4.8 ASSESSMENT OF HUMAN ERROR FROM TRANSPORTATION ACCIDENT STATISTICS - VERNON S. ELLINGSTAD AND DAVID L. MAYER

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Introduction

Baker and Lamb (1992) have recently reported on a study of commuter and air taxi accidents during the period from 1983 through 1988 they obtained data from the National Transportation Safety Board's Aviation Accident Data Base on a total of 719 fixed wing aircraft involved in 122 commuter and 597 air taxi accidents and subjected these data to an extensive process of analysis. They identified twelve major crash categories (as well as an "other" and an "undetermined" classification) that provided useful groupings of the Part 135 accidents for more focused analysis. They also evaluated each accident record to determine whether factors associated with (a) the pilot, (b) ground personnel, (c)air traffic control, (d) aircraft malfunction, (e) airport conditions, and (f) weather had contributed to the accidents. Pilot condition or pilot error was identified in about 74 percent of these accidents. Human factors issues such as fatigue, improper procedures, and decision errors were observed for individual cases and emerged as safety issues when the cases were aggregated. The Baker and Lamb study provides a useful description of an important class of aircraft accidents.

At last year's Transportation Research Board meeting Hegwood (1992) presented an analysis of general aviation accidents from 1988. She attempted to evaluate the prevalence of human factors issues in these accidents by applying a modification of Feggetter's (1982) checklist to a sample of 50 general aviation accident records in the NTSB data base. She coded cognitive, social and situational human factors in these accidents after inspecting the NTSB factual reports, briefs of accident and accident narratives. Her analysis identified human factors as contributing to 90 percent of the 50 accident sample, as compared to 82 percent that had been originally identified by the NTSB as caused or contributed to by human factors flaws in information processing (80 percent of the accident sample) and errors in judgment or decision making (66 percent of the sample) were particularly notable findings. Again, this study provides useful descriptive information to the aviation safety and human factors communities by examining aviation accidents in the aggregate.

On October 14, 1992 the Safety Board adopted a study of alcohol and other drug involvement in fatal general aviation accidents during the period from 1983 through 1988. This study revealed a small decline in the number and percent of alcohol related general aviation accidents over the study years, to a rate of about 6 percent in the late 1980s. A slightly higher proportion of alcohol related fatal (to the pilot) crashes occur at night than is the case for fatal to the pilot crashes that do not involve alcohol. Disappointingly, no strong evidence of differential causation between alcohol involved and non-alcohol involved accidents emerged from the study -- that is to say we did not discover human failures that were clearly associated with alcohol impairment in these accident records. This study depended, of course, on factual and analytic data derived from the NTSB Aviation Accident Data Base.

As a final example of what I am sure that you have guessed by now to be illustrations of the application of accident data bases (and their associated accident statistics) I would like to mention a study that is currently in progress in the Safety Studies Division at the Safety Board. This study is an assessment of flight crew performance in Part 121 air carrier accidents determined by the Board to have involved flight crew error. Ben Berman and his colleagues are now in the process of refining taxonomies of flight crew errors that were identified through a detailed analysis of accident data, including factual and analytic records, as well as cockpit voice recorder transcripts and other investigative information. They are also deriving, from the same data sources, empirical characterizations of operational factors such as workload, situational awareness and communication flow whose relationships to flight crew error can then be assessed. We hope that this analysis, in the aggregate, of a fairly large collection of major air carrier accidents will reveal some of the human performance issues that may not be readily apparent in a single accident.

The balance of this paper will explore a couple of issues that affect the usefulness of accident databases for safety research generally, and human factors research in particular. Mayer and Ellingstad (1992) note a number of problems in the use of accident data bases designed for purposes other than research and analysis, including: treatment of missing data; database structure and design; and representativeness of the records in the database. These are important technical considerations that will influence the quality and usefulness of accident research, but they are outside the scope of our discussion today. Instead, I would like to concentrate on two issues: (a)the importance of examining accidents in the aggregate, and (b)the need for improving our measurements of "cause."

Why Bother With Accident Statistics?

The National Transportation Safety Board (NTSB) is a premier accident investigation agency and it produces definitive analyses of individual transportation accidents. These analyses are based on extensive field and laboratory investigations, a party system that ensures the consideration of widely differing points of view, and very extensive deliberation. They produce, in most cases, a formal statement of the “probable cause,” of the accident, and, where appropriate, recommendations for action to correct safety defects. You will shortly have evidence from my colleagues Jim Danaher and Jerry Walhout of the impressive scope and quality of these investigations. Why then do we bother to collect and analyze collections of accident data stored in our computers?

The first answer to this question has to do with seeing the forest, in addition to all of the individual trees that are represented by the separate accidents. Assessment of accident trends requires the aggregation of data from all of the individual accidents that are investigated. Standardization of data elements and methods of data collection have obvious importance in accounting for the patterns of accidents over time, as do considerations of reliability and validity of the data that these trends are based on.

A second, and perhaps even more important rational for aggregate analyses (accident studies) is that accident causes are not always evident, even to the most extensive, well organized, and professionally conducted single investigation. Sometimes this is due to the presence of what we might call "weak causes," influences which, in a statistical sense, account for only a modest (but reliable) proportion of the variance. other accidents, or classes of accidents, may be produced by multiple causes that interact in complex ways. It should not be surprising that the kinds of causes that we are focusing on today -- the human factors -- are often (if not usually) both weak and multiple.

Finally, transportation accidents always occur in a context that must be understood and accounted for. The influence on accidents of factors such as operator workload, hours of service, task complexity, and the like can probably only be understood statistically -- that is, on the basis of aggregate studies of accidents for which the requisite human performance data has been collected.

Measuring Accident Causes

The Safety Board makes an important formal distinction between "fact" and "analysis" in its investigation of accidents. The investigative process of yields a body of "fact" that describes and documents the accident circumstances and that supports "analysis" intended to yield an assessment of probable cause. Similarly, in addition to a collection of factual information, the accident database may include analysis and some representation of the cause(s) of accidents.

One of the implicit assumptions of accident analysis has always been that if the *cause* of an accident is known, similar accidents can be prevented in the future. This notion has its roots in fault tree analysis. If specific accident-producing modes of failure can be identified, then accidents can be prevented by strengthening these weak links. Some modes (e.g., metal fatigue or tire failure) are relatively well understood and, more importantly, they leave identifiable physical traces that survive the accident, however, generally leave little direct evidence for later analysis. Consequently, accident databases usually capture more information representing hardware failures and other directly observable phenomena, than human errors.

Grouping similar accidents by type or category is perhaps the simplest and most common representation of causation in accident data bases. While it is often possible to classify accidents as belonging to a specific type (e.g., mid-air collision, VFR into IMC, loss of control, etc.), this rarely explains why an accident occur. Accidents -- even relatively simple ones -- often result from multiple causes.

Some accident data bases address this issue by recording a narrative statement of accident causation, generally produced by a trained analyst, using a somewhat structured vocabulary. The Aviation Safety Reporting System (ASRS) maintained by NASA (Rosenthal and Mellone, 1989) utilizes this kind of text-based key-word system. The NTSB Aviation Accident System also contains a 200 work narrative statement of probable cause, although this is not the primary method of recording accident causes in the NTSB database. While this approach provides the opportunity for rich expression of causal relations, methods of analysis for text data are, at present, limited.

The current NTSB aviation database uses a somewhat more complex coding system that identifies from one to five *"occurrences"* (see Figure 1) that make up the accident Sequence *of Events* Associated with each occurrence is a "Phase of Flight" code (see Figure 2).

For each occurrence/phase of flight recorded the accident investigator also records a set of coded explanations or "findings" that account for that occurrence. A primary set of findings consisting of a "subject" (23107 - Altimeter), a "modifier" (3121 - Misread), and a "person" (4000 - pilot in command) can be entered to account for the occurrence. An underlying explanatory factor (e.g., 33130 - physical impairment, alcohol; pilot in command) can also be associated with this occurrence. The sequence of events system is intended to comprehensively represent the events in a single accident in a formal coding structure that permits the examination of common patterns across accidents of particular types.

This approach is complicated somewhat by the fact that more than one "sequence of events" may be necessary to account for a particular accident. In many accidents a simple chronological listing of occurrences in the order in which they occur is sufficient to account for accident causation. In other circumstances the causal sequence of events may be different from the temporal sequence of events. This is particularly true when factors that significantly pre-date the accident sequence of occurrences (e.g., maintenance failures, pilot sleep loss, etc.) must be causally associated with accident events.

An additional complication in attempting to capture the details of accident causation in a sequence of events coding structure concerns the assessment of relationships between multiple accident factors or findings. It would be useful, for example, to assess the extent to which the pilot's sleep loss contributed to his vigilance decrement, and how much that in turn contributed to failure to detect a critical signal. Current database redesign efforts at the Safety Board are directed to the incorporation of such information in the sequence of events data system.

A related issue in quantifying accident causation is the assessment of the strength of the relationship of each separate occurrence or factor in the sequence of events to the accident itself. Military aviation investigation systems have, for example, indicated which event in the sequence made the accident inevitable. The Safety Board does not presently code that information.

While possessing great potential explanatory and analytic power, coded representations of causal chains such as that just described can be very complicated to use. Current efforts to improve the Safety Board's database are directed to improvements in this area as well.

Additional Information Needed To Account For Human Causes

In addition to documentation of the factual aspects of an accident and an assessment of causation; a human factors analysis is an important component of a full investigation. In this context "human factors information" must be understood to refer to a complete accounting of human-equipment interaction in the accident situation, and not the "mental state" or disposition of the people involved in the accident. There must, for example, be a thorough accounting of task demands placed on the operator as well as the operational requirements of the task(s). Preferably, this analysis should be standardized across all accidents in the database. In effect, what is needed is a retrospective task analysis which helps to identify and code system failures. Drury (1983) detailed several such alternatives for coding consumer product accidents, but no such method has emerged for transportation accidents. The need for standardization and the realization that not all accident investigations will be conducted by professionals trained in human factors, suggests that checklists or other "cookbook" methods may be needed.

Conclusions

Transportation accident databases will continue to provide the primary basis for most empirical diagnoses of safety problems and evaluations of safety countermeasures. Improvements in database technology as well as database design can be expected to make these sources of information increasingly useful but significant attention must be directed to improving both the collection and analysis of relevant data regarding the circumstances, contexts and causes of accidents -- and particularly the human factors.

Task-oriented human factors information about accident scenarios is often missing or unusable in transportation accident databases. This kind of information is sometimes overlooked because of an inadequate understanding of human factors by accident investigators. More often, however, these data are not collected because human failings do not leave the same kind of permanent physical traces that broken vehicular components do.

Sometimes human factors information, and other analytic findings, are collected but not coded well or completely. Improved methods of quantifying causality, and representing relationships between multiple causes are needed to render databases more useable in this regard.

Human factors researchers should and need to use accident databases in their work, but great care must be taken to use these tools effectively. Greater participation by researchers in the design of databases and the collection of data will increase their suitability for our work.

References

Baker, S.P. and Lamb, M.W.(1992) Human factors in crashes of commuter airplanes and air taxis. Final Report, FAA Contract #DTFA01-90-C-00046.

Drury, C. and Brill, M. (1983). Human Factors in consumer product accident investigation. Human Factors, 25(3).

Feggetter, A.J. (1982). A method for investigating human factor aspects of aircraft accidents and incidents. Ergonomics, 25**,** p. 1065-1075.

Hegwood, J.A. (1992). Application of modified Feggetter model to identification of selected human factors in 1988 general aviation accidents Paper presented at the 71st Annual Meeting of the Transportation Research Board, Washington, DC.

International Civil Aviation Organization. (1987). Accident/Incident Reporting Manual. Author: Montreal, Quebec, Canada.

Mayer, D.L. and Ellingstad, V.S. (1992) Using Transportation Accident Databases in Human Factors Research, Human Factors Society Annual Meeting, Atlanta, GA.

National Transportation Safety Board (1992) Alcohol and Other Drug Involvement in Fatal General Aviation Accidents. 1983 Through 1988, Washington, D.C.

Rosenthal, L.J. and Mellone, V.J. (1989). Human factors in ATC operations: anticipatory clearance in ASRS Research Workshop: Human Factors Work Group.