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Relationship between human error intervention strategies and unsafe acts: The role of strategy implementability

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ABSTRACT

To understand the impact of safety recommendations on human error, the present study employs the Human Factor Intervention Matrix to develop a model for an intervention strategy and a level of mitigation on unsafe acts. The study empirically examines it on large longitudinal commercial aviation accident reports of Taiwan by using hierarchical regression analysis. Consistent with previous findings and others' assumptions, the mitigating effects are contingent upon the intervention strategy and unsafe act. We find that the strategies of the organizational/administrative approach influence various unsafe acts, but the strategies of technology/engineering approach and human/crew approach are suitable remedies for perceptual error and decision error, respectively. Furthermore, strategy implementability, which can be appraised by the criteria of feasibility, acceptability, cost, effectiveness, and sustainability, exhibits a moderating effect on the relationship of intervention strategy-unsafe acts. According to the results herein, mitigating broad human errors by systemic remedies is ineffective, unless the targeted human error is comprehensively identified and an appropriate intervention strategy on frontline operators can be directly exerted.

1. Introduction

Flight safety is the most crucial standard in the aviation industry, and thus the entire civilian aviation community has committed tremendous resources to satisfy this requirement. However, with global aviation activity predicted to continuously rise, the probability exists that the rate of accidents will also rise (Hsu et al., 2010). Apart from pilot-error, which still accounts for approximately 70% of aviation accidents, maintenance, design flaws, and operational deficiencies are typically cited as causes of accidents (Liou et al., 2007). Pilot-error accidents have consistently dominated accident statistics from 1940s to the present (Sanders et al., 1976). Indeed, previous research noted that poor or improper decision-making is a leading contributor to pilot-error accidents (Harris, 1994). Thus, in recent years the concentration of aircrew error in flight operations has shifted away from technical skill deficiencies and toward non-technical (or soft) skills that underpin effective crew resource management (CRM), such as decision-making, attitudes, supervisory factors, and organizational culture (Li and Harris, 2013). CRM training is focused on the effective use of all available resources: human resources, hardware, and information to facilitate crew cooperation and alleviate decision error in flight operation (Helmreich and Foushee, 2010). By contrast, human risk, such as careless operation, negligence, poor judgment, and failure to obey standard operating procedures (SOP), has been identified as the dominant aspect of risk in air traffic controllers (ATC). Additionally, dangerous situations in aviation frequently result from coordination or communication failures between air traffic controllers and other flight staff (Chiou and Chen, 2010). Maintenance errors are divided into acts of omission, commission, or timing and precision, and the most common maintenance error in a Boeing database involves omissions (Hobbs, 2008). Effective remedies to maintenance error require a systemic approach, not only towards issues at the level of the technicians and their work environment, but also to organizational factors such as procedures, task scheduling, training and licensing (Yadav, 2010).

The majority of present studies have focused on identifying the cause of aviation incidents and accidents, yet their results may have neglected the recommendations offered by experienced investigators, which could have led to the development of effective intervention strategies (Shappell and Wiegmann, 2009). On the other hand, systemic intervention is suggested to broadly reduce accidents (Hollnagel, 2005) through improvements to training, equipment, the work environment, and other conditions (Hobbs, 2008). However, analyses often reveal that accidents repeat the same sequence of events that have been played out many times before (Wiegmann and Shappell, 2001). A safe fight relies not only on aircraft technology, but also on the full cooperation of flight crews, ground staff and maintenance workers (Chen et al., 2009).

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Given more than 70% of aviation accidents are attributable to human error causal factors (Wiegmann and Shappell, 2001), the efficacy of imposing a remedy without comprehensively consideration of the intervention purpose to mitigate a specific human error is questionable. Targeting human error with appropriate and implementable intervention strategies therefore is the most effective way to eliminate and reduce the impact of an adverse event.

The present study looks to achieve the following goals. First, it contributes to the safety management system literature by proposing a methodology for integrating the Human Factor Analysis and Classification System (HFACS; Shappell and Wiegmann, 2003) and the Human Factor Intervention Matrix (HFIX; Shappell and Wiegmann, 2009) so as to alleviate human error in flight operations. Second, it responds to calls in the safety management system literature (e.g. Shappell and Wiegmann, 2009; Li and Harris, 2006) to disclose the relevance between specific human error intervention strategies and unsafe acts and to illustrate how the implementable level of an intervention strategy may moderate the mitigation effect of the human error remedy. Third, it extends a previous study (Chen et al., 2017) by examining a longitudinal dataset from the macro-view perspective in order to offer insight into the efficacy of safety recommendations in aviation accident reports. Based on the causal relationship and existing research, we hypothesize that an appropriate intervention strategy has a positively mitigating effect on targeted unsafe acts. In addition, the strategic management literature suggests that intended goals are achieved by strategy implementation, rather than formulation (Wiklund and Shepherd, 2003). Therefore, the study utilizes previously established evaluation criteria (Shappell and Wiegmann, 2009; Chen et al., 2017) to appraise the implementable level of an intervention strategy, hypothesizes that it presents successful potential for such a strategy, and shows a moderating effect on the intervention strategy-unsafe act nexus.

2. Theoretic background

2.1. Human errors in aviation

Safety in the aviation industry can certainly not be compromised. Between 2002 and 2011, the occurrence rates of hull loss on commercial jets and turboprop aircrafts are 1.75 and 1.31 per million departures, respectively (Shao et al., 2013). Even the low-probability accidents in aviation are associated with an extremely high cost, i.e., loss of life (Stanton and Walker, 2011). The Federal Aviation Administration (2011) reported that human error has not decreased over the past few decades and remains a major cause of aviation mishaps. Shappell et al. (2007) found that nearly 60% of commercial aviation accidents can be directly attributed to unsafe acts. Unsafe acts are committed by frontline operators (e.g., aircrew, flight attendants, maintenance staff, and other ground support personnel) in complex systems and immediately affect the system. These unsafe acts can be roughly classified into unintentional errors or willful violations (Scarborough et al., 2005). The errors are further categorized into decision error, skill-based errors, and perceptual errors (Shappell and Wiegmann, 2003).

Decision errors generally represent conscious decisions/choices made by an individual and carried out as they are intended, but prove inadequate for the situation at hand. Obvious decision errors include improper procedure, misdiagnosed emergency, excess ability, inappropriate maneuver, and poor decision (Wiegmann and Rantanen, 2003). Skill-based errors are the most prevalent form of aircrew error among commercial aviation accidents (Shappell et al., 2007). Skill-based errors are generally considered as highly practiced routine behavior that occurs with little or no conscious thought (Reason, 1990). Common skill-based errors include breakdown in visual scan, failure to prioritize attention, inadvertent use of flight controls, omission of a step in the procedure, omitted checklist item, poor technique, and over-controlled aircraft (Wiegmann and Rantanen, 2003).

Perceptual errors occur when one's perception of the situation differs from reality, because of degradation of sensory input. Compared with decision errors and skill-based errors, perceptual errors contribute only slightly to commercial accidents, because of the application of advanced avionics, warning devices, and awareness; pilots are also taught to rely on their primary instruments, rather than the outside world, particularly during the approach phase of flight (Wiegmann and Shappell, 2003). By contrast, violations represent a willful disregard for the rules and regulations that govern safety. The following behaviors are classified as violations in accident/incident investigation: failed to adhere to brief; failed to use the radar altimeter; flew an unauthorized approach; violated training rules; flew an overaggressive maneuver; failed to properly prepare for the flight; brief unauthorized flight; not current/qualified for the mission; intentionally exceeded the limits of the aircraft; continued low-altitude flight in visual meteorological conditions or clear weather with primary reference to terrain (Wiegmann and Rantanen, 2003).

2.2. Human Factor Intervention Matrix and remedies of human error

Human error is deemed as a significant contributing factor to flight safety (Gill and Shergill, 2004). At some point, human error will contribute to failure in complex systems that are designed, operated, maintained, and managed by human beings (Plant and Stanton, 2012). Human decisions and actions at an organizational level are implicated in all accidents (Reason, 1997). Shappell and Wiegmann (2009) suggested the application of the HFACS to investigate human errors in flight operations and selected suitable approaches from the HFIX to develop an intervention strategy when the cause of occurrence is identified.

HFACS was originally designed and developed as a human error framework for investigating and analyzing human error accidents in U.S. military aviation operations; currently, the framework is the most popular tool for investigating human errors in flight operations (Li and Harris, 2006). The HFACS classifies human errors into four levels (Wiegmann and Shappell, 2003): Level-1 (unsafe acts of operators) is active failure and is further classified into two categories, namely, errors and violations. Level-2 (preconditions for unsafe acts) involves latent and active failures. Latent failures underlay the causal chain of events, which can address noticeable active failures. Level-3 (unsafe supervision) comprises latent failures. The causal chain of events creates unsafe acts that reach the level of line managers/supervisors. Level-4 (organizational influences) is a latent failure. To explore the pattern of routes to failure, Li et al. (2008) applied the HFACS to analyse 41 commercial aviation accidents involving aircraft registered in Taiwan. They found that significant associations exist between errors at the operational level and organizational inadequacies at the immediate adjacent levels (precondition for unsafe acts) and high levels in the organization (unsafe supervision and organizational influences). This finding provided a methodology for developing a human error intervention strategy where remedial safety actions are aimed at high organizational areas that share the highest numbers of associations with factors at low organizational levels (Li and Harris, 2013).

Though HFACS is popular method for analysing causal factors, it has been criticised for the lack of in-depth detail associated with its coding system (O'Connor, 2008). The lack of granularity of HFACS was addressed by DoD-HFACS, a derivative developed by the U.S. Department of Defense. DoD-HFACS added an additional level of classification to HFACS and extended the original 18 categories of human error of accidents to 147 nanocodes that allow users to study specific operation problems with more detailed analysis (DoD, 2005). Dekker (2001) criticized that the framework merely repositions human errors by shifting them from the forefront to higher up in the organization instead of finding solutions for them. Thus, the Human Factor Intervention Matrix (HFIX) was proposed to address this defect and to assist not only