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A framework for identifying and analyzing sources of resilience and brittleness: A case study of two air taxi carriers

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ABSTRACT

The increasing interest in resilience engineering (RE) has led to a demand for frameworks that undertake safety assessments from such a standpoint. However, the few existing frameworks have drawbacks, such as not analyzing the sources of resilience (SRs) and the sources of brittleness (SBs) side-by-side. Moreover, they limit themselves to investigating resilience in pre-determined units of analysis (e.g., teams), neglecting the fact that resilience might be in any element of a socio-technical system. This article introduces a framework for identifying and analyzing SRs and SBs jointly, which do not constrain the identification process to any specific unit of analysis within the investigated system. The sources should be identified and analyzed across five categories: the opposite SR or SB; the risk from the SB; the effectiveness of the SR; those originating from either internal processes or the external environment; those arising from formal or informal practices. A case study of two air taxi carriers illustrates the application of the framework.

Relevance to industry: Resilience engineering (RE) is an emerging safety management paradigm concerned with normal work, rather than emphasizing learning from incidents. The proposed framework allows the identification and analysis of the most salient sources of resilience and brittleness. It can be applied for investigating resilience at any unit of analysis within a socio-technical system, supporting the identification of strengths and weaknesses from the RE perspective.

1. Introduction

Some paradigms that still are strongly rooted in industry have been subjected to increasing criticism, such as the one that regards the human being as the weak link in a complex system and who, because of this, should be removed from the front-line and be substituted by automation (Hollnagel and Woods, 2005). Besides contributing to keeping alive what is probably the most detrimental assumption about the cause of accidents (i.e., humans are to be blamed for accidents), this paradigm also denies the fact that, most of the time, it is front-line operators' ability to adapt that keeps badly-designed systems operational (Dekker, 2006). Nevertheless, adaptations often create new hazards that are not recognized by organizations, either because they are not detected or because identifying them is unsettling for a number of reasons, such as: (a) the overt recognition of adaptations might expose management flaws that create the need for workers to adapt; (b) constraining adaptations might compromise productivity improvements due to the adaptations themselves; (c) the absence of overt recognition of adaptations makes it easier to blame operators when things go wrong (Dekker, 2007).

The impossibility of having full control over and full knowledge of complex systems (Cilliers, 1998) has also not been explicitly taken into account when designing the safety management practices currently dominant in the industry. Thus, the limits and systemic impacts of safety practices are not usually assessed, which contributes to establishing a false feeling of safety and control. While it is psychologically comfortable, this feeling is detrimental to safety culture (Hollnagel, 2004).

In academic studies, safety management innovations have been investigated by a number of communities of practice (Saleh et al., 2010). These communities may be regarded as groups of researchers who often also involve practitioners, and who share a research agenda and a vocabulary. They approach a given subject from a perspective that partially differs from and partially overlaps with the perspectives adopted by other communities of practice (Hoffman and Militello, 2009). This study is aligned with a community of practice deemed resilience engineering (RE), which has relationships with other communities that to a greater or lesser extent have implications for safety. Examples of such communities are those

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of high reliability organizations, cognitive systems engineering, complex systems and safety culture.

RE might be defined as a safety management paradigm that aims at identifying, analyzing and improving the resilience of systems (Nemeth et al., 2009). For its part, resilience is the ability of a system to adjust its functioning prior to, during, or following changes and disturbances, so that it can sustain the operations required under both expected and unexpected conditions (Hollnagel, 2011). Even though the application of the concept of resilience to safety is fairly recent, it has been used over years in other contexts, such as in psychology, ecology and physics. In all of those areas, the purpose of investigating resilience is to reach a better understanding of a system's ability to survive, adapt and recover, whether the system is the human mind, an ecosystem, a material or an organization (Hollnagel et al., 2006).

The increasing interest in RE has demanded frameworks for identifying and analyzing sources of resilience (SRs) and their opposite, sources of brittleness (SBs). However, some assessments of resilience have not adopted any explicit analytical framework (e.g., Gomes et al., 2009; Morel et al., 2009), which makes it difficult to compare and generalize the results of different studies. Other studies, while adopting clear analytical frameworks, limit themselves to investigating resilience in some pre-determined units of analysis, such as the safety management system (Saurin and Carim Junior, 2011; Hale and Heijer, 2006) and the behavior of small teams (Furniss et al., 2011). While searching for resilience in specific elements of a socio-technical system allows a deep investigation, it also neglects the fact that resilience might be in any element of that system. Another drawback of the existing frameworks (e.g., Furniss et al., 2011) is that they do not consider resilience and brittleness side-by-side. This means that they do not recognize the SBs that demand the existence of the SRs, and so it is not questioned whether the SRs could be unnecessary if the SBs were eliminated. Moreover, it is not common for studies on RE to have a traceable line from concrete observations to high-level resilient principles (Furniss et al., 2011).

In this context, this study introduces a framework for identifying and analyzing SRs and SBs which can be applied in socio-technical systems, without constraining the identification process to any specific unit of analysis within the selected system. Thus, it does not matter whether the sources are in a team within the larger socio-technical system selected or whether they are in the system's management routines. An effort should be made to identify the sources wherever they emerge, within the boundaries established for the investigation. The application of the framework is illustrated by a case study of two air taxi carriers in Brazil. This service is usually demanded either when clients need air transportation to destinations not served by regular commercial flights or simply to suit the passenger's convenience (Sheehan, 2003). The choice of this sector was driven by the fact that, both the operation of an aircraft and the aviation industry as a whole, are widely regarded as having strong characteristics of complex systems (Perrow, 1984), and so they more emphatically demand that RE principles be applied. Moreover, from 1999 to 2008, air taxi carriers accounted for 23.2% of all aircraft accidents in Brazil (CENIPA, 2010).

2. Principles of RE

There are several studies that have proposed characteristics and design principles of resilient systems (Nemeth et al., 2009; Hollnagel et al., 2008; Hollnagel et al., 2006). In this paper, the principles proposed by Costella et al. (2009) are adopted, since they compile the principles established by previous studies:

(a) Top management commitment: this implies that safety is a core organizational value, rather than a temporary priority. The adoption of this principle sets up a barrier against production pressures on safety;
(b) Learn from both incidents and normal work (learning): RE emphasizes learning from the analysis of normal work, while it does not neglect learning from incidents. According to this principle, monitoring the implementation of procedures is as important as designing procedures, since the former contributes to reducing the gap between work as imagined by managers and work as performed by front-line operatives;
(c) Increase flexibility (flexibility): since an underlying assumption of RE is that human errors are inevitable, work system design must be error-tolerant and recognize that variability management is as important as variability reduction. In line with this, designers should aim at increasing the variability that leads to positive outcomes and decreasing the variability that leads to unwanted events. This principle also implies that people at the front-line (particularly first-level supervisors) are able to make important decisions without having to wait unnecessarily for management instructions;
(d) Be aware of system status (awareness): everyone in the system should be aware both of their own current status and the status of the defenses in relation to the limit of the loss of control. In particular, awareness is critical both for anticipating the changing nature of risks and for assessing the trade-off between safety and production.

It is possible to trace a parallel between the principles put forward by Costella et al. (2009) and the four cornerstones of RE proposed by Hollnagel (2011), who elaborated on each of them in detail. The principle of learning equates to the Hollnagel (2011) proposal that resilient systems must know what has happened, i.e., they must know how to learn the right lessons from the right experience. The principle of flexibility is dealt with by Hollnagel (2011) to the extent that he argues that resilient systems must know what to do, i.e., how to respond to disruptions and disturbances by adjusting normal functioning. The principle of awareness is implicit in the Hollnagel's idea that resilient systems must know what to look for (how to monitor performance) and what to expect (how to anticipate future threats). While top management commitment was not made explicit by Hollnagel (2011), it is still maintained as a RE principle in this article because it is a major prerequisite if, as desired, there is to be learning, awareness and flexibility.

3. Framework for identifying and analyzing SBs and SRs

3.1. Who should apply the framework

In the case studies reported by this article, the framework was applied by two researchers, who hold post-graduation degrees on ergonomics and safety management. Nevertheless, the framework was designed to be also applied by ergonomics practitioners. In fact, whether researchers or practitioners are applying the framework, the following qualifications are desirable: (a) to be acquainted with the framework's underlying theoretical background, especially on RE; (b) possessing basic technical knowledge of the domain investigated, although a stage of the application process may be specifically designed for this purpose, if necessary (e.g., the researcher or practitioner could attend training events in the company to be investigated, before starting the investigation); and (c) preferably, either the researcher or practitioner should not be an employee in the company under investigation, since this may bias the data collection and analysis process (e.g., he/she may erroneously take some issues for granted, neglecting a deep investigation).