Reliability Engineering and System Safety 175 (2018) 13–18

Contents lists available at ScienceDirect

Reliability Engineering and System Safety

journal homepage: www.elsevier.com/locate/ress

A risk interpretation of sociotechnical safety perspectives

Terje Aven[a,*], Marja Ylönen[b]

[a] University of Stavanger, Norway
[b] VTT Technical Research Centre of Finland, Finland

A B S T R A C T

This paper addresses 'sociotechnical perspectives on safety', highlighting common ideas and principles for understanding, studying and managing the safety of sociotechnical systems, such as high-risk industries. These perspectives can be characterised in different ways, but, for the purpose of the present paper, three features are focused on: i) that a holistic view is needed to manage safety, covering knowledge from different disciplines (technology, social sciences, etc.), ii) that complex systems cannot be fully predicted and controlled, and iii) that safety management consequently needs to highlight robustness and resilience in addition to risk analysis. Some works have been conducted to understand these perspectives in relation to risk, risk analysis and risk management, but most of these have been based on traditional concepts and approaches to risk, using quantitative probabilistic risk assessments. In this paper we revisit the issue, using more recent ideas and approaches for understanding, assessing and managing risk, where uncertainty is a main component of risk. We show that, when framed according to these ideas and approaches, the risk field can provide a supporting platform for the sociotechnical perspectives and supplement the types of means to properly manage safety. Some implications for safety and risk regulation are also discussed.

1. Introduction

Different approaches are used to study and manage the safety of technical systems like nuclear power plants and offshore installations. Basically, we can distinguish between two main categories of such approaches: the engineering risk assessment perspective and the sociotechnical perspective. The foundation and practices vary for these perspectives, but some common features can be identified when looking for the big picture of current applied safety work for such systems. For risk assessments, the aim is to provide system understanding by the use of simple linear models (such as event trees and fault trees), then to quantify the risk and compare it with predefined criteria as input to a decision-making process. The sociotechnical perspective points to the limitations of this risk assessment approach, arguing that systems like nuclear power plants and offshore installations are complex systems and that important aspects for safety are not taken into account when using the linear risk assessment models. For a complex system, it is not possible to accurately predict the system performance and accurately estimate risk on the basis of knowing the performance of the system components. There are interactions, and there will always be surprises relative to the knowledge of the analysts and experts and the models they are applying. The message is that the risk assessment approach is not able to provide a satisfactory analysis and control of the hazards and threats that can occur in such systems. Other approaches are needed and, of these, the most commonly referred to are robust analysis and resilient engineering. These approaches seek to make the systems better able to cope with surprises.

The risk assessment and risk management community has met this criticism in different ways. It is stressed that the models and tools used have limitations and that the results always need to be seen in relation to the assumptions and simplifications made. Yet the analysis and results can be informative for the decision makers. There is also a continuous drive to improve models and tools, make them more detailed and accurate, with the expectations that the risk estimations are becoming better and better.

We have also seen that a new way of thinking about risk has developed, as summarised in Section 3. This work has been motivated by this critique linked to sociotechnical systems, but it has also come from self-reflections within the risk assessment and management community. It has been shown that the traditional risk approaches based on probability calculus are too narrow to properly reflect all relevant aspects of risk and uncertainties, for sociotechnical systems but also for other types of systems and activities. It is realised that it is necessary to better reflect the uncertainties and knowledge when conceptualising and assessing risk, to be able to deal with risk concealed in beliefs and assumptions made. Surprises relative to the knowledge is also a topic that is captured by these developments.

The present paper seeks to integrate these developments in the risk field with the current perspectives on socio-technical systems. The aim of the paper is to show that, when suitably framed and conceptualised, the risk field can provide a platform for the sociotechnical perspectives on safety. There is no conflict between these perspectives and the risk assessment and management approaches when these are based on the new ideas and principles mentioned above. The paper builds on earlier works, including Wynne [46], Jasanoff [22] and Gooday [15], which

* Corresponding author.
E-mail address: terje.aven@uis.no (T. Aven).

https://doi.org/10.1016/j.ress.2018.03.004
Received 5 November 2017; Received in revised form 15 February 2018; Accepted 3 March 2018
Available online 6 March 2018
0951-8320/

point to and discuss the fact that the social and cultural understandings of safety are not integrated with technical risk assessment and related management, and that these different 'schools' do not really speak well with each other.

We will discuss the integration of the sociotechnical perspectives and approaches regarding risk in Section 3, following a brief introduction of the sociotechnical perspectives to safety in Section 2. Section 4 will discuss how a closer integration of the risk analysis and management approach and the sociotechnical perspective on safety can be utilised to improve risk and safety regulations. Finally, Section 5 provides some conclusions.

2. Sociotechnical perspectives on safety

The history of sociotechnical-systems thinking is traced to the UK's Tavistock Institute of Human Relations and studies on the implications of human factors for work systems [14,45]. Researchers highlighted human and social factors, alongside the technology affecting the work system. The following definition of a sociotechnical system derives from the context of work systems: *"The concept of sociotechnical system was established to stress the reciprocal interrelationship between humans and machines and to foster the program of shaping both the technical and social conditions of work, in such a way that efficiency and humanity would not contradict each other"* [24,41].

In the work system studies, the sociotechnical includes the following dimensions: 1) two or more persons, interaction with some form of 2) technology, 3) and internal work environment (both physical and cultural), 4) external environment (can include political, regulatory, technological, economic, educational and cultural sub-environments), 5) an organisational design and management subsystems [24]. The example illustrates that sociotechnical thinking includes micro-, meso- and macro aspects and their interconnections.

From work systems studies and organisational design and change management, sociotechnical thinking has spread to other fields and been exploited in various contexts [11]. In the context of information technology, it has been argued that sociotechnical thinking is especially relevant for the design, development, implementation and use of information technology systems. According to Coakes and Coakes [[11], 281], sociotechnical thinking *"addresses vital issues in combining the use of powerful information and communication technologies with effective and humanistic use of people."*

Hence, the term 'sociotechnical' was introduced to capture the interconnections between the social and technological aspects. In a nutshell, sociotechnical can be defined as referring to the interconnectedness and complexity of social and technical systems [24,30].

Different disciplines add new ideas into sociotechnical thinking

Several disciplines have participated in discussions of sociotechnical aspects. Therefore, the sociotechnical concept has different meanings. In social sciences and, particularly, in science and technology studies (STS), the interest has been in analysing how sociotechnical actor-networks, i.e. hybrid actors or actants, are formed. We often see things as social or technical by nature, but STS have shown that things deemed either social or technical are, in fact, a combination of both aspects [25]. When humans make new innovations, they modify knowledge and technological artefacts, as well as their own identities. For instance, new technology requires new competences, experts, new roles and responsibilities, while undermining the role of older experts, thus affecting identities, competences and power relationships within a company. Artefacts have consequences for the ways in which humans relate to each other. Hence, reciprocity and inherent interconnectedness are characteristics of humans and technology in sociotechnical actor-networks.

As an example of a sociotechnical phenomenon, we can take road humps. They are designed by engineers to get car drivers to reduce their speed and, thus, to enhance road safety. Car drivers are, however, also affected by their cultural context as well as situational factors. Hence, the end result is a consequence of technical, cultural and psychological factors, i.e. sociotechnical aspects.

Sociotechnical approaches have adopted ideas from general systems theory, for instance that the system consists of interconnected components. Each component is unaware of the behaviour of the whole system and it cannot see the influences of its actions [24]. Furthermore, interconnectedness of different systems generates complexity that is difficult, if not impossible, to govern and regulate. Hence, complexity is inherent in sociotechnical systems thinking. It means that a system as a whole cannot be accurately predicted by knowing the states of the individual elements of the system. Complexity arises from the multiplied networks of relationships, interactions and interconnectedness between the components or subsystems. As a result, the boundaries of systems become obscure [13].

With regard to safety critical organisations, sociotechnical thinking has become highly relevant. Resilience engineering has emphasised the interdependency of system effectiveness, efficiency and safety. If the system is not able to take into account both the technical and social aspects, it will lead to unsuccessful system performance or even accidents in the long run [19,30].

Accident investigations in the high-risk industries have shown that accidents are sociotechnical by nature. Accidents and failures are consequences of interconnections between technical deficiencies, human errors, organisational and inter-organisational problems in communication, lack of regulation, etc. [1,12,26,39]. Technical and social systems (including organisations) and processes are interdependent, which increases complexities and the possibility of negative surprises. These observations have led to the shift in our understanding of safety. Safety is increasingly seen as an emergent phenomenon and a by-product of several interacting systems [18]. This kind of sociotechnical systemic understanding of safety has called for a more integrated and holistic view of safety, and this has also challenged some current regulatory approaches, such as solely looking for compliance with the regulations. Then we can ask: How should regulation be changed, in order to better consider the sociotechnical aspects of safety?

It has been demonstrated that a conventional root-cause analysis is an unsuitable tool for capturing the complexity of a sociotechnical system [13,30]. Sociotechnical systems are time-dependent, they change continuously, and therefore it is impossible to trace the situation that existed before the accident. That is also due to the emergent nature of sociotechnical systems [13,30]. The notion of emergence—a characteristic of socio-technical systems—refers to a new kind of relatedness between the systems and subsystems [35]; in addition, it means that sociotechnical systems are in a continuous process of change and, as mentioned, there are difficulties in reconstructing the situation as it was before the accident. Therefore, root-cause analysis may even lead to errors in the management of safety in complex systems [13,30].

One can summarise that, due to complexity and the emergent nature of sociotechnical systems, they embrace the following aspects:

1) Knowledge gained from sociotechnical systems is uncertain.
2) Harms are not easily foreseeable.
3) It is difficult to reconstruct what happened before the accident.
4) Causes for effects are difficult to find (see [13]).

In addition, the sociotechnical approach to safety includes the following dimensions:

1) Safety as an emergent phenomenon.
2) Safety as a by-product of several interacting systems.
3) Safety cannot be separated from the other functions of an organisation; therefore, for instance change management, work process management or project management need to be seen as relevant functions in terms of safety. That requires an integrated understanding of the totality of an organisation. Safety should be seen as an outcome of the success of core functions of the organisation and as consequence of inter-organisational relationships.