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Safety culture assessment: A fuzzy model for improving safety performance in a radioactive installation

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ABSTRACT

Culture is a complex concept and this paper is devoted to improving the safety culture in safe-critical organizations. The culture of any organization in the international nuclear industry is centered on safety. This reflects human awareness and the recognition that strict attention to safety is essential if the benefits of this form of power are to be realized. For a nuclear organization safety culture is the dominant aspect of the organizational culture. Assessing the safety culture of an organization is not easy because there is no simple indicator that measures its state. From the perspective of the nuclear power industry there is no consensus on the essential attributes of safety culture and suitable safety performance indicators. Furthermore, there are no commercially available safety culture tools that can satisfactorily assess the safety culture of an organization and most methods cannot fully solve the subjectivity of safety culture assessment. In this context, this paper presents a fuzzy model for safety culture assessment using safety performance indicators able to predict changes in an organization's safety performance. These indicators are based on six elements necessary for developing a safety culture: top-level commitment to safety, organizational learning, organizational flexibility, awareness, just culture and emergency preparedness. The model uses the concepts and properties of fuzzy set theory to model the indicators and to assess the results of their application. To exemplify its use we performed an exploratory case study on the radiopharmaceuticals package dispatch process of a Brazilian radioactive installation.

1. Introduction

The analysis of the Chernobyl accident conducted by the International Atomic Energy Agency (IAEA) through the International Nuclear Safety Advisory Group (INSAG) states that "Safety culture is a necessary characteristic to reach safety in nuclear installations and therefore it must be possible to assess its status in order to improve it and maintain it in optimal levels" (International Atomic Energy Agency (IAEA), 1994). Since then, many efforts have been made to assess safety culture in nuclear organizations (International Nuclear Safety Advisory Group (INSAG), 1991; Obadia et al., 2007; Wreathall et al., 2006; Lee, 1998; Jacobs and Haber, 1994), aiming at the development of a safety culture management approach and recognizing that the safety culture of an organization shapes people's underlying behaviors (Carvalho, 2006; Carvalho et al., 2006) with immediate implications for all other necessary safety measures.

INSAG (International Nuclear Safety Advisory Group (INSAG), 1991) evidences the safety culture among the operating personnel of a nuclear power plant by means of three measures: (1) the environment created by local management, (2) the attitudes of individuals at all levels, and (3) the actual safety experience at the plant. Moreover, the working environment should include defined safety responsibilities and detailed practices at all levels. Therefore, the effectiveness of the organization's safety culture should be reflected in the performance of the facility. According to INSAG (International Nuclear Safety Advisory Group (INSAG), 1991), the establishment of a positive relationship between safety culture and the actual safety of the organization depends on safety performance indicators that can be used to infer changes in safety culture and consequently predict changes in safety performance. The challenge is to identify measurable organizational factors or attributes that influence safety.

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The INSAG report (International Nuclear Safety Advisory Group (INSAG), 1991) proposes a self-assessment of safety culture for use by nuclear organizations. The method uses the Safety Culture Three Level model developed by Schein (1992), illustrated in Fig. 1. Schein's three levels of culture are: artifacts which are visible, such as aspects of layout and the space where people work; espoused values which can be determined, such as equality of opportunity, team work, safety as a priority, etc.; and basic assumptions which are tacit and intangible such as the nature of time and space and human activities. The use of Schein's model gives a good understanding of the less tangible or visible aspects of safety culture in an organization. Safety culture assessment is then performed by means of questionnaires or interviews to collect information on employee attitudes, opinions or perceptions related to each component level of culture linked with the safety culture characteristics. INSAG emphasizes that a safety culture questionnaire sometimes becomes longer than expected, is less user-friendly and is difficult to interpret.

Obadia et al. (2007) describe a safety management system for high-risk organizations. This safety management system is based on the scoring systems and assessment criteria adopted by the model of excellence of the Brazilian quality award, in which was introduced the INSAG safety culture approach. The score assigned to each criterion of excellence depends on the degree of attention paid to their corresponding requirements, representing the organization working practices and their corresponding results. The management system was theoretically developed and then implemented at a Brazilian nuclear research installation using quantitative written questionnaires as a method for collecting data. Five different options relating to the respondent level of perception were presented for each question, established according to a summing Likert scale. The total score of each question corresponds to the summing of all values related to the selected respondent's perception levels.

The methods described above and most of the other methods for the assessment of safety culture (Lee, 1998; Reiman and Oedewald, 2007, 2009; Electric Power Research Institute – EPRI, 2000; Reiman and Pietikäinen, 2010) do not deal with the subjectivity aspect of safety culture assessments based on people's perceptions, and they also do not describe measures of the consistency among evaluators. To deal with these issues, this research uses the Fuzzy Set Theory (FST) approach to develop a method for safety culture assessment. The method is based on leading safety performance indicators, defined according to the six safety culture attributes presented in Section 3.

2. Safety performance indicators

The contemporary view on safety emphasizes that safety-critical organizations should be able to assess and manage the safety of their activities proactively (Carvalho, 2011). This new safety paradigm must be endorsed by the organizational safety management to be successful. Therefore we need new methods to measure safety according to culture safety concepts, considering that safety is a phenomenon that is hard to describe measure, confirm and manage.

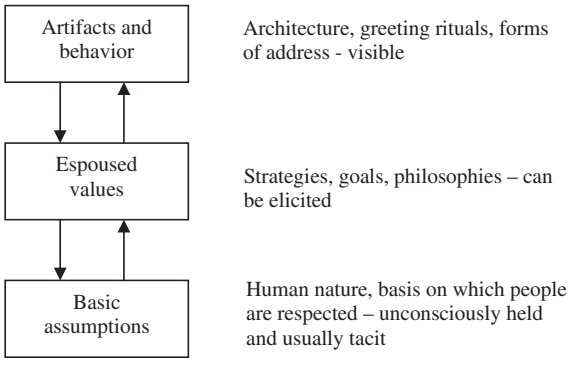

Fig. 1. Organizational culture levels, according to Schein (1992).

Scientists in the field of safety-critical organizations state that safety emerges when an organization is willing and able to work according to the demands of its asks and when people understand the changing vulnerabilities of their work environment (Carvalho, 2011; Carvalho et al., 2009; Dekker, 2005; Hollnagel et al., 2006). In this context managing the organization and its sociotechnical phenomena is the essence of safety management (Reiman and Oedewald, 2007, 2009). Thus, safety management relies on systematic anticipation to monitor the evolution of organizational performance in which various safety indicators play a key role in providing information on current organizational safety performance. Indicators that enable anticipation of performance evaluation are called leading indicators.

The safety performance indicators that have commonly been used in traditional safety management have often been lagging indicators, measuring outcomes of activities, or things, and events that have already happened (e.g., injury rates, radiation doses, incidents and accidents). These indicators are reasonably objective, easy to quantify, and can be used without costly changes to the existing system. It can be questioned, however, whether they really indicate the actual safety of organization processes because they are normally based on low numbers, and their feedback analysis suffers from the hindsight bias effect (Dekker, 2005). Lagging indicators may be more useful to confirm effects in the long term than to manage immediate changes in dynamic environments. To monitor such changes quickly, put into effect good work practices and anticipate vulnerabilities, organizations should define leading indicators. These should be able to grasp organizational practices and processes that antecede (lead) changes in the safety performance of the people in the organization. Hollnagel et al. (2008) calls this kind of control feed-forward control, because it relies on the anticipation of effects instead of past outcomes of events used in traditional feedback-based safety management.

The challenge in terms of using lagging safety performance indicators for monitoring the current safety level is the unclear causal link between past events and current safety performance. Monitoring should not rely solely on lagging indicators but also on indicators of current activities and the potential of the organization to succeed in the future.

Several reasons for using leading indicators have been proposed in the literature:

- they provide information on where to focus improvement efforts (Reason, 1997);
- they direct attention to proactive measures of safety management rather than reactive follow-up of negative occurrences or trending of events (Woods et al., 2006);
- they provide early warning signs of potential weak areas or vulnerabilities in the organizational risk control system or technology (Wreathall, 2010);
- they focus on precursors to undesired events rather than the undesired events themselves (Electric Power Research Institute – EPRI, 2000);
- they provide information on the effectiveness of the safety efforts underway (International Atomic Energy Agency – IAEA, 2000);
- and they describe the organization's health, not only sickness or the absence of it (International Atomic Energy Agency – IAEA, 2008).