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Structuring an effective human error intervention strategy selection model for commercial aviation

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A B S T R A C T

Flight safety cannot be compromised. Thus, commercial airlines should constantly develop safety management strategies to mitigate the diverse hazardous factors in flight operations. Given the constraint of organizational resource, a commercial airline may not have sufficient resources to implement all the necessary strategies simultaneously. This study uses a well-structured process to develop a qualitative evaluation model that will enable airlines to identify human errors and select an intervention strategy with the highest success potential. To clarify the decision problem, the Human Factors Intervention Matrix framework is utilized to construct the decision hierarchy. The Analytic Hierarchy Process is then used to attain the priorities of potential alternative strategies for various unsafe acts. Finally, Zero-One Goal Programming models are formulated to select an optimal portfolio based on the specific target and the available organizational resources. An empirical study is presented to illustrate the application of the proposed model. According to the results of the combined model, an optimal portfolio, including the intervention approaches of organizational/administrative, human/crew, and operational/physical environment, can remediate four unsafe acts, namely, decision errors, skill-based errors, perceptual errors, and violations, under resource constraints of the organization.

1. Introduction

Flight safety is the most crucial standard in aviation industry; thus, tools are continuously being developed and diversified to satisfy this requirement (Flouris and Yilmaz, 2009). However, with global aviation activity predicted to rise continuously, the probability exists that this rise will bring with it an attendant increase in accident rate (Hsu et al., 2010). Analyses often reveal that accidents repeat the same sequence of events that have been played out many times before (Shappell et al., 2007). Dekker and Woods (2010) asserted the benefits of collecting stories about negative near-miss events (errors and incidents) because these risky encounters will manifest in real accidents that occur in that system. Moreover, an overlap exists between the aspects of incidents and accidents, that is, the recombination of incident narratives has predictive (and potentially preventive) value. Finally, developing error-resistant and error-tolerant designs helps prevent errors from progressing into incidents or accidents.

At present, the majority of studies have focused on identifying the cause of aviation incidents and accidents. The results of such studies may have neglected the recommendations offered by experienced investigators, which could have led to the development of effective intervention strategies (Shappell and Wiegmann, 2009). Given that commercial airlines may not have sufficient resources to implement all necessary intervention strategies simultaneously to improve the safety of flight operations, a rationalization process is crucial to select potentially successful strategies and achieve the optimal cost benefit of the available resources of an aviation corporation (Macmillan and Tampoe, 2000). The present study proposes a structuring model that integrates Human Factors Intervention matrix (HFIX), Analytic Hierarchy Process (AHP), and Zero-One Goal Programming (ZOGP) to attain the optimal solution for mitigating a variety of human errors. This study also aims to combine the possible outcomes obtained from individual ZOGP models. Specifically, this study demonstrates how an integrated HFIX, AHP, and ZOGP model can be used as an aid in problem selection in human error intervention strategy. To provide a systematic approach and set priorities among multi-criteria and tradeoff objectives, the AHP is employed prior to ZOGP formulation.

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2. Background

2.1. Human factors in aviation

Safety in the aviation industry cannot be compromised. According to an analysis by the International Civil Aviation Organization (2013), the accident rates of commercial airplanes range from 2.8 ppm to 4.2 ppm. 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. A previous study (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, 2012). Decision errors generally represent conscious decisions/choices made by an individual and carried out as 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 Shappell, 2001). 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 overcontrolled aircraft. 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 (Shappell and Wiegmann, 2012). By contrast, violations represent a willful disregard for the rules and regulations that govern safety (Wiegmann and Shappell, 2001). The following behaviors were 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, and unauthorized low-altitude canyon running.

2.2. Measures to remediate human errors

Human error is considered a prominent threat to flight safety (Harris and Li, 2010). At some point, human error will contribute to failure in complex systems, which 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). To identify human errors, Wiegmann and Shappell (2001) proposed the Human Factors Analysis and Classification System (HFACS) to assist investigators in exploring the active failure and latent failure of frontline operators in accidents and incidents. HFACS was originally designed and developed as a human error framework for investigating and analyzing human error accidents in US military aviation operations; currently, the framework is the most popular tool for investigating human errors in flight operations (Li and Harris, 2006). The HFACS framework classifies human errors into four levels (Shappell and Wiegmann, 2012): 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) is 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 framework to analyze 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 direction for developing a human error intervention strategy; in this strategy, 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). In addition, previous research applied the theory of planned behavior to study the influential factors of violation behavior and found that management attitudes may influence operators' attitudes, group norms, work pressures, and violation behavior (Fogarty and Shaw, 2010).

In summary, the majority of existing studies emphasized identifying the cause and intervention of human errors in flight operations. However, no specific study developed a rationalization process that can assist decision-makers in evaluating and selecting the optimal solution within a corporation's available resources.

3. Proposed model

An integrated model was presented to select an optimal human error intervention strategy within a restricted resource (Fig. 1). In this model, the HFIX framework was adopted in the first phase to define the evaluation criteria and intervention approaches considered in the decision-making process. After defining these

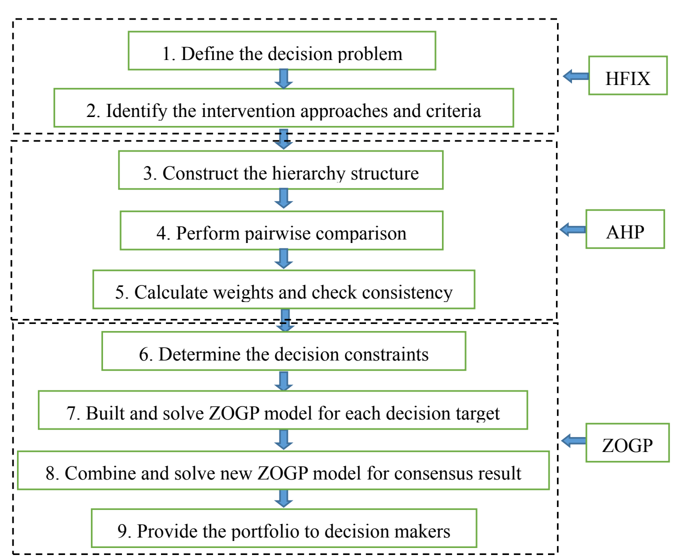

Fig. 1. Overview of the proposed model.