Applying tools and techniques from the study of complex, adaptive systems to workplace safety

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1. Introduction

Contemporary work environments are increasingly characterized by high levels of sociotechnical complexity (Carayon *et al.,* under review; Leveson, 2012). In such systems, highly diverse combinations of social-organization and technical entities, often widely distributed across geographical space and ethnic/cultural boundaries, must safely and effectively function within the constraints of ambiguous and highly dynamic economic and situational constraints. Under these circumstances, manifestations of organizational dysfunction, including the potential for serious accidents and disasters, can often be traced to an inadequate understanding and subsequent inability to cope with the unintended consequences of unforeseen interactions across the multiple layers of sociotechnical complexity that characterize such systems. Challenges in studying such systems and reliably analyzing the factors underlying the potential for risk are profound (Waterson *et al*., under review).

Recently, investigators have begun to explore the potential for applying modeling and simulation tools and techniques to: (1) assess risk within individual sociotechnical systems, and (2) empirically examine the nature of risk inherent in such systems in general (e.g., Hettinger *et al*, under review). In our presentation we provide an overview of the potential advantages of such approaches and, in particular, their relation to the broader study of complex, sociotechnical work systems.

2. Methods

A literature review was conducted to identify recent scientific and technical papers addressing modeling and simulation approaches to the study of safety in complex sociotechnical systems. A review of the literature dealing with complex, adaptive systems in the biological science, physics and the social sciences (e.g., political science, sociology, etc.) was also conducted. The purpose of these analyses was to assess the current state-of-the-art in modeling and simulation as it could apply to the analysis of safety in complex, sociotechnical work systems.

3. Results

A total of seven published studies addressing modeling and simulation techniques

relevant to safety in real-world work settings were uncovered. These studies primarily made use of system dynamics modeling (SDM) methods (e.g., Sterman, 2000), although hybrid approaches combining SDM with other methods, such as agent-based modeling, were identified. In general, these methods appear to be useful in capturing the complex communication and feedback relationships between system components, and are also potentially useful in assessing the impact of system/component modifications. The literature on modeling complex, adaptive systems in the biological sciences suggests an intriguing degree of commonality with sociotechnical systems, particularly with respect to: (1) the critical nature of hierarchical relationships between system components and sub-systems, and (2) the rules that govern transmission of information across the boundaries between components and sub-systems (e.g., Holland, 2012).

4. Discussion

As Leveson (2012) has argued, the nature of human work, and in particular the characteristics of social-organizational and technical systems that support it, has fundamentally changed in recent decades. Society is in the midst of an era of accelerating sociotechnical complexity for which analytic techniques developed to examine simpler, more linear work systems are no longer as useful as they once were. Modeling and simulation afford one strategic path for developing the means to understand the complexity of contemporary work systems, and the literature we reviewed suggests that we may be on the cusp of important and intriguing developments in its development and application.

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