

# Human Error and Commercial Aviation Accidents: An Analysis Using the Human Factors Analysis and Classification System

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**Objective:** The aim of this study was to extend previous examinations of aviation accidents to include specific aircrew, environmental, supervisory, and organizational factors associated with two types of commercial aviation (air carrier and commuter/on-demand) accidents using the Human Factors Analysis and Classification System (HFACS). **Background:** HFACS is a theoretically based tool for investigating and analyzing human error associated with accidents and incidents. Previous research has shown that HFACS can be reliably used to identify human factors trends associated with military and general aviation accidents. **Method:** Using data obtained from both the National Transportation Safety Board and the Federal Aviation Administration, 6 pilot-raters classified aircrew, supervisory, organizational, and environmental causal factors associated with 1020 commercial aviation accidents that occurred over a 13-year period. **Results:** The majority of accident causal factors were attributed to aircrew and the environment, with decidedly fewer associated with supervisory and organizational causes. Comparisons were made between HFACS causal categories and traditional situational variables such as visual conditions, injury severity, and regional differences. **Conclusion:** These data will provide support for the continuation, modification, and/or development of interventions aimed at commercial aviation safety. **Application:** HFACS provides a tool for assessing human factors associated with accidents and incidents.

## INTRODUCTION

*“Flying is not inherently dangerous, but to an even greater extent than the sea, it is terribly unforgiving....”*

– Captain A. G. Lumplugh, British Aviation Insurance Group

Since Silas Christofferson first carried passengers on his hydroplane between San Francisco and Oakland harbors in 1913, engineers and psychologists have endeavored to improve the safety of passenger and cargo flights. What began as an industry fraught with adversity and at times tragedy has emerged as arguably one of the safest modes of transportation today.

Indeed, no one can question the tremendous strides that have been made since those first passenger flights nearly a century ago. However, little improvement has been realized in the last decade even though commercial aviation accident rates have reached unprecedented levels of safety over the last half century. Some have even suggested that the current accident rate is as good as it gets – or is it?

The challenge for the Federal Aviation Administration (FAA) and other civil aviation safety organizations is to improve an already very safe industry. The question is where to start when most of the “low-hanging fruit” (e.g., improved power plant and airframe technology, advanced avionics,

and the introduction of automation) have been “picked.”

Although percentages vary, most would agree that somewhere between 60% and 80% of aviation accidents are attributable, at least in part, to human error (Shappell & Wiegmann, 1996). Given such estimates, it seems surprising that with few exceptions (e.g., Billings & Reynard, 1984; Gaur, 2005; Li, Baker, Grabowski, & Rebok, 2001; Shappell & Wiegmann, 2003a, 2003b; Wiegmann & Shappell, 2003), most studies have focused on situational factors or pilot demographics, rather than the underlying human error associated with accidents. Whereas no one disagrees that factors such as weather, lighting (i.e., day vs. night), and terrain contribute to accidents, pilots have little, if any, control over them. Likewise, little can be done to affect one’s gender, age, occupation, or even flight experience, as flight hours alone are not the sole determinant of a safe pilot.

What’s more, if the current accident rate is any indication, it would appear that situational and pilot demographic data alone have provided only modest effects on aviation safety in the last decade – apart from identifying target populations for the dissemination of safety information. This is not to say that these variables are trifling, nor would anyone argue that they do not influence aviation safety. However, given the multifactorial nature of accidents (Baker, 1995), it may make more sense to examine these variables within the context of what is known about human error and accident causation. Perhaps then aviation accidents can be reduced beyond current levels.

The problem is that unlike situational and demographic variables that are tangible and well-defined, human error is much more complex and elusive, making it difficult to apply any sort of investigative methodology that is both easily understood and universally accepted. Without a structured and standardized classification scheme, one is left with little more than narrative summaries of the event, making it virtually impossible to quantify and trend specific types of human error either within or across aviation domains. However, that may have changed with the development of the Human Factors Analysis and Classification System (HFACS) in the mid-1990s. In fact, since the U.S. Navy/Marine Corps fielded the original version in 1997, HFACS has been used to reliably investigate and classify human error in a variety of high-risk settings, including military and

general aviation (GA; Gaur, 2005; Reinach & Viale, 2006; Shappell & Wiegmann, 2003a, 2003b, 2004; Tvaryanas, Thompson, & Constable, 2005; Wiegmann & Shappell, 2001a, 2003).

## HFACS

It is generally accepted by accident investigators in the field that aviation accidents are the result of a chain of events culminating with the unsafe acts of operators (i.e., aircrew). The aviation industry is not alone in this belief, as the safety community in general has embraced a sequential theory of accident investigation since Heinrich, Peterson, and Roos (1931) first published their axioms of industrial safety. Yet those who espouse a sequential view of accident causation are not without their critics. Some would argue that out of the ardent pursuit for accident “causes” a culture of blame has arisen. Indeed, Dekker (2001, 2002) has suggested that rather than search for “who did what wrong,” perhaps efforts are better spent trying to understand why the particular act or behavior seemed right to the individual at the time. Although such views have intuitive appeal, their utility when documenting, archiving, and retrospectively analyzing large accident databases has yet to be fully delineated and realized.

The view that traditional accident investigation is little more than an effort to assign blame may be true for some inquiries (e.g., legal proceedings, insurance claims), but most *safety* investigators would argue that their goal is to simply prevent the accident from happening again. It was with the latter view in mind that HFACS was developed (Shappell & Wiegmann, 2001). Drawing upon Reason’s (1990) concept of latent and active failures, HFACS describes human error at each of four levels: (a) organizational influences, (b) unsafe supervision (i.e., middle management), (c) preconditions for unsafe acts, and (d) the unsafe acts of operators (e.g., aircrew, maintainers, air traffic controllers; Figure 1). A brief description of each causal category is provided in Table 1 to familiarize the reader. A complete description of all 19 HFACS causal categories is available elsewhere (see Wiegmann & Shappell, 2003).

## Purpose

The goal of the present study was threefold: (a) to extend our previous HFACS analyses beyond military and GA to include commercial aviation;

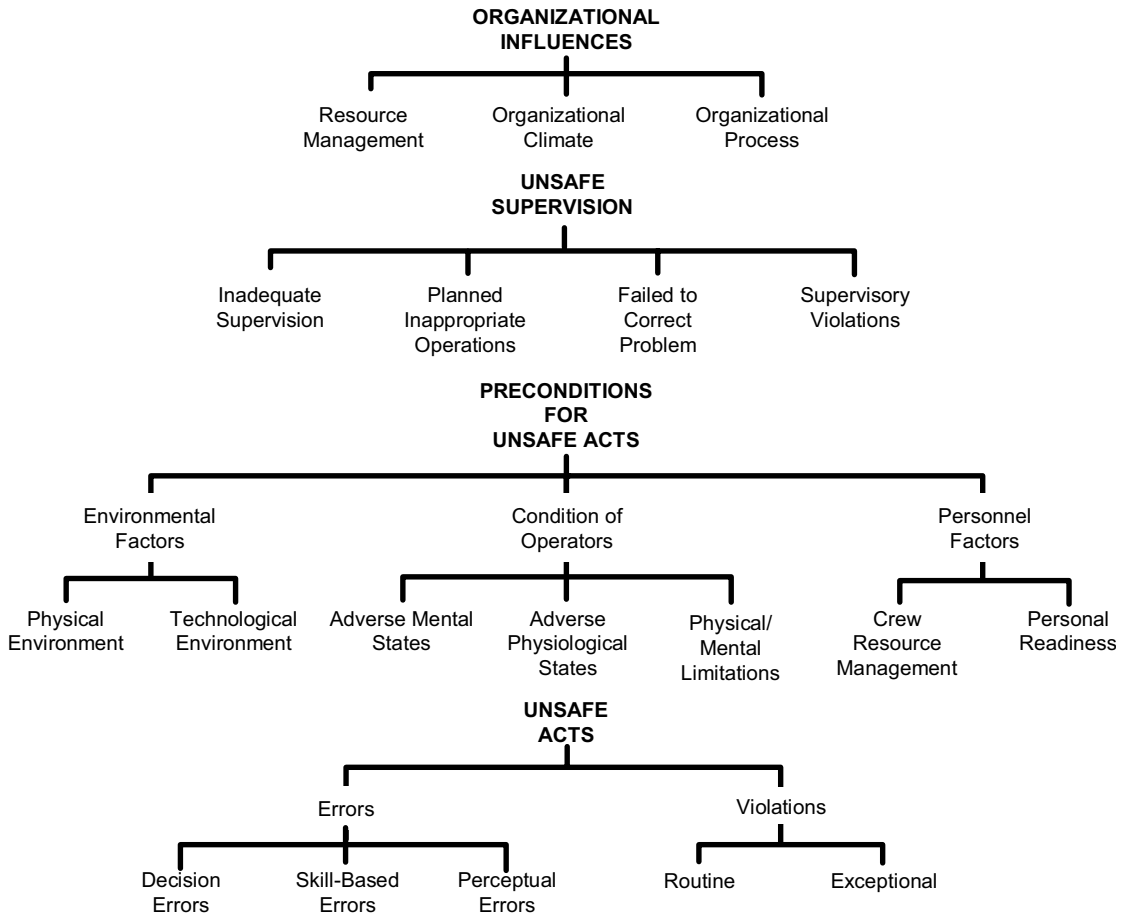


Figure 1. The HFACS framework.

(b) to combine the power of a theoretically derived human error framework with traditional situational and demographic variables from the commercial aviation database, such as visual conditions, injury severity, and regional differences; and (c) to examine any relationships over an extended period of time (i.e., 13 years). In accomplishing these objectives, the present study will provide a unique perspective into the role human error plays in the genesis of commercial aviation accidents.

**METHOD**

**Data**

Commercial aviation accident data from the calendar years 1990 through 2002 were obtained from databases maintained by the National Transportation Safety Board (NTSB) and the FAA’s National Aviation Safety Data Analysis Center (NASDAC). When describing commercial aviation, the FAA distinguishes between two types of

commercial operations: those occurring under 14 Code of Federal Regulations (CFR) Part 121, air carrier operations, and those occurring under 14 CFR Part 135, commuter/on-demand operations. Both were examined here. Note, however, that the Federal Aviation Regulations (FARs) were changed in 1997 to require smaller 14 CFR Part 135 “scheduled” commuter carriers operating aircraft that carry 10 or more passengers to operate under more stringent FAR Part 121 rules. Thus the distinction between scheduled FAR Part 135 and scheduled FAR Part 121 operators has become somewhat blurred. Nevertheless, the overwhelming majority of the 14 CFR Part 135 accidents involved “non-scheduled” on-demand flights. Only final reports that involved aircrew or supervisory error were included in this study. A total of 1,020 accidents, of which 181 involved air carrier aircraft and 839 involved commuter/on-demand aircraft, were submitted to further analysis.

**TABLE 1:** Brief Description of HFACS Causal Categories

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	Organizational Influences
Organizational climate:	Prevailing atmosphere/vision within the organization, including such things as policies, command structure, and culture.
Operational process:	Formal process by which the vision of an organization is carried out including operations, procedures, and oversight, among others.
Resource management:	How human, monetary, and equipment resources necessary to carry out the vision are managed.
	Unsafe Supervision
Inadequate supervision:	Oversight and management of personnel and resources, including training, professional guidance, and operational leadership, among other aspects.
Planned inappropriate operations:	Management and assignment of work, including aspects of risk management, crew pairing, operational tempo, etc.
Failed to correct known problems:	Those instances in which deficiencies among individuals, equipment, training, or other related safety areas are "known" to the supervisor yet are allowed to continue uncorrected.
Supervisory violations:	The willful disregard for existing rules, regulations, instructions, or standard operating procedures by managers during the course of their duties.
	Preconditions for Unsafe Acts
Environmental factors	
Technological environment:	This category encompasses a variety of issues, including the design of equipment and controls, display/interface characteristics, checklist layouts, task factors, and automation.
Physical environment:	Included are both the operational setting (e.g., weather, altitude, terrain) and the ambient environment (e.g., as heat, vibration, lighting, toxins).
Condition of the operator	
Adverse mental states:	Acute psychological and/or mental conditions that negatively affect performance, such as mental fatigue, pernicious attitudes, and misplaced motivation.
Adverse physiological states:	Acute medical and/or physiological conditions that preclude safe operations, such as illness, intoxication, and the myriad pharmacological and medical abnormalities known to affect performance.
Physical/mental limitations:	Permanent physical/mental disabilities that may adversely impact performance, such as poor vision, lack of physical strength, mental aptitude, general knowledge, and a variety of other chronic mental illnesses.
Personnel factors	
Crew resource management:	Includes a variety of communication, coordination, and teamwork issues that impact performance.
Personal readiness:	Off-duty activities required to perform optimally on the job, such as adhering to crew rest requirements, alcohol restrictions, and other off-duty mandates.
	Unsafe Acts
Errors	
Decision errors:	These "thinking" errors represent conscious, goal-intended behavior that proceeds as designed, yet the plan proves inadequate or inappropriate for the situation. These errors typically manifest as poorly executed procedures, improper choices, or simply the misinterpretation and/or misuse of relevant information.
Skill-based errors:	Highly practiced behavior that occurs with little or no conscious thought. These "doing" errors frequently appear as breakdown in visual scan patterns, inadvertent activation/deactivation of switches, forgotten intentions, and omitted items in checklists. Even the manner or technique with which one performs a task is included.
Perceptual errors:	These errors arise when sensory input is degraded, as is often the case when flying at night, in poor weather, or in otherwise visually impoverished environments. Faced with acting on imperfect or incomplete information, aircrew run the risk of misjudging distances, altitude, and descent rates, as well as of responding incorrectly to a variety of visual/vestibular illusions.
Violations	
Routine violations:	Often referred to as "bending the rules," this type of violation tends to be habitual by nature and is often enabled by a system of supervision and management that tolerates such departures from the rules.
Exceptional violations:	Isolated departures from authority, neither typical of the individual nor condoned by management.

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## Causal Factor Analysis Using HFACS

Six pilots were recruited from the Oklahoma City area as subject matter experts (SMEs). All were certified flight instructors with a minimum of 1,000 flight hr at the time they were recruited. Each pilot was provided roughly 16 hr of instruction on the HFACS framework, which included didactic lecture and practice (with feedback) using the HFACS framework with NTSB and NASDAC accident reports. After training, the pilot-raters were randomly assigned accidents such that at least 2 separate pilot-raters independently analyzed each accident.

Using both narrative and tabular data, the pilot-raters were instructed to classify each human causal factor using HFACS. Note that only those causal and contributory factors identified by the NTSB were classified. That is, the pilot-raters were instructed *not* to introduce additional causal factors that were not identified by the original investigation.

After the pilot-raters made their initial classifications (skill-based error, decision error, etc.), the two independent ratings were compared. Overall, pilot-raters agreed on the classification of causal factors within the HFACS framework more than 85% of the time. Where disagreements existed, the corresponding pilot-raters were instructed to reconcile their differences, and the consensus classification was included for further analysis.

### Human Factors Quality Assurance

The pilot-raters used in this study possessed a great deal of technical expertise in aviation, which allowed them to process the information contained in accident reports. They were also well trained in HFACS, which provided some level of expertise and reliability when assessing human error (Wiegmann & Shappell, 2001a). Nevertheless, pilots are not usually human factors experts as well. Therefore, to further validate the coding performed by the pilot-raters, SMEs with expertise in human factors and aviation psychology conducted a quality check of the coding. To aid in the process, descriptive statistics were used to identify accident causal factors that appeared theoretically inconsistent with the HFACS category that was assigned. These outliers were subsequently reviewed independently by a minimum of 2 human factors SMEs. After they came to consensus, the codes were compared with the pilot ratings and a deter-

mination was made regarding the final classification. Less than 5% of all pilot-rater classifications were modified as a result of the human factors quality assurance process.

## RESULTS

### Overall

A summary of the HFACS analyses of commercial aviation accidents can be found in Table 2. What is apparent from the data is that the majority of human causal factors involved aircrew and their environment (i.e., unsafe acts of operators and preconditions for unsafe acts), rather than unsafe supervision or organizational influences. Notably however, when organizational influences were observed, they typically involved operational processes, such as inadequate or non-existent procedures, directives, standards, and requirements, or, in the case of commuter/on-demand operations, inadequate surveillance of operations. Unsafe supervision, however, typically involved inadequate supervision in general or the failure to provide adequate training.

As anticipated, a large number of environmental conditions were identified within the commercial aviation data, particularly those associated with aspects of the physical environment, such as weather and lighting. However they were not uniformly distributed across air carrier and commuter/on-demand operations, as considerably more issues associated with the physical environment were observed during commuter/on-demand operations (63%) than during air carrier operations (37%). In contrast, the data revealed surprisingly few problems associated with the technological environment.

Preconditions for unsafe acts were also frequently observed within the accidents we examined. For instance, crew resource management (CRM) failures were identified in nearly 1 out of every 5 air carrier accidents examined. Even more interesting, the nature of the CRM failure differed between the two types of commercial operations. That is, whereas over 60% of the CRM failures associated with air carrier accidents involved in-flight CRM failures (e.g., in-flight crew coordination, communication, and monitoring of activities), over 80% of the CRM failures observed during commuter/on-demand operations involved pre-flight activities (e.g., flight planning and briefing).

Although not as common, the condition of the

**TABLE 2:** Frequency and Percentage of Accidents Associated With Each HFACS Causal Category by Type of Operation

HFACS Category	N (%)		
	Air Carrier (N = 181)	Commuter/ On-Demand (N = 839)	Total (N = 1020)
Organizational Influences			
Organizational climate	0 (0.0)	4 (0.5)	4 (0.4)
Operational process	21 (11.6)	29 (3.5)	50 (4.9)
Resource management	4 (2.2)	0 (0.0)	4 (0.4)
Unsafe Supervision			
Inadequate supervision	15 (8.3)	21 (2.5)	36 (3.5)
Planned inappropriate operations	3 (1.7)	5 (0.6)	8 (0.8)
Failed to correct known problems	0 (0.0)	0 (0.0)	0 (0.0)
Supervisory violations	0 (0.0)	2 (0.2)	2 (0.2)
Preconditions for Unsafe Acts			
Environmental conditions			
Technological environment	11 (6.1)	4 (0.5)	15 (1.5)
Physical environment	67 (37.0)	525 (62.6)	592 (58.0)
Conditions of the operator			
Adverse mental states	6 (3.3)	60 (7.2)	66 (6.5)
Adverse physiological states	6 (3.3)	18 (2.1)	24 (2.4)
Physical/mental limitations	6 (3.3)	39 (4.6)	45 (4.4)
Personnel factors			
Crew resource management	34 (18.8)	75 (8.9)	109 (10.7)
Personal readiness	0 (0.0)	3 (0.4)	3 (0.3)
Unsafe Acts of the Operator			
Skill-based errors	77 (42.5)	499 (59.5)	576 (56.5)
Decision errors	71 (39.2)	303 (36.1)	374 (36.7)
Perceptual errors	10 (5.5)	56 (6.7)	66 (6.5)
Violations	31 (17.1)	205 (24.4)	236 (23.1)

Note. Numbers in table are frequencies and percentages (parentheses) of accidents that involved at least one instance of an HFACS category. For example, 77 of the 181 air carrier accidents (77/181 or 42.5%) were associated with at least one skill-based error. Because accidents are generally associated with more than one causal factor, the percentages in the table do not add up to 100%.

operator was cited as a causal factor in several of the accidents. For instance, adverse mental states (e.g., diverted attention and pressure) were identified in just over 7% of the commuter/on-demand accidents, followed by physical/mental limitations (e.g., lack of experience) and adverse physiological states (e.g., spatial disorientation and visual illusions).

As with other aviation operations (Gaur, 2005; Shappell & Wiegmann, 2003b, 2004; Wiegmann & Shappell, 1997, 2001a, 2003) the majority of commercial aviation accident causal factors were found at the unsafe act level. Indeed, just over half of the accidents were associated with at least one skill-based error (56.5%) and over a third with decision errors (36.7%). Unfortunately, differentiating between the two types of violations post hoc

is difficult at best, as most investigations do not provide the detail necessary to make a reliable distinction between the two types of violations. Therefore, the overarching category of violations was used, rather than the subordinate categories of routine and exceptional violations, revealing that 23.1% of the accidents involved this type of unsafe act. Perceptual errors were much less common, identified in roughly 7% of the accidents.

Because of the differences between air carrier and commuter/on-demand operations (e.g., airframes, crew composition, and size of the organization), it was anticipated that there would be variation in the pattern of human error observed, particularly where the unsafe acts of aircrew were concerned. However, a comparison of the unsafe acts committed during these operations (Table 2)

yielded very little disparity. In fact, the only significant difference involved skill-based errors, which were nearly twice as likely during accidents involving commuter/on-demand accidents ( $\chi^2 = 17.368, p < .001$ ; odds ratio = 1.982). On the surface, it did appear that slightly more violations were committed during accidents involving commuter/on-demand operations, as compared with air carrier operations; however, the difference was not statistically significant. Likewise, the small differences observed for decision errors and perceptual errors were not significantly different.

Note that due to the large sample size, a conservative  $p$  value of  $p < .001$  was adopted to reduce the likelihood that spurious significant results would be obtained.

Similar to GA accident data we have reported (Shappell & Wiegmann, 2003a, 2003b, 2004; Wiegmann & Shappell, 2003), there was little variation in the distribution of unsafe acts committed annually by aircrew flying either air carrier or commuter/on-demand operations (Figure 2). It appears that when accidents did occur, they were typically associated with more skill-based errors,

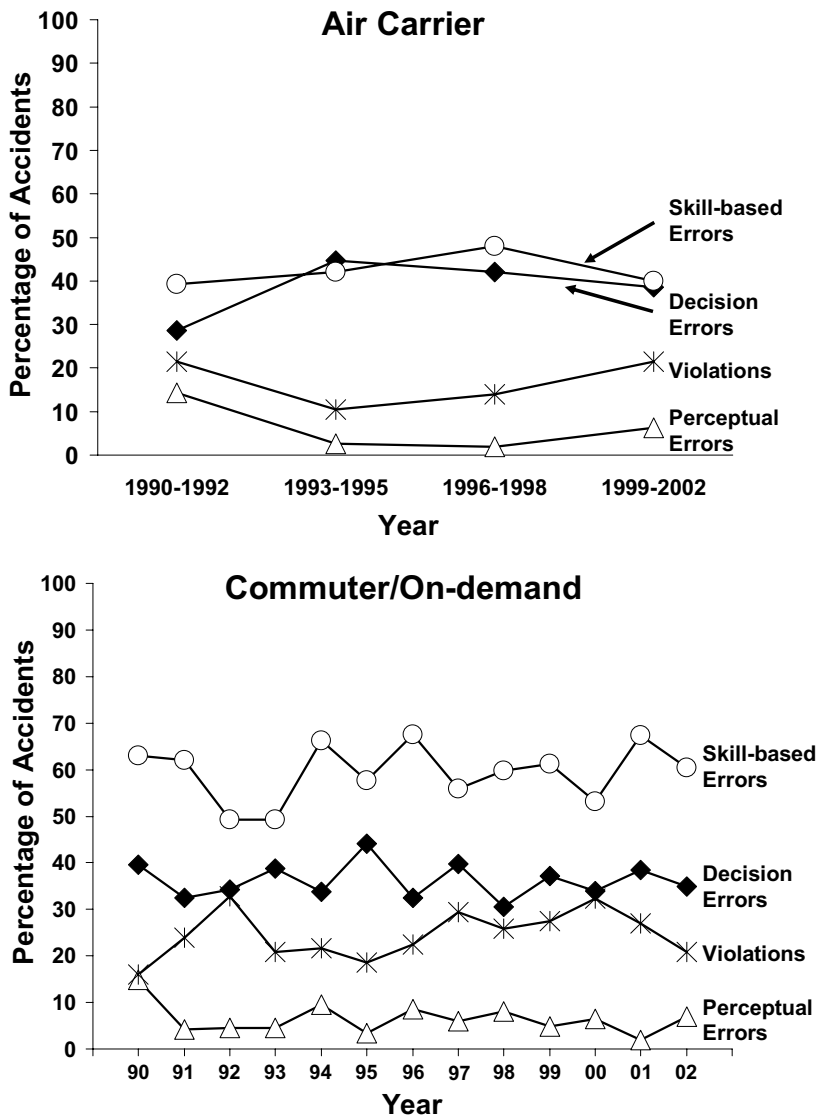


Figure 2. Percentage of unsafe acts committed by aircrew during air carrier and commuter/on-demand operations by year. Note that the percentages will not add to 100% (see note to Table 2 for explanation).

followed by decision errors, violations, and perceptual errors, in that order. This was true even though the air carrier data had to be averaged over 3- to 4-year blocks because of the small number of accidents during this time frame. Moreover, with the exception of violations, which demonstrated a slight increase since the 1993 to 1995 period, the annualized data were relatively flat, suggesting that there has been little impact on any specific type of human error over the last 13 years.

**Commuter/On-Demand Operations**

Because of the relatively small number of air carrier accidents in our data related to aircrew/supervisory error, additional fine-grained analyses of those data were not possible. However, the same was not true for commuter/on-demand operations. Therefore, a series of more detailed analyses were conducted using these data.

*Visual Conditions.* Given the relatively large percentage of accidents associated with the physical environment, in particular those associated with prevailing weather and lighting, it seemed reasonable to examine these two causal factors more closely. As can be seen in Figure 3a, nearly

30% of the accidents occurred during instrument meteorological conditions (IMC), a situation during which pilots are required to use instruments to maintain clearance from terrain and other objects such as aircraft. A similar percentage occurred during twilight (i.e., dusk or dawn) or nighttime conditions (Figure 3b).

To capitalize on the threat posed by both of these environmental factors, the meteorological and lighting conditions were combined to create a new variable that captured the “visual” conditions at the time of the accident. Specifically, two levels of visual conditions were created: (a) “clear” visual conditions, which included accidents that occurred during visual meteorological conditions (VMC), when pilots have sufficient visibility outside the cockpit to fly without referring to their instruments, and daylight conditions, and (b) “impoverished” visual conditions, which included accidents occurring during IMC or at twilight/night.

Unlike the results seen with weather and lighting conditions alone, when they were combined the percentage of accidents occurring in clear visual conditions was only marginally higher than

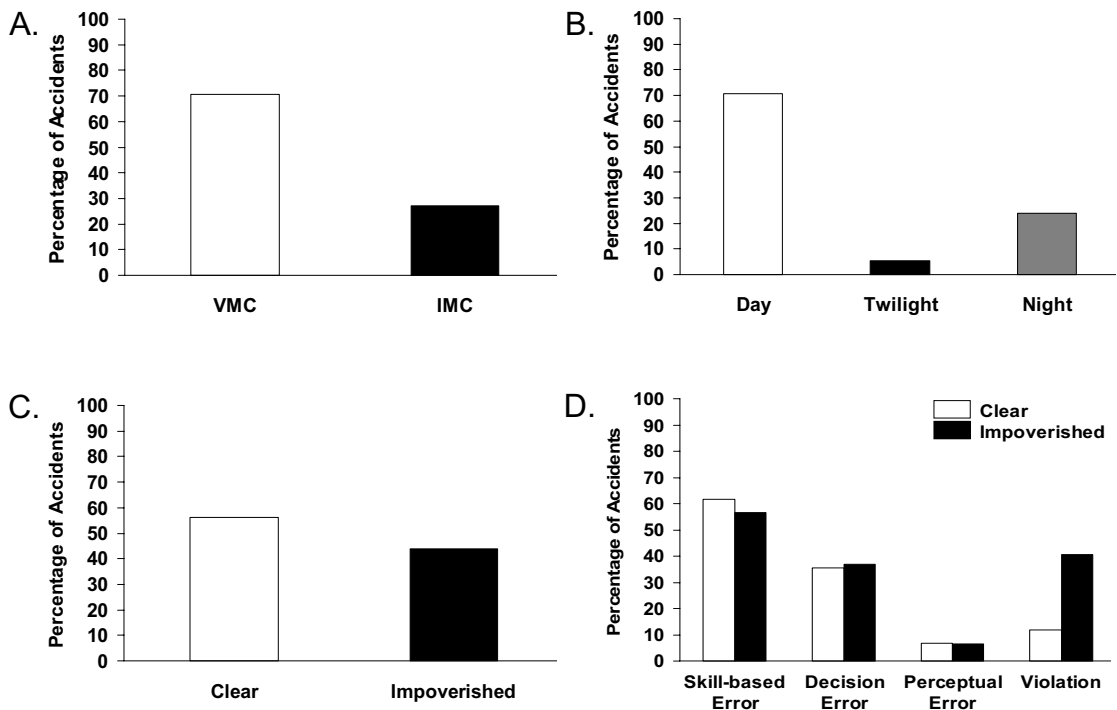


Figure 3. Percentage of commuter/on-demand accidents by (a) weather conditions, (b) lighting conditions, (c) visual conditions, and (d) visual conditions by unsafe acts

those occurring in visually impoverished conditions (Figure 3c). It would appear that whereas weather and lighting conditions are important factors in aviation, their impact is potentially exacerbated when the ability of a pilot to see outside the aircraft is considered.

Naturally, one might expect the pattern of human error to be different during accidents in clear versus visually impoverished conditions as well. Although there were differences, skill-based errors were still the most common errors observed during accidents in both visual conditions (Figure 3d). However, violations such as intentional flight into IMC while operating under visual flight rules (VFR; i.e., VFR flight into IMC) were 5 times more likely to be attributed to accidents in visually impoverished conditions ( $\chi^2 = 92.332, p < .001$ ; odds ratio = 5.077). What makes VFR flight into IMC particularly disturbing is that visual flight rules are federal regulations that permit pilots to operate safely during VMC, *not* IMC.

Of note, the failure to adhere to procedures/directives (violation), poor in-flight planning/decision making (decision error), in-flight loss of control (skill-based errors), and the failure to maintain sufficient airspeed (skill-based error) were also commonly cited as causes during accidents in visually impoverished conditions. The failure to adhere to procedures/directives (violation) was also frequently seen among accidents in clear conditions, as was poor in-flight planning/decision making (decision error). However, commuter/on-demand accidents occurring in the clear, unlike those in impoverished visual conditions, were often associated with the selection of unsuitable terrain (decision error) and the inability to compensate for winds (skill-based error).

*Injury Severity.* Previous investigations of GA accidents have shown distinct differences in the pattern of human error associated with fatal and nonfatal aviation accidents (Shappell & Wiegmann, 2003a, 2003b; Wiegmann & Shappell, 2003). A similar examination of commuter/on-demand accidents revealed that roughly 30% of all commuter/on-demand accidents resulted in at least one fatality. Consistent with our previous findings, skill-based errors were associated with the majority of fatal and nonfatal accidents, followed by decision errors, violations, and perceptual errors. Of note however, violations were more than 3 times as likely to be associated with fatal accidents ( $\chi^2 = 48.239, p < .001$ ; odds ratio = 3.145).

Causal factors such as intentional VFR flight into IMC (violation), poor in-flight planning/decision making (decision error), and control of the aircraft and airspeed (skill-based error) were the most frequently cited aircrew errors linked with fatal accidents. In contrast, nonfatal accidents appear to be more closely aligned with the failure to compensate for winds (skill-based error), loss of directional control on the ground (skill-based error), selection of unsuitable terrain (decision error), poor in-flight planning/decision making (decision error), and the failure to follow procedures/directives (violation).

Given the similarity in the pattern of human errors associated with visual conditions and injury severity (fatal vs. nonfatal), it made sense to examine the combination of the two variables. When this was done, the largest percentage of fatal commuter/on-demand accidents occurred in visually impoverished conditions. In contrast, when the accident occurred in clear visual conditions, a much smaller percentage resulted in fatalities. Indeed, commuter/on-demand accidents were over 4 times more likely to result in fatalities if they occurred in visually impoverished conditions ( $\chi^2 = 83.978, p < .001$ ; odds ratio = 4.256).

Perhaps more important, skill-based errors were still the most frequently cited human error during fatal accidents in impoverished visual conditions. However, the differences observed in previous analyses among skill-based errors, decision errors, and violations were much less obvious. Nevertheless, fully one half of the fatal accidents occurring in visually impoverished conditions involved at least one violation – often intentional VFR flight into IMC.

*Regional Comparisons.* Our previous investigation of GA accidents (Detwiler et al., 2006) suggested that differences might also exist in the pattern of human error associated with commuter/on-demand accidents in Alaska and the rest of the United States. However, our regional investigation of commuter/on-demand aviation accidents, unlike GA accidents, revealed no significant differences between Alaska and the rest of the United States with regard to the various categories of unsafe acts. Even the fine-grained analysis of unsafe acts revealed similar patterns for commuter/on-demand accidents occurring in Alaska and the rest of the United States. The only notable difference involved the type of decision errors and violations committed. Whereas the most common violation

observed in the rest of the United States involved the failure to adhere to procedures and directives, intentional VFR flight into IMC was more common in Alaska. It was also noteworthy that the decision to take off or land on unsuitable terrain was observed more often in Alaska.

## DISCUSSION

In the present study we examined a variety of human and environmental factors associated with more than 1,000 commercial aviation accidents over a 13-year time frame. Given the sheer number of causal factors associated with these accidents, one might believe that there are literally thousands of ways to crash an aircraft. The results of this study, however, demonstrate that accidents that appear to be unique on the surface can be organized based upon underlying situational, demographic, and cognitive mechanisms of accident causation. In this way, previously unidentified trends can be exposed.

Given the nature of the data, the discussion has been organized such that the HFACS analysis associated with both air carrier and commuter/on-demand accidents will be presented first. Because of the relative size of the sample, this initial analysis of all commercial aviation accidents will be followed by a more focused examination of commuter/on-demand accidents to include traditional situational and demographic variables such as visual conditions, injury severity, and regional differences.

### Organizational Influences and Unsafe Supervision

When considering all commercial aviation accidents occurring between 1990 and 2002, nearly 70% were associated with some manner of organizational, supervisory, or aircrew failure, although the percentages varied slightly when air carrier (45%) and commuter/on-demand (75%) aviation accidents were considered separately. Of these, surprisingly few were associated with organizational and/or supervisory causal factors, particularly within the commuter/on-demand aviation industry. That is, the vast majority of human causal factors identified were associated with the aircrew. Still, organizational influences related to operational processes were identified within the accident data. What's more, the exact type of failure

identified appeared to be specific to the type of operation involved. For instance, air carrier accidents were typically associated with the manner in which procedures or directives were communicated, assuming they existed at all. In contrast, commuter/on-demand accidents were more often associated with a lack of organizational oversight. Exactly why this difference existed is beyond the scope of this investigation; however, these data may provide direction for those studying how organizational issues influence commercial aviation safety.

Like those associated with the organization, causal factors attributed to supervisors/middle management centered on a single HFACS causal category (i.e., inadequate supervision) rather than the full range of supervisory factors described within the framework. However, unlike organizational influences, large differences were not observed between air carrier and commuter/on-demand operations. Instead, when supervisors were identified as causal/contributory in the chain of events leading to an accident, issues such as the lack of general supervision/oversight or the failure to provide adequate training were usually reported.

Arguably, the data are what they are; however, we cannot help but wonder if a larger question does not loom over the commercial accident data. Namely, does the current accident data reflect the scope of the organizational/supervisory problem within commercial aviation, or is it possible that issues associated with middle- and upper-level management are underreported?

Consider, for example, a recently published report in which 48 accidents representing the full spectrum of civil aviation in India were examined using HFACS (Gaur, 2005). Of these, nearly half (21/48) involved aircraft operations similar to those reported here. Although it was not possible to separate the summary findings by type of operation, it is interesting that Gaur (2005) reported a large percentage of accidents as attributable, at least in part, to organizational influences (52%) and unsafe supervision (25%). Previous studies have shown that GA accidents are typically not associated with the organizational influences and unsafe supervisory categories of HFACS (Detwiler et al., 2006; Wiegmann et al., 2005), therefore, it is likely that most, if not all, of the organizational and supervisory causal factors identified by Gaur (2005) were associated with commercial aviation.

To the extent that management of U.S. air carriers can be compared with foreign flagged air carriers, it may be possible that the current investigative process does not capture all the organizational influences associated with commercial aviation accidents. Likewise, it can be argued that even seasoned NTSB and FAA accident investigators are not without inherent biases that may predispose their investigation toward the aircrew rather than supervisors or organizations. Indeed, it is difficult for even the most open-minded investigator to come to the field without some level of preconceived notions and perceptions, particularly when the same errors are seen again and again.

At a minimum, then, it may be prudent to examine current aviation accident investigation training curricula as they relate to the identification of organizational and supervisory factors. It might also prove beneficial to incorporate the use of a human error framework that includes supervisory and organizational components in an effort to provide some degree of standardization, thereby protecting investigators from biases inherent in any investigation.

### **Preconditions for Unsafe Acts**

With a couple of notable exceptions, causal categories within the preconditions for unsafe acts category were also lightly populated. One of those exceptions was the large proportion of accidents influenced by prevailing weather conditions and reduced visibility. This was not particularly surprising because studies such as the one conducted by Baker, Lamb, Li, and Dodd (1993) reported similar results. However, what makes this particular finding noteworthy is that the problem appears to have persisted even though the FAA and its industry partners have gone to great lengths over the last several years to improve pilot skills and weather decision making.

A similar effort has been invested in CRM training, particularly within the air carrier industry. However, in the 2 decades since its implementation, the debate continues over whether or not these pioneering efforts have been effective (Salas, Burke, Bowers, & Wilson, 2001). After all, the findings here and elsewhere (U.S. General Accounting Office, 1997; Wiegmann & Shappell, 2001a) suggest that CRM failures still contribute to a large proportion of commercial aviation accidents. Even so, there may be reason for guarded optimism with regard to existing CRM programs. Whereas on

average nearly 1 in 5 air carrier accidents examined here were attributable, at least in part, to a CRM failure, the percentage dropped dramatically to just 1 out of 55 accidents in 2002. Whether this was a statistical anomaly or a sustained improvement in the area remains to be seen.

Previous studies suggested that factors associated with the physical environment and CRM would be identified among the commercial data, but it was surprising that other areas, in particular the condition of the operator (aircrew), were not seen more often in the accidents we examined. The exception involved commuter/on-demand aviation accidents, in which a number of adverse mental states (64 out of 839 accidents or 7.2%) and physical/mental limitations (43 out of 839 or 4.6%) were observed.

In some ways, the fact that many commuter/on-demand aviation operations involve single pilots may explain why adverse mental states played a more prominent role among these accidents. For instance, without a second set of eyes in the cockpit, any distraction would likely be exacerbated and detract the pilot from the task at hand (i.e., flying the aircraft). Likewise, the aviation literature is beset with examples in which pressure, either self-induced or from management, has led a pilot to accept risks beyond his or her abilities. Indeed, at least one study has suggested that this may be the case with commuter/on-demand aviation in Alaska (Conway, Mode, Berman, Martin, & Hill, 2005).

Perhaps more disconcerting than issues of attention and psychological pressure were the large number of commuter/on-demand aviation accidents associated with the pilot's lack of experience – something rarely seen among the air carrier accidents examined. Whether this represents a lack of flight hours or merely inexperience with the operational setting or aircraft needs to be explored. The answer may not be simply providing pilots more flight hours. After all, flying straight and level in VMC will not prepare a pilot for the complexities of instrument flight or the dangers of flying in other potentially hazardous environments. One may need to take a closer look at these specific accidents to identify putative interventions.

### **Unsafe Acts of Operators (Aircrew)**

As in our previous efforts involving civil and military aviation (Wiegmann & Shappell, 1997,

1999, 2001a, 2001b), skill-based errors were the most prevalent form of aircrew error among the commercial aviation accidents examined. Particularly widespread were technique errors associated with controlling the aircraft. More important, when the commercial data reported here were combined with our previous investigations of GA accidents (Detwiler et al., 2006; Wiegmann et al., 2005), an interesting finding emerged. It appears that the percentage of skill-based errors associated with accidents increases consistently as one moves from air carrier (43%) to commuter/on-demand (60%) and GA (73%) operations.

At first glance, this would seem to imply that pilot skill and proficiency is best among the air carrier industry and becomes progressively more suspect within commuter/on-demand and GA operations. Recall that skill-based behavior is generally viewed as highly practiced, routine behavior that occurs with little or no conscious thought (Rasmussen, 1982; Reason, 1990). The key is that once a particular skill is developed, it must be maintained through repetition and experience. That being said, most people would agree that GA pilots fly less and participate in fewer recurrent training sessions as compared with their commercial counterparts. In some cases, initial training may also be less rigorous within the GA environment. It stands to reason, then, that their overall skill and proficiency would be less than that of their commercial counterparts, which may explain why skill-based errors are more prevalent among GA accidents.

However, the same cannot be said for commuter/on-demand pilots, who in some cases obtain more flight time than their air carrier counterparts and may participate in the same level of initial and recurrent training. Instead, the data seem to suggest that commuter/on-demand aircrews fall somewhere in between air carrier and GA pilots with regard to piloting skill and proficiency – something that, if true, may necessitate additional regulations and currency requirements beyond those that currently exist within the industry. On the other hand, the data may simply reflect well-known differences in the sophistication of aircraft being flown (e.g., whether the aircraft was outfitted with conventional instrumentation or technically advanced avionics). Alternatively, it could reflect operational requirements placed on the aircrews (e.g., flying very structured, well-planned operations vs. comparatively less structured flights) or, maybe, something that has yet to be considered.

Skill-based errors were not the only error form identified among the accidents we examined. Decision errors, violations, and, to a lesser extent, perceptual errors were also identified. For example, decision errors were observed in roughly 4 out of every 10 commercial aviation accidents, whereas violations and perceptual errors were observed in 23% and 7% of the accidents, respectively. Some have even argued that decision errors and violations are of the same ilk (i.e., both involve decisions by aircrew that go awry) and should actually be combined in the HFACS framework. If this were true, the combined causal category of decision error/violation would be roughly equivalent to that seen with skill-based errors.

On the surface, combining decision errors and violations may make sense, given that both involve “conscious decisions,” but the motivation behind them and the intervention strategies that have proven effective in the past argue against it. That is, violations represent the *willful* disregard for the rules and regulations and are often driven by intrinsic motivation, overconfidence, and other hazardous attitudes. In contrast, decision errors are often the result of a lack of knowledge and/or information, rather than one’s attitude, *per se*.

Perhaps more important, the potential intervention/mitigation strategies to address these unsafe acts are arguably different as well. For instance, whereas scenario-based training, in-flight planning aids, and education may improve pilot decision making, these approaches have been largely ineffective in stemming violations. Instead, enforcing current standards and increasing accountability in the cockpit may be the only effective means to reduce violations of the rules – a tactic that is often difficult to employ in civil aviation. As a result, the FAA and commercial aviation industry may have to look to other avenues to reduce violations. One possibility may be the use of flight simulators that can demonstrate the hazards associated with violating the rules (Knecht, Harris, & Shappell, 2003), although this has been largely untested within the commercial aviation industry.

Perceptual errors, unlike skill-based errors, decision errors, and violations, contributed to the smallest percentage of commercial accidents and considerably less than has been reported in military aviation (Wiegmann & Shappell, 2003). However, given the nontactical, nonaerobatic nature of commercial flight, this was not altogether unexpected. What’s more, a considerable effort has

been brought to bear over the last several decades by the aerospace engineering and human factors communities to improve avionics, warning devices (ground collision avoidance systems), and awareness of perceptual errors caused by visual and vestibular illusions. It would appear that those efforts have paid substantial dividends.

It is interesting to note that the differences observed among skill-based errors, decision errors, perceptual errors, and violations remained largely consistent across the 13 years of the study. The only possible exception was observed with air carrier accidents, in which violations evidenced a small increase since 1993. Then again, some degree of caution should be taken in interpreting this particular finding, given that the air carrier data had to be collapsed into 3- to 4-year blocks because of the relatively small number of air carrier accidents occurring annually. What this seems to imply is that interventions employed in the 1990s have had at best ubiquitous effects on the errors and violations committed by aircrew. Then again, it is possible that there has been no sustained impact of any particular intervention program – a finding, if true, that raises serious concerns regarding the focus of many previous efforts in commercial aviation safety.

### Visual Conditions and Injury Severity

With the development of sophisticated navigation instrumentation and other avionics, it is possible to fly safely in environments without any external visual cues. Yet piloting an aircraft into visually impoverished environments without the necessary instruments or training can, and often does, lead to disaster. One needs to look no further than the accident data reported here to see the magnitude of this hazard within commuter/on-demand aviation – that is, nearly one half of all commuter/on-demand accidents occurred in a visually impoverished environment. Of those, an alarming 70% resulted in fatalities. In contrast, only about 30% of the accidents that occurred in broad daylight resulted in a fatality.

Although interesting, this finding alone contributes little to understanding *why* aircraft crash in poor weather or at night. However, when it was combined with HFACS, a distinguishable pattern of human error emerged. Indeed, although skill-based and decision errors were cited in a large proportion of these accidents, violations of the rules and regulations were 5 times more likely to occur

during accidents in visually impoverished conditions than in clear conditions. That is, intentional VFR flight into IMC, poor in-flight planning, and simply the failure to control the aircraft were commonly associated with fatal accidents, particularly when they occurred in visually impoverished environments. What's more alarming is that many of these causal factors have been identified to some extent in the past (e.g., Baker et al., 1993).

So why is this still a problem and, more importantly, why would a professional pilot decide to fly into hazardous weather? At least one study (Burian, Orasanu, & Hitt, 2000) has suggested that pilots with less experience may “not trust what their eyes are telling them and so proceed on blindly” (p. 1.25). Wiegmann, Goh, and O'Hare (2002) suggested that under certain conditions these errors, referred to as *plan continuation errors*, are more often attributable to poor situation assessment than to motivational judgment per se. In other words, sometimes experienced pilots simply misjudge the situation and make an honest mistake. Regardless, proper planning, both in the air and on the ground, is a critical component of flight safety. The solution may be to improve the quality of weather-related information to the pilot so that sound decisions can be made.

However, it is one thing to “misjudge” weather information or make a bad decision, it is quite another to willfully fly into IMC without proper training or equipment. Such an act begs the question, “Why would someone take such an exceptional risk?”

One possibility is social pressure. Indeed, there are several examples of pilots being pressured by passengers or other aircrew to continue to their destination despite cues that they should do otherwise (Holbrook, Orasanu, & McCoy, 2003). In fact, at least for GA, the presence of passengers on board seems to influence the likelihood that an accident would be associated with VFR flight into IMC (Goh & Wiegmann, 2002).

Still, social pressures cannot fully explain why a pilot would elect to fly VFR into IMC, particularly during cargo or repositioning flights, in which no passengers are on board. Alternatively, Batt and O'Hare (2005), O'Hare and Owen (1999), and O'Hare and Smitheram (1995) have offered an explanation structured around how pilots frame the situation of continuing or discontinuing flight into adverse weather. They found that pilots who framed diverting from a flight plan as a loss (e.g.,

loss of time, economic loss, or expense of effort) tended to continue flight into adverse weather; whereas those who framed a rerouting decision as a gain (e.g., in personal safety) tended to divert more. It is quite likely that gains and losses take on more meaning as pilots get closer to their destination.

Another possibility is that commuter/on-demand pilots, on average, may not have the requisite experience to decide when a particular situation is beyond their ability. Although this argument may hold for GA, in which pilot experience varies from the novice to pilots with thousands of flight hours, commuter/on-demand pilots typically have more experience than their GA counterparts well before their first paying passenger boards the aircraft. Experience is a double-edged sword, however, as others (e.g., Thomson, Onkal, Avcioglu, & Goodwin, 2004) have suggested that as pilots gain experience through more flight hours, risk taking may also increase because of overconfidence and successful exposure to risky events. Put simply, experts may be more likely than novices to take risks.

### Regional Differences

In many ways, Alaska is the one of the world's most demanding aviation environments, offering virtually every situation with which a pilot or operator might be confronted. In a sense, there are very few situations experienced by pilots in the lower 48 states that have not been experienced by those in Alaska. Perhaps this is why few differences were observed in the pattern of human error associated with Alaska and the rest of the United States.

However, one area in which differences did exist was the violation of rules and regulations – to be specific, VFR flight into IMC. Precisely why commuter/on-demand pilots would be more prone to fly into adverse weather in Alaska than in the rest of the United States is unknown, but at least one study (Conway et al., 2005) has shown that aircrews of high-risk operators in Alaska (those with a higher fatal crash rate than would be expected, given the number of pilots they employed) differed from other operators in both experience and working conditions. On average, pilots of high-risk operators worked more hours per day and week than did control pilots. They were also more likely to fly into unknown weather conditions. Although Conway et al. (2005) did not identify any specific reason these pilots were more prone to take risks, they did suggest that factors

such as “pilot fatigue and experience, financial pressures on operators, and inadequate weather information” (p. 56), particularly in combination, may provide some clues.

Another area in which regional differences existed involved takeoff and landing from unsuitable terrain. Although rarely associated with fatalities, these accidents are no less important, given the staggering cost to recover an aircraft stuck on a sandbar or some other remote area. These accidents are much easier to understand than VFR flight into IMC, given that in Alaska there are simply not a lot of concrete runways and taxiways for landing and takeoff. Instead, Alaskan commuter/on-demand pilots may have to resort to frozen ice, sandbars, and other natural runways for support. It is not surprising that what appears suitable from the air turns out to be unsuitable for aircraft when landed upon.

The obvious solution is to provide more suitable runways; pour more concrete, if you will. However, given the remoteness and harsh conditions of some of these areas, providing traditional runways would not be practical. Alternatively, some sort of training and awareness of what constitutes a suitable landing area, combined with the creation of more traditional runways where possible, may be the only viable solution.

### CONCLUSIONS

The findings presented here represent the marriage of traditional demographic and human error analyses of commercial aviation (air carrier and commuter/on-demand). Although some of the findings may come as no surprise, they do provide data where often only opinion existed. What's more, they provide additional information for the development, implementation, and quantifiable assessment of putative intervention and mitigation strategies.

However, it can be argued that accident investigations and therefore the accident record are inherently biased and/or incomplete. Although this may be true in some situations, it is certainly not universally true. Likewise, one can argue that post hoc analysts such as the raters used in this study are not privy to all the details of the investigation and are limited to data contained in the final reports. Yet even with these caveats, it still makes more sense to base intervention and mitigation strategies on data collected from the field rather than on theory, conjecture, and opinion.

It has been said that sometimes the best studies ask more questions than they answer. If that is indeed true, then perhaps the present study was worthwhile. Regardless of one's opinion of accident data and the current aviation accident investigation process, these data present a picture of the underlying human error component of commercial aviation accidents. Note that we were careful to say that the data presented here represent a picture, not *the* picture. After all, there are other views of accident causation, as mentioned earlier, and other comparisons yet to be made.

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