristics of culture that most likely are contributing to safety in a positive way and which are worth aiming at. However, the discussion on the characteristics of good safety culture has also lead to superficial assessment and development tools, which has resulted in discussions whether the concept has any value. Reiman and Rollenhagen [61] indicated that the concept has a value of a *boundary object*, bridging scientists' and practitioners' conceptualizations. We argue that one practical benefit of the concept is that it bridges the modern safety conceptualizations and practical needs to assess safety. Hollnagel [30] sees *safety* as an "epiphenomenon" which means that *safety* is an incidental product of some process that has no effects of its own. If we adopt that view on nature of safety then it is impossible to conclude too much about e.g. safety of an organization. Therefore safety culture is a usable construct: safety culture of an organization can be understood as organization's *potential* for safety [59,45,60]. Thus, even if