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Routes to failure: Analysis of 41 civil aviation accidents from the Republic of China using the human factors analysis and classification system

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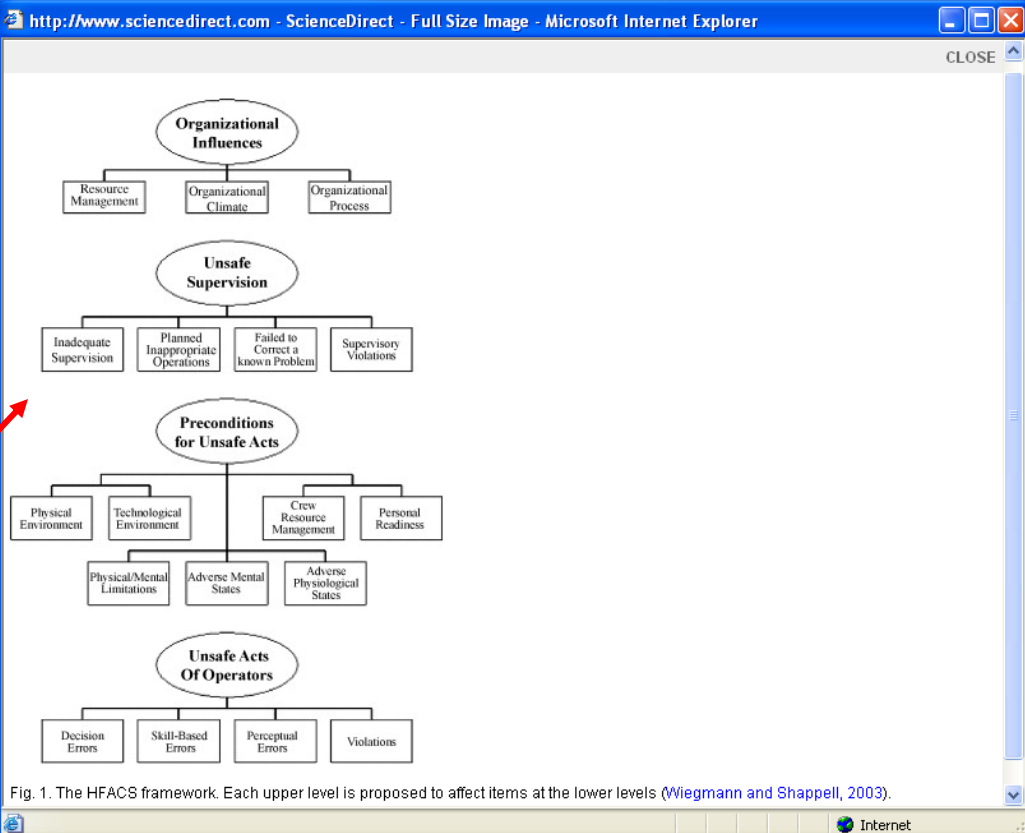


Fig. 1. The HFACS framework. Each upper level is proposed to affect items at the lower levels (Wiegmann and Shappell, 2003).

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Routes to failure: Analysis of 41 civil aviation accidents from the Republic of China using the human factors analysis and classification system

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Abstract

The human factors analysis and classification system (HFACS) is based upon Reason's organizational model of human error. HFACS was developed as an analytical framework for the investigation of the role of human error in aviation accidents; however, there is little empirical work formally describing the relationship between the components in the model. This research analyses 41 civil aviation accidents occurring to aircraft registered in the Republic of China (ROC) between 1999 and 2006 using the HFACS framework. The results show statistically significant relationships between errors at the operational level and organizational inadequacies at both the immediately adjacent level (preconditions for unsafe acts) and higher levels in the organization (unsafe supervision and organizational influences). The pattern of the 'routes to failure' observed in the data from this analysis of civil aircraft accidents show great similarities to that observed in the analysis of military accidents. This research lends further support to Reason's model that suggests that active failures are promoted by latent conditions in the organization. Statistical relationships linking failable decisions in upper management levels were found to directly affect supervisory practices, thereby creating the psychological preconditions for unsafe acts and hence indirectly impairing the performance of pilots, ultimately leading to accidents.

Keywords: Accident analysis; Human error; Human factors analysis and classification system (HFACS)

1. Introduction

When investigating the causes of aviation accidents, the human factors focus has now shifted away from investigating skill deficiencies and has moved toward other factors such as decision-making, attitudes, supervisory factors and organizational culture (Diehl, 1989; Jensen, 1997). This change in emphasis has resulted in human error frameworks and accident investigation schemes being developed that investigate and categorize the organizational factors and psychological precursors surrounding the accident in an attempt to develop a more complete understanding of the circumstances and hence aid in the development of effective prevention strategies.

The human factors analysis and classification system (HFACS) (Shappell and Wiegmann, 2001, 2003, 2004; Wiegmann and Shappell, 1997, 2001a,b,c, 2003) is perhaps the most widely used human factors analysis framework.

HFACS was developed from Reason's organizationally based model of human error (Reason, 1990, 1997). In this model active failures (errors) of front-line operators (in this case pilots) combine with latent failures lying dormant in the system to breach its defences. These latent failures are spawned in the upper levels of the organization and are related to management and regulatory structures.

HFACS addresses human errors and the factors underpinning them at four levels. The framework is described diagrammatically in Fig. 1. Level-1 (unsafe acts of operators—active failures) is the level at which the majority of accident investigations have been focused in the past. These are the behaviours of the flight crew on the flight deck that contribute directly to the accident. Failures at this level can be further classified into two sub-categories: errors and violations. Errors fall into three basic error types (skill-based, decision and perceptual). Violations, however, are instances of the willful disregard of rules, which subsequently result in an accident. Level-2 (preconditions for unsafe acts—latent/active failures) addresses the psychological precursors to the active failures at level-1, such as the substandard conditions of the operators and the operating envi-

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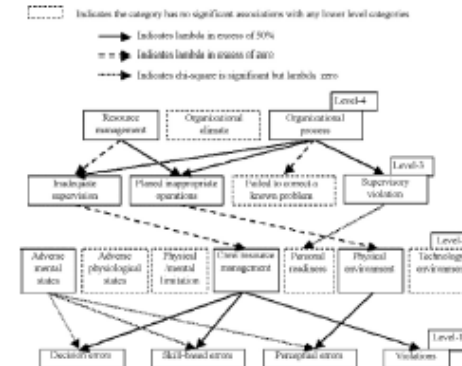


Fig. 2. Paths between categories at the four levels in the HFACS framework showing the significant associations ($p < 0.001$) using Chi-square (χ^2) and lambda (λ).

group the level-2 category 'CRM' was significantly associated with three categories of unsafe act: 'decision errors'; 'skill-based errors' and 'violations'. In the second grouping 'adverse mental states' was also significantly associated with three categories of unsafe act: 'decision errors'; 'skill-based errors' and 'perceptual errors'. The final relationship was between the HFACS level-2 category of the 'physical environment' and the level-1 category of 'perceptual error'.

Of particular note are the downward relationships the category of poor CRM has with the three level-1 categories. Inspection of the associated odds ratios show between (approximately) a 30–40-fold increase in the likelihood of error or violation in the presence of poor CRM practices.

4. Discussion

It can be seen from the data presented in Table 1 that the majority of HFACS categories had large enough numbers of instances of occurrence in the data set to allow reasonable confidence in the pattern of results obtained. All categories also exhibited good levels of inter-rater reliability ranging from 63.4% for the HFACS level-4 category of 'resource management' to 95.1% for the level-2 category of 'adverse physiological states'. These were as good as, or in excess of the levels reported in previous studies (e.g. Gaur, 2005; Li and Harris, 2005a; Wiegmann and Shappell, 1997).

Reason (1990, 1997) proposed that latent conditions promoting unsafe acts are inevitably present in all systems. The original decision on how to allocate resources made at the highest levels in the organization may originally have been based on sound commercial arguments but such inequities can create reliability or safety problems in other, operational parts of the system. The analyses in this paper clearly show that inadequacies at

HFACS level-4 ('organizational influences') had associations with further inadequacies at HFACS level-3 ('unsafe supervision') (see Table 2 and Fig. 2). The category of 'organizational processes' is a particularly important factor at this highest organizational level. Poor 'organizational processes' were associated with inadequacies in all categories at the level of 'unsafe supervision' and hence indirectly were ultimately at the root of many operational errors resulting in accidents. In the HFACS framework inadequacies in 'organizational processes' includes such issues as imposing excessive time pressures on staff; poor mission scheduling; poor incentivization; management failing to set clearly defined objectives; poor risk management programmes; inadequate management checks for safety and failing to establish safety programmes. 'Resource management' (which involved the selection, staffing and training of human resources at an organizational level; excessive cost cutting; providing unsuitable equipment, and a failure to remedy design flaws) also showed strong relationships with the two level-3 categories of 'inadequate supervision' and 'planned inappropriate operations'. Both Reason (1990) and Wiegmann and Shappell (2003) hypothesized that inappropriate decision-making by upper-level management can adversely influence the personnel and practices at the supervisory level, which in turn affects the psychological pre-conditions and hence the subsequent actions of the front-line operators. This study provides statistical support for this hypothesized relationship. A similar pattern of results was also found in the analysis of 523 ROC air force accidents previously reported by Li and Harris (2006a,b).

The level-2 ('preconditions for unsafe acts') category of 'CRM' was perhaps the key factor in HFACS framework. CRM encompasses issues such as a lack of teamwork on the flight deck; poor communication between flight crew; failures of leadership and inadequate crew briefings. Inadequacies in CRM



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