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Principles of adaptive management in complex safety–critical organizations

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ABSTRACT

This paper contributes to safety management by bringing in ideas from organizational complexity theories. Much of the studies and the literature on organizations as complex adaptive systems have focused on how to produce new innovations or how to increase financial effectiveness. We take the view that safety–critical organizations can be perceived as complex adaptive systems, and we discuss what this means for the management of safety. Our aim is to elaborate on the issue of what kinds of principles the management of safety should be based on in complex adaptive systems. In brief, we suggest that safety management should be *adaptive*, building on several different principles. Based on literature on complex adaptive systems we first identify the general features of complex adaptive systems, such as self-organizing and non-linearity, which need to be considered in management. Based on the features of complex adaptive systems, we define eight key principles of adaptive safety management and illustrate usefulness of the principles in making sense of the practice of safety management.

1. Introduction

The way safety is managed in an organization depends heavily on the beliefs and assumptions the management and personnel have concerning organizational behaviour and safety. Both researchers and practitioners within the safety field have tended to focus on an absence of negative events as being a proof of safety. Variance in human activity has been seen as a major causal factor in accidents and incidents. Safety management has thus focused on identifying the possible ways things can go wrong, and then seeking to prevent such possible deviations by implementing barriers, emphasizing procedural adherence, creating redundant systems, supervising work and making clear the distribution of responsibilities. The numbers of accidents and other negative events, such as breakdowns, adverse events and process leaks, have been used as indicators of safety. This classical safety management paradigm views organizations as machine-like entities. However, disappointments in the results achieved by the classical safety management paradigm together with the evolution in several scientific disciplines have led to an emerging view of safety as something more than the negation of risk. This new paradigm for safety management is supported by an increased application of complexity theories in safety science (e.g. Dekker et al., 2011; Goh et al., 2010; Dekker, 2011a).

We view safety as a dynamic and emerging property of the organization, including both the social and technological aspects of it. Safety management is here defined as the practice of managing the production of safety in an organization. This paper contributes to the safety management literature by bringing in ideas from organizational complexity theories. We take the view that safety–critical organizations can be perceived as complex adaptive systems and we discuss what this means for the management of safety in such systems. Our aim is to elaborate on the issue of what kinds of principles the management of safety should be based on in complex adaptive systems. In brief, we suggest that safety management should be *adaptive*, building on several different principles and changing to fit the environment and situational factors of the organization (cf. Obolensky, 2010).

2. Research strategy and methods

This paper is mostly a theoretical study, building on the literature on complex adaptive systems and safety management. However, the origins of the present study are found in two lines of empirical research carried out in parallel by the authors. The first

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line of research has focused on safety management in the nuclear power industry (Reiman et al., 2011; Reiman and Rollenhagen 2012a, 2012b). The second line of research has been carried out in the health care domain (Pietikäinen et al., 2012). Our empirical research and our experiences in various safety consultancy projects in different safety critical fields led us to the realization that many managers and experts in safety–critical domains experienced contradicting demands, but lacked a theoretical framework to conceptualize what management principles they needed for trade-offs and balancing. We noticed that the contradictions perceived by the managers and experts had similarities to the Competing Values Framework (CVF, Cameron and Quinn, 2011; Quinn and Rohrbaugh, 1983). However, we felt that by analysing the conceptualizations of managers and experts we could only get as far as we did, that is point out the lack of frameworks and the fact that these contradictions had similarities to the CVF. But the findings could not be explained solely by that framework. Consequently, we needed to develop a more elaborated and complex framework for making sense of safety management in practice. The analysis of the case material also suggested that safety management (perhaps not surprisingly) was a very complex task, and that models of safety management should not simplify the task too much. We therefore decided to approach the challenge from the opposite viewpoint: given that safety management is about managing a complex adaptive system, and given what we know about the characteristics of such systems, what principles for safety management can we then extract from this knowledge? Here we had to turn to the literature concerning complex adaptive systems and safety management, and approach safety management from a more theoretical perspective. Nevertheless, we acknowledge that our reading of that literature has been guided by our previous empirical findings.

Based on our empirical findings and the literature, we developed a framework of adaptive safety management that we describe in this paper. The paper is structured as follows. We begin by introducing key concepts of complexity and the complex adaptive system. Then we consider the challenges of managing these systems first in general and second in safety–critical domains. In Section 4 we introduce our conceptualization of the principles for management of safety in complex adaptive systems and illustrate usefulness of the principles in making sense of safety management. Section 5 summarizes our main arguments and outlines some expected critique.

3. Complex adaptive organizations – a selected oversight of the literature

The literature of complexity is massive. In this paper, we mainly and selectively draw on the applications of complexity theories in organization and management research based on the assumption that they are most relevant for understanding the management of safety–critical organizations.

3.1. Complexity science and the properties of complex adaptive systems

'Complexity' can be defined as a feature of a system that arises as a result of the interactions of the individual components of the system (Dekker et al., 2011, p. 941; McDaniel and Driebe, 2001, p. 12). This means that the behaviour of the system cannot be reduced to an aggregate of the behaviour of its constituent components (Dekker et al., 2011, p. 941). 'Complexity' has to be differentiated from 'complicated' (Cilliers, 1998). Complicated systems, at least in principle, can be taken apart and put together again (e.g. a jet airliner). A complicated system is thus reducible to its constituent components, whereas a complex system is not.[1] 'Complexity science' is the study of complex systems. McKelvey identifies two schools of complexity science: the European and the American school (McKelvey, 2004, pp. 318–321). While the European school draws mostly on the natural (physical) sciences, the American school draws on life sciences, social sciences and chaos theory. However, complexity science should not be perceived as a single unified theory, nor as two complementary theories, but rather as a loose collection of theories and models of adaptive, complex systems. Complexity science perceives organizations as 'complex adaptive systems'.

A 'complex adaptive system' (CAS) is a collection of individual *agents* with freedom to act in ways that are not always predictable, and whose actions are interconnected so that one agent's actions change the context for other agents (Plsek and Greenhalgh, 2001). These agents interact in a non-linear way creating system-wide patterns (Eoyang and Holladay, 2013) and higher and higher levels of complexity (McMillan, 2008, p. 60). The agents differ from each other and none understands the system in its entirety. This diversity is a source of invention and improvisation. As the agents are interdependent on each other, relationships among agents can be considered to be the essence of a complex adaptive system. Understanding a complex adaptive system requires understanding of patterns of relationships among agents (McDaniel and Driebe, 2001, p. 15).

Based on literature on complex adaptive systems (Stacey, 1996; Cilliers, 1998, 2010; Holland, 2002; McDaniel and Driebe, 2001; Plsek and Greenhalgh, 2001; Kurtz and Snowden, 2003; Sterman, 2006; Plowman and Duchon, 2007; McMillan, 2008; Goldstein et al., 2010; Eoyang and Holladay, 2013), we have in Table 1 summarized the following general features of organizations as complex adaptive systems[2].

Self-organization and emergence represent two key concepts for understanding the dynamics of complex adaptive organizations. The phenomenon of self-organization entails that control in complex adaptive systems is always distributed rather than centralized. Thus, distributed control strategies are needed in order to manage complex organizations. The related (but also philosophically controversial, see e.g. Corning (2002), Sawyer (2005), Johnson (2006), and Bedau and Humphreys (2007)) concept of emergence denotes the arising of global characteristics of the system (in an organizational context these characteristics refer, for instance, to practices, structures and processes) from characteristics of agents and their relationships, without being reducible to these characteristics[3].

[1] Complexity science treats systems as genuinely complex. This ontological stance differs from an epistemological view of complexity. In the epistemological view, things can look very complex but closer inspection may reveal that complexity is a consequence of our limited knowledge of the system rather than a property of the system itself (ontology).

[2] In complexity science, the term 'strange attractor' is important. Attractor in general refers to properties toward which a system tends to evolve. An attractor is a 'strange attractor' if the exact values of the system in the attractor cannot be predicted. In organizations, 'strange attractors' can be things such as shared practices, values and standards of performance that define the space inside which individual performance takes place (see Knowles, 2002, p. 98). However, the features listed in Table 1 cover the issues we have deemed relevant for the purpose of this study, and the omission of strange attractor is intentional. In this paper, we refer directly to the organizational factors of importance to emergence and self-organization.

[3] A typical example given of an emergent property is the way in which consciousness emerges from the interactions between neurons in the brain (Cilliers, 2010, p. 4; McMillan, 2008, p. 63). McMillan (2008, p. 63) equates the collective identity of groups to a similar emergent phenomenon. The emergent phenomena are variously called either patterns (Stacey, 2005; Eoyang and Holladay, 2013), or system properties (McDaniel and Driebe, 2001). The views of the effects of the emergent properties on individual agents (in a process called downward causation) are the most contested part of the debate on emergent properties (see Sawyer, 2005). Some authors distinguish weak emergence from a strong emergence, suggesting that only strongly emergent properties such as norms or values have causal powers toward individuals (Sawyer, 2005). On the organizational level, strongly emergent phenomena can include shared beliefs and practices (culture) as well as work climate (Sawyer, 2005).