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Human risk factors associated with pilots in runway excursions

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ABSTRACT

A breakdown analysis of civil aviation accidents worldwide indicates that the occurrence of runway excursions represents the largest portion among all aviation occurrence categories. This study examines the human risk factors associated with pilots in runway excursions, by applying a SHELLO model to categorize the human risk factors and to evaluate the importance based on the opinions of 145 airline pilots. This study integrates aviation management level expert opinions on relative weighting and improvement-achievability in order to develop four kinds of priority risk management strategies for airline pilots to reduce runway excursions. The empirical study based on experts' evaluation suggests that the most important dimension is the liveware/pilot's core ability. From the perspective of front-line pilots, the most important risk factors are the environment, wet/containment runways, and weather issues like rain/thunderstorms. Finally, this study develops practical strategies for helping management authorities to improve major operational and managerial weaknesses so as to reduce the human risks related to runway excursions.

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1. Introduction

The International Civil Aviation Organization's (ICAO) definition of a runway excursion is used worldwide: a runway excursion is an event in which an aircraft veers off or overruns the runway surface during either takeoff or landing. There are two types of runway excursion accidents: runway overruns, in which the aircraft goes past the end of the runway, and runway veer-offs, in which the aircraft goes off the side of the runway. Analysis of accident data has identified that the highest rate of accidents occurs in the "runway excursion" category, where the aircraft departs the runway during takeoff or landing. Runway excursions have continued to be the cause of more than 25% of all commercial aircraft accidents annually (IATA, 2013). The Flight Safety Foundation (FSF) Runway Safety Initiative team found that commercial transport aircrafts were involved in 417 runway excursion accidents worldwide from 1995 through March 2008. Thirty-four runway excursion accidents were fatal, with 712 fatalities (FSF, 2009). A study of runway excursion published by the Australian Transport Safety Bureau (ATSB, 2008) focused on a worldwide commercial jet aircraft fleet for a calendar year period from 1998 to 2007 and found that there were 141 runway excursion accidents identified over the 10-year reporting period, which resulted in 550 fatalities to passengers, crew, and persons on the ground. According to the statistics of the Aviation Safety Council (ASC) in Taiwan, runway excursions account for the major portion of all types of accidents: 22 out of 57 domestic turbojet accidents during 1999–2014 (ASC, 2015a). Therefore, identifying the risk factors leading to these accidents and creating strategies and undertaking actions to mitigate runway excursions are of great urgency.

ICAO has dedicated its efforts to developing a strategy to prevent runway excursions, as well as offering a toolkit for runway excursion risk reduction. The toolkit, which is called runway excursion risk reduction (RERR), is the joint contribution by the Flight Safety Foundation (FSF), EuroControl, the International Federation of Airline Pilots' Association (IFALPA), the International Federation of Air Traffic Controllers' Associations (IFATCA), NLR Air Transport Safety Institute, the Australian Transport Safety Bureau (ATSB), the Airport Council International (ACI), and the Civil Air Navigation Services Organization (CANSO). It includes a detailed study including air carrier flight data analysis programs, self-audit checklists for airport operators and CAAs, suggestions for runway excursion risk management processes for operators, case studies of runway excursions, and practices recommended for airport and air navigation service providers. However, no study in the literature has yet explored the risk perceptions of runway excursions from the

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pilots' point of view. This paper identifies key human risk factors and obtains a relative weighting that may be useful in reducing such excursions.

Human factors play a critical role in every aviation activity, from flight training to airline management. Statistics attribute about 75% of aircraft accidents to lapses in human performance (ICAO, 1993). An understanding of human factors is visibly demonstrated through appropriate attitudes and behaviors that result in a reduction of human error in systems and reduces the risk of potential mismatches between the required level and actual level of human performance in the working environment (CAA, 2014). The report ASC Taiwan Aviation Occurrence Statistics 2005–2014 presented accident risk factors, with the human factor being the top one; it is as high as 54.7%, including 47.6% related to pilots and 7.1% related to other personnel (ASC, 2015b). This paper identifies human risk factors associated with pilots in runway excursions in order to effectively reduce the severe threat of fatalities and losses caused by runway excursion accidents and incidents.

2. Model construction

2.1. Human risk factors model

Edward (1972) stated that all aviation accidents are composed of four factors: software, hardware, environment, and liveware. This is known as the SHEL model, which identifies four kinds of interactive resources. Edwards indicated that the source of all aviation accidents can be categorized as one (Liveware) or a combination of these three major relationships (Liveware-Software, Liveware-Hardware, and Liveware-Environment). Hawkins (1993) modified this to include the interactive nature of person-to-person relationships focusing on those between liveware and software, as well as among hardware, environment, and liveware, to describe situations that people encounter in their working environments.

Accidents usually result from organizational or managerial issues composed of a series of errors that are sometimes difficult for front-line personnel to recognize or control. In practice, the Human Factors Training Manual of ICAO (1993) emphasizes the organizational issues of airline maintenance operations. In addition, IATA (2006) provided human, technical, environmental, organizational, and insufficient data, with each category, except the last, subdivided into contributing factors in its accident classification system. These types of division underlie the aviation risk assessment.

Focusing on organizational risk issues, Chang and Wang (2010) combined the IATA (2006), IATA (2006), ICAO (1993), and related concepts into a new human-organization component added to the SHELL model and called it the SHELLO model. The SHELLO model that forms the basis of our work incorporates the human factor of pilots/liveware at its core. The model consists of the key primary liveware of the SHELL model and its five interactive dimensions: the core capacity of pilots (Liveware), interaction between pilots and software (Liveware-Software), interaction between pilots and hardware (Liveware-Hardware), interaction between pilots and the environment (Liveware-Environment), interaction between pilots and others (Liveware-Liveware), and interaction between pilots and the organization (Liveware-Organization).

2.2. Preliminary pilot risk factors in the SHELLO dimension

Runway excursion events occur when an aircraft is taking off or landing, and they involve many factors, ranging from unstable approaches to runway conditions. It is important that all parties involved (pilots, air traffic controllers, airport authorities, etc.) work together to mitigate the hazards that result in runway excursions. The selection of pilot risk factors in a runway excursion for each dimension in the SHELLO model follows the classification framework of the SHELL model, the IATA accidents classification framework, the FSF runway excursion awareness toolkit, other related literature, case studies, and experts' suggestions. We found 70 preliminary risk factors in the six dimensions with specific and important risks for pilots involved in a runway excursion (Tables 1–6).

3. Methods

The empirical analysis covers the three stages of the expert questionnaire. The first-stage survey focused on the pilots' perspective concerning the importance of risk factors contributing to runway excursions, which are of absolute value from the their individual point of view. The top thirty-one significant risk factors from the first-stage survey were selected for the next-stage expert questionnaire. Due to the limited resources of management, the relative important risk factors should be considered a priority. The decision-makers from flight managers, CAA, and accident investigators need to assign weights to those important risk factors to assess their relative importance and improvement-achievability.

'Front-line' personnel are uniquely qualified to observe and report potential threats before they manifest themselves as events, and lessons can be learned from errors that did not actually translate into events, but could if repeated in the future. The policies and practices of an organization and its management directly impact upon the magnitude of runway excursion risk exposure, as well as the ability to identify and manage that risk (IATA, 2011b). The advantages of this hierarchal approach are to first select the important factors from the most credible users (the pilots) and then analyze the relative importance and improvement strategies from top managers (senior managers of air carriers, government officers, and so forth). The geometric mean score, AHP, and fuzzy method are separately done in the stages.

There are limitations on the amount of information that humans can effectively handle (Miller, 1956). To help the experts make effective assessments on the relative importance degree (weight) of pilot risk factors, we use a pairwise comparison approach. The analytic hierarchy process (AHP) as proposed by Thomas Saaty (1980) is an effective tool for dealing with complex decision-making problems. It is a theory of measurement through pairwise comparisons and relies on the judgments of experts to drive priority scales.

As suggested by AHP, a 1–9 ratio scale is used to compare two criteria (e.g. risk factors) for indicating the strength of their relative importance. The values of 1, 3, 5, 7, and 9 represent equal importance, weak importance, essential importance, demonstrated importance, and extreme importance, respectively; while the values 2, 4, 6, and 8 are used to compromise between the above values. The steps involved in the AHP are given as follows.

1. *Formation of the pair-wise comparison matrix*: Applying this procedure to all n alternatives will result in a positive $n \times n$ reciprocal matrix with all its elements $x_{ij} = 1/x_{ij}(i = 1,2,...,n; j = 1,2,...,n)$.
2. *Computation of the Eigen values and Eigen vectors and relative importance weights*: The relative importance of all n alternatives can be obtained by applying the normalized eigenvector method.
3. *Evaluation of the consistency ratio*: The final step is to check the matrix consistency through an evaluation of the consistency ratio, $CR = CI/RI$, where the consistency index $CI = (\lambda_{\max} - n)/(n-1)$, and $\lambda_{\max}$ is the maximum eigenvalue of the normalized matrix. The value of the random consistency index RI is randomly generated according to the number of factors (Saaty, 2004). The value of CR should be less than 0.10 to achieve better level of consistency. However, due to the high number and

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