Presented at the 11th International Symposium on Aviation Psychology. Columbus, OH: The Ohio State University. 2001.

APPLYING THE HUMAN FACTORS ANALYSIS AND CLASSIFICATION SYSTEM (HFACS) TO THE ANALYSIS OF COMMERCIAL AVIATION ACCIDENT DATA

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The Human Factors Analysis and Classification System (HFACS) is a general human error framework originally developed and tested within the U.S. military as a tool for investigating and analyzing the human causes of aviation accidents. Based upon Reason's (1990) model of latent and active failures, HFACS addresses human error at all levels of the system, including the condition of aircrew and organizational factors. The purpose of the present study was to assess the utility of the HFACS framework as an error analysis and classification tool outside the military. Specifically, HFACS was applied to commercial aviation accident records maintained by the National Transportation Safety Board (NTSB). Using accidents that occurred between January, 1990 and December, 1996, it was demonstrated that HFACS reliably accommodated all human causal factors associated with the commercial accidents examined. In addition, the classification of data using HFACS highlighted several critical safety issues in need of intervention research. These results demonstrate that the HFACS framework can be a viable tool for use within the civil aviation arena.

INTRODUCTION

Humans by their very nature make mistakes; therefore, it should come as no surprise that human error has been implicated in a variety of occupational accidents, including 70% to 80% of those in civil and military aviation (O'Hare et al., 1994; Yacavone, 1993). In fact, while the number of U.S. Navy/Marine Corps aviation accidents attributable solely to mechanical failure have decreased markedly over the past 40 years, those attributable at least in part to human error have declined at a much slower rate (Shappell & Wiegmann, 1996). Given findings such as these, it would appear that interventions aimed at reducing the occurrence or consequences of human error have not been as effective as those directed at mechanical failures. Clearly, if accidents are to be reduced further, more emphasis must be placed on the genesis of human error as it relates to accident causation.

The prevailing means of investigating human error in aviation accidents today remains the analysis of accident and incident data. Unfortunately, most accident reporting systems are not based on any theoretical framework of human error. Indeed, most accident reporting systems are designed and employed by engineers and front-line operators with only limited backgrounds in human factors. As a result, these systems have been useful for identifying engineering and mechanical failures but relatively ineffective and narrow in scope where human error exists. Even when human factors are addressed, the terms and variables are often ill-defined and archival databases poorly organized. The end result is that post-accident databases are typically not conducive to a traditional human error analysis, making the identification of intervention strategies onerous (Wiegmann & Shappell, 1997).

Addressing the Problem

If the FAA and the aviation industry are to achieve their goal of significantly reducing the aviation accident rate over the next ten years, the primary cause of aviation accidents (i.e., human factors) must be addressed. However, simply increasing the amount of money and resources spent on human factors research is not the solution. Indeed, a great deal of resources and efforts are currently being expended. Rather, the solution is to redirect safety efforts so that they address important human factors issues. However, this assumes one thing, that we <u>know</u> what the important human factors issues are. Therefore, before research efforts can be systematically refocused, a comprehensive analysis of existing databases needs to be conducted to determine those human factors responsible for aviation accidents and incidents. Furthermore, if these efforts are to be sustained, new investigation methods and techniques need to be developed so that data gathered during human factors accident investigations can be improved, and analysis of the underlying causes of human error facilitated.

To accomplish this, a general human error framework is needed around which new investigative methods can be designed and existing postaccident databases restructured. Recently, Human Factors Analysis and Classification System (HFACS) has been developed to meet these needs (Shappell & Wiegmann, 2001). This system, which is based on Reason's (1990) model of latent and active failures, Specifically, HFACS describes human error at each of four levels of failure: 1) unsafe acts of operators (e.g., aircrew), 2) preconditions for unsafe acts, 3) unsafe supervision, and 4) organizational influences.

HFACS was originally developed for the U.S. Navy and Marine Corps as an accident investigation and data analysis tool. Since its original development however, HFACS has been employed by other military organizations (e.g., U.S. Army and Air Force, and Canadian Forces) as an adjunct to preexisting accident investigation and analysis systems. To date, the HFACS framework has been applied to over 1,000 military aviation accidents yielding objective, data-driven intervention strategies while enhancing both the quantity and quality of human factors information gathered during accident investigations (Shappell et al., 1999)

Other organizations such as the FAA and NASA have explored the use of HFACS as a complement to preexisting systems within civil aviation in an attempt to capitalize on gains realized by the military (Ford et al., 1999). Still, few systematic efforts have examined whether HFACS is indeed a viable tool within the civil aviation industry, even though it can be argued that considerable overlap exists. The purpose of the present study was to empirically address this issue by applying the HFACS framework, as originally designed for the military, to the classification and analysis of civil aviation accident data.

METHOD

Database

A comprehensive review of all accidents involving Code of Federal Air Regulations (FAR) Part 121 and 135 Scheduled Air Carriers[1] between January 1990 and December 1996 was conducted using database records maintained by the NTSB and the FAA. Of particular interest to this study, were those accidents attributable, at least in part, to the aircrew. Consequently, accidents due solely to catastrophic failure, maintenance error and unavoidable weather conditions such as turbulence and wind shear were not included. Furthermore, only those accidents in which the investigation was completed, and the cause of the accident determined, were included in this analysis. One hundred nineteen accidents met these criteria, including 44 accidents involving FAR Part 121 operators and 75 accidents involving FAR Part 135 operators.

HFACS Classification

The 119 aircrew-related accidents yielded 319 causal factors for further analyses. Each of these NTSB causal factors was subsequently coded independently by both an aviation psychologist and a commercially-rated pilot using the HFACS framework. Only those causal factors identified by the NTSB were analyzed. That is, no new causal factors were created during the error-coding process.

RESULTS

HFACS Comprehensiveness

All 319 (100%) of the human causal factors associated with aircrew-related accidents were accommodated using the HFACS framework. Instances of all but two HFACS categories (i.e., organizational climate and personal readiness) were observed at least once in the accident database. Therefore, no new HFACS categories were needed to capture the existing causal factors and no human factors data pertaining to the aircrew was left unclassified during the coding process.

HFACS Reliability

Disagreements among raters were noted during the coding process and ultimately resolved by discussion. Using the record of agreement and disagreement between the raters, the reliability of the HFACS system was assessed by calculating Cohen's kappa - an index of agreement that has been corrected for chance. The obtained kappa value was .71, which generally reflects a "good" level of agreement according to criteria described by Fleiss (1981).

HFACS Analyses

Unsafe Acts

At the unsafe acts level, skill-based errors were associated with the largest percentage of accidents. Approximately 60% of all aircrew-related accidents were associated with at least one skill-based error. This percentage was relatively similar for FAR Part

[1] FAR Part 121 Schedule Carriers refers to major commercial airlines whose operations are governed by the Federal Aviation Regulations (FAR), Part (i.e., section) 121. FAR Part 135 schedule carriers refers to smaller commuter airlines or air services whose operations are governed by FAR Part 135.

121 carriers (63.6%) and FAR Part 135 carriers (58.7%). The proportion of accidents associated with skill-based errors has remained relatively unchanged over the 7-year period examined in the study. Notably however, the lowest proportion of accidents associated with skill-based errors was observed in the last two years of the study (1995 and 1996).

Among the remaining categories of unsafe acts, accidents associated with decision errors constituted the next highest proportion (i.e., roughly 29% of the accidents examined). Again, this percentage was roughly equal across both FAR Part 121 (25.0%) and Part 135 (30.7%) accidents. With the exception of 1994 in which the percentage of aircrew-related accidents associated with decision errors reached a high of 60%, the proportion of accidents associated with decision errors remained relatively constant across the years of the study.

Similar to accidents associated with decision errors, those attributable at least in part to violations of rules and regulations were associated with 26.9% of the accidents examined. Again, no appreciable difference was evident when comparing the relative percentages across FAR Part 121 (25.0%) and 135 (28.0%). However, the relative proportion of accidents associated with violations increased appreciably from a low of 6% in 1990 to a high of 46% in 1996.

Finally, the proportion of accidents associated with perceptual errors was relatively low. In fact, only 17 of the 119 accidents (14.3%) involved some form of perceptual error. While it appeared that the relative proportion of Part 121 accidents associated with perceptual errors was higher than Part 135 accidents, the low number of occurrences precluded any meaningful comparisons across either the type of operation or calendar year.

Preconditions for Unsafe Acts

Within the preconditions level, CRM failures were associated with the largest percentage of accidents. Approximately 29.4% of all aircrew-related accidents were associated with at least one CRM failure. A relatively larger percentage of FAR Part 121 aircrew-accidents involved CRM failures (40.9%) than did FAR Part 135 aircrew-related accidents (22.7%). However, the percentage of accidents associated with CRM failures remained relatively constant over the 7-year period for both FAR Part 121 and 135 carriers.

The next largest percentage of accidents were those associated with adverse mental states (13.4%), followed by physical/mental limitations (10.9%) and adverse physiological states (1.7%). There were no accidents associated with personal readiness issues. The percentage of accidents associated with a physical/mental limitation was slightly higher for FAR Part 135 carriers (16%) compared to FAR Part 121 carriers (2.3%), but accidents associated with adverse mental or adverse physiological states were relatively equal across carriers. Again, however, the low number of occurrences in each of these accident categories precluded any meaningful comparisons across calendar year.

Supervisory and Organizational Factors

Very few of the NTSB reports that implicated the aircrew as contributing to an accident also cited some form of supervisory or organizational failure. Indeed, only 16% of all aircrew-related accidents involved some form of either supervisory or organizational involvement. Overall however, a larger proportion of aircrew-related accidents involving FAR Part 135 carriers involved supervisory failures (9.3%) than did those accidents involving FAR Part 121 carriers (2.3%). In contrast, a larger proportion of aircrew-related accidents involving FAR Part 121 carriers involved organizational factors (20.5%) than did those accidents involving FAR Part 135 carriers (4.0%).

DISCUSSION

HFACS Comprehensiveness

The HFACS framework was found to accommodate all 319 causal factors associated with the 119 accidents involving FAR Part 121 and 135 scheduled carriers across the 7-year period examined. This finding suggests that the error categories within HFACS that were originally developed for use in the military, are applicable within commercial aviation as well. Still, some of the error-factors within the HFACS framework were never observed in the commercial aviation accident database. For example, no instances of such factors as organizational climate or personal readiness were observed. In fact, very few instances of supervisory factors were evident at all in the data.

One explanation for the scarcity of such factors could be that contrary to Reason's model of latent and active failures upon which HFACS is based, such supervisory and organizational factors simply do not play as large of a role in the etiology of commercial aviation accidents as once expected. Consequently, the HFACS framework may need to be pared down or simplified for use with commercial aviation. Another explanation, however, is that these factors do contribute to most accidents, yet they are rarely identified using existing accident investigation processes. Nevertheless, the result of this study indicate that the HFACS framework was able to capture all existing causal factors and no new error-categories or aircrew cause-factors were needed to analyze the commercial accident data.

HFACS Reliability

The HFACS system was found to produce an acceptable level of agreement among the investigators who participated in this study. Furthermore, even after this level of agreement between investigators was corrected for chance, the obtained reliability index was considered "good" by conventional standards. Still, this reliability index was somewhat lower than those observed in studies using military aviation accidents, which in some instances have resulted in nearly complete agreement among investigators (Shappell & Wiegmann, 1997).

One possible explanation for this discrepancy is the difference in both the type and amount of information available to investigators across these studies. Unlike the present study, previous analysts using HFACS to analyze military accident data often had access to privileged and highly detailed information about the accidents, which presumably allowed for a better understanding of the underlying causal factors and hence produced higher levels of reliabilities. Another possibility is that the definitions and examples currently used to describe HFACS are too closely tied to military aviation and are therefore somewhat ambiguous to those within a commercial setting. Indeed, the reliability of the HFACS framework has been shown to improve within the commercial aviation domain when efforts are taken to provide examples and checklists that are more compatible with civil aviation accidents (Wiegmann et al., 2000).

HFACS Analysis

Given the large number of accident causal factors contained in the NTSB database, each accident appeared, at least on the surface, to be relatively unique. As such, commonalities or trends in specific error forms across accidents were not readily evident in the data. Still the recoding of the data using HFACS did allow for similar error-forms and causal factors across accidents to be identified and the major human causes of accidents to be discovered.

Specifically, the HFACS analysis revealed that the highest percentage of all aircrew-related accidents were associated with skill-based errors. Furthermore, this proportion was lowest during the last two years of this study, suggesting that the percentage of accidents associated with skill-based errors may be on the decline. To some, the finding that skill-based errors were frequently observed among the commercial aviation accidents examined is not surprising given the dynamic nature and complexity of piloting commercial aircraft, particularly in the increasingly congested U.S. airspace. The question remains, however, as to the driving force behind the possible reduction in such errors. Explanations could include improved aircrew training practices or perhaps better selection procedures. Another possibility might be the recent transition within the regional commuter industry from turboprop to jet aircraft. Such aircraft are generally more reliable and contain advanced automation to help off-load the attentional and memory demands placed on pilots during flight.

Unfortunately, the industry-wide intervention programs and other changes that were made during the 1990's were neither systematically applied nor targeted at preventing specific error types, such as skill-based errors. Consequently, it is impossible to determine whether all or only a few of these efforts are responsible for the apparent decline in skill-based errors. Nevertheless, given that an error analysis has now been conducted on the accident data, future invention programs can be strategically targeted at reducing skill-based errors. Furthermore, the effectiveness of such efforts can be objectively evaluated so that efforts can be either reinforced or revamped to improve safety.

The observation that both CRM failures and decision errors are associated with a large percentage of aircrew-related accidents is also not surprising given that these findings parallel the results of similar HFACS and human error analyses of both military and civil aviation accidents (Wiegmann & Shappell, 1999). What is surprising, or at least somewhat disconcerting, is the observation that both the percentage and rate of aircrew-related accidents associated with both CRM and decision errors has remained relatively stable. Indeed, both the FAA and aviation industry have invested a great deal of resources into intervention strategies specifically targeted at improving CRM and aeronautical decision making (ADM), with apparently little overall effect.

The modest impact that CRM and ADM programs have had on reducing accidents may be due to a variety of factors, including the general lack of a systematic analyses of accidents associated with these problems. Consequently, most CRM and ADM training programs have used single case studies to educate aircrew, rather then focus on the fundamental causes of these problems in the cockpit using a systematic analysis of the accident data. Another possible explanation for the general lack of CRM and ADM effectiveness, is that most training programs involve classroom exercises that are not followed up by simulator training that requires CRM and ADM principles to be applied. More recent programs, such as the Advanced Qualification Program (AQP), have recently been developed to take this next step of integrating ADM and CRM principles into the cockpit. Given that the current HFACS analyses has identified the accidents associated with these problems, at least across a seven year period, a more fine grained analyses can be conducted to identify the specific problems areas in need of training. Furthermore, the effectiveness of the AQP program and other ADM training in reducing aircrew accidents associated with CRM failures and decision errors can be systematically tracked and evaluated.

The percentage of aircrew related accidents associated with violations (e.g., not following federal regulations or a company's standard-operating-procedures) exhibited a slight increase across the years examined in this study. Some authors (e.g., Geller, 2000) have suggested that violations, such as taking short-cuts in procedures or breaking rules, are often induced by situational factors that reinforce unsafe acts while punishing safe actions. Not performing a thorough preflight inspection due to the pressure to achieve an on-time departure would be one example. However, according to Reason's (1990) model of active and latent failures, such violation-inducing situations are often set up by supervisory and management policies and practices.

Such theories suggest that the best strategy for reducing violations by aircrew is to enforce the rules and to hold both the aircrew and their supervisors/organizations accountable. Indeed, this strategy has been effective with the Navy and Marine Corps in reducing aviation mishaps associate with violations (Shappell & Wiegmann, 2001). Still, as mentioned earlier, very few of the commercial accident reports examined in this study cited supervisory or organizational factors as accident causes, suggesting that more often than not, aircrew were the only ones responsible for the violations. Again, more thorough accident investigations may need to be performed to identify the possible supervisory and organizational issues associated with these events.

SUMMARY AND CONCLUSIONS

This investigation demonstrates that the HFACS framework, originally developed for and proven in the military, can be used to reliably identify the underlying human factors problems associated with commercial aviation accidents. Furthermore, the results of this study highlight critical areas of human factors in need of further safety research and provide the foundation upon which to build a larger civil aviation safety program. Ultimately, data analyses such as that presented here will provide valuable insight aimed at the reduction of aviation accidents through data-driven investment strategies and objective evaluation of intervention programs. The HFACS framework may also prove useful as a tool for guiding future accident investigations in the field and developing better accident databases, both of which would improve the overall quality and accessibility of human factors accident data.

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