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Human and organizational error data challenges in complex, large-scale systems

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ABSTRACT

In complex, large-scale systems, event analyses are constrained by the quality of the data gathered, the maturity of the associated reporting system, and the training and background of the investigator and reporter. Such constraints place limits on the adequacy and strength of analyses conducted with the data. In this paper, we focus on the challenges of measuring performance variability in complex systems, using the lens of human and organizational error modeling. This paper begins with an overview of human and organizational error assessments, and then introduces the particular challenges of data needs in human reliability analyses. A case study of human and organizational error analysis in a complex, large-scale system, marine transportation in Puget Sound, is used to illustrate the impact of the data challenges on risk assessment processes. Suggestions for future research conclude the paper.

1. Introduction

Risk may be defined as a measure of the probability and severity of an unwanted event. Risk events occur for a variety of reasons, as seen in Fig. 1 (Harrald et al., 1998; Reason, 1997). Sometimes risk events are the result of *basic or root causes*, such as inadequate operator knowledge, skills or abilities, or the lack of a safety management system in an organization. Risk events could also result from *immediate causes*, such as a failure to apply basic knowledge, skills, or abilities, or an operator impaired by drugs or alcohol. *Incidents* are unwanted events that may or may not result in accidents; *accidents* are unwanted events that have either *immediate* or *delayed consequences*. Immediate consequences could include injuries, loss of life, property damage, and persons in peril; delayed consequences could include further loss of life, environmental damage, and financial costs. Fig. 1 depicts the risk event error chain, and illustrates that risk events often occur because the error chain *cascades:* a basic cause can occur *and* an immediate cause *and* an incident will trigger an accident (Reason, 1997). Absent risk reduction measures to interrupt the error chain, basic causes can cascade into immediate causes, which can cascade into an incident, which can trigger an accident. The key to risk mitigation, therefore, is to introduce risk reduction interventions at appropriate points in the error chain so as to prevent the cascade.

Fig. 1 suggests a linear, cascading process that leads from basic and root causes to the onset of an accident. However, recent experience with events such as the BP Texas City oil refinery explosion on March 23, 2005, which resulted in 15 deaths and more than 170 injuries (Baker et al., 2007); the space shuttle *Challenger* and *Columbia* accidents (Columbia Accident Investigation Board (CAIB), 2003; Vaughan, 1996); and the recent allision of the container ship *Cosco Busan* with the San Francisco Bay Bridge in November 2007 that spilled 58,000 gallons of oil in San Francisco Bay (US Department of Justice, 2008), as well as recent research (Hollnagel, 2004; Hollnagel et al., 2008), suggest that the roots of accident causation may be more complex in large-scale systems, involving non-linear interdependencies among organizational, group and individual factors in the system. In addition, systemic views of risk and accident causation (Hollnagel, 2004; Hollnagel et al., 2008) view accidents as emergent phenomena that arise from the variability of organizational, group and individual performance, with roots in processes at each of those levels. In all of these approaches to evaluating and assessing risk, however, the need to consider the role of human and organizational error is clear (Popova and Sharpanskykh, 2007; Rasmussen, 1983, 1986; Reason, 1990, 1997; Stroeve et al., 2007; Swain, 1987; Swain and Guttmann, 1983). Thus, in this paper we focus on the data challenges of

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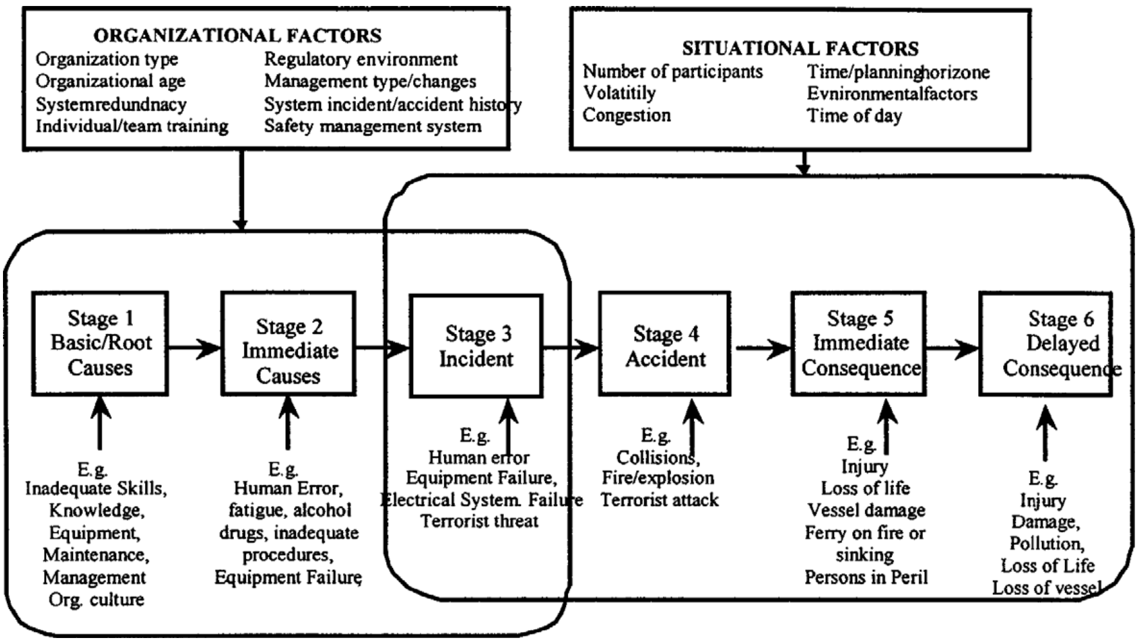

Fig. 1. Risk event error chain (Grabowski et al., 2000).

measuring performance, using the lens of human and organizational error modeling. The paper begins with an overview of human and organizational error assessments, and then introduces the particular challenges of data needs in human reliability analyses. A case study of human and organizational error analysis in a complex, large-scale system, marine transportation in Puget Sound, is used to illustrate the impact of the data challenges on the risk assessment process. Suggestions for future research conclude the paper.

2. Human and organizational error assessment

A number of approaches for representing, modeling and assessing the role of human and organizational error in complex, large-scale systems have been developed. Turner (1978) and Perrow (1984) provided early models and explanations for understanding the role of humans and organizations in accidents in complex, socio-technical systems; Reason (1990) advanced the Swiss Cheese model, which suggested that accidents occur when active failures and latent pathogens are aligned in a complex system. Swain (1987) and Swain and Guttmann (1983) introduced techniques for human reliability analyses, and identified performance shaping factors such as environmental factors (birds on an airport runway, windstorms, ice in a channel, limited visibility), physiological states (fatigue), psychological states (high stress, high workload), and organizational factors (lack of safety management systems, a poor safety culture, inadequate training) to relate context and conditions to human errors.

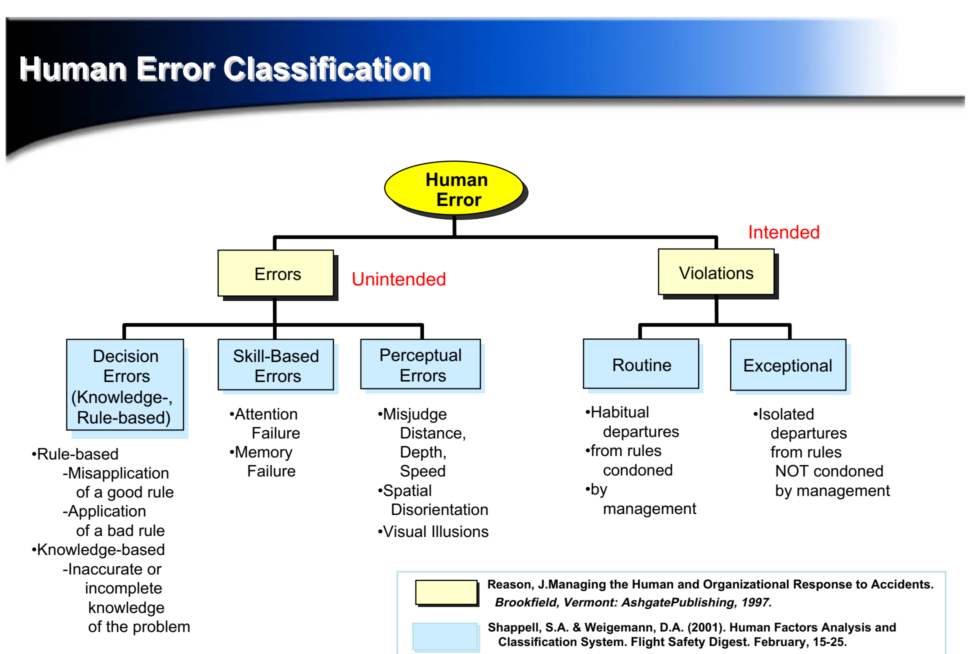

Fig. 2. Human error classification.