2009

The Effect of Human Factors in Aviation Maintenance Safety

Andrea M. Georgiou

THE EFFECT OF HUMAN FACTORS IN AVIATION MAINTENANCE SAFETY

Andrea M. Georgiou
Middle Tennessee State University
Murfreesboro, Tennessee

Even with the increasing rate of technology innovation, the ultimate responsibility for the safety of a flight lies with humans. According to Boeing, human error accounts for 70% of commercial airplane accidents. This research aims to investigate the human factors that exist in aviation maintenance as well as the extent to which these factors affect safety. Utilizing the National Transportation Safety Board (NTSB) online accident database, the researcher reviewed accidents between 1996 through 2006 caused by maintenance-related errors. The results indicate the top four maintenance errors with the highest number of fatalities were: a).failure to properly complete tasks, b).improper maintenance, c).improper installations, and d). failure to detect or identify problems. In addition, the human factors most prevalent among the attitudes of both Aviation Maintenance Technicians (AMT's) and the Federal Aviation Administration (FAA) officials were demanding deadlines, environmental / personal distractions, and lack of proper use of maintenance manuals or instructions.

Whether a trip is planned for leisure or work, air travel plays a vital role in the day to day lives of individuals worldwide. A vast majority of the population from the working class to the upper class travel through the air transportation industry and are therefore directly affected by aviation safety. The large scope of individuals concerned with safe air travel forces the constant surveillance of accidents and incidents by the Federal Aviation Administration (FAA) government agency, National Transportation Safety Board (NTSB), researchers, and public attention through media. In 2008, Southwest Airlines gained some unwanted attention when the largest fine in FAA history was issued of 10.2 million dollars for allegedly flying at least 117 of its planes in violation of mandatory safety checks (Levine, 2008; Griffin & Bronstein, 2008). Not only does this place increased attention towards Southwest Airlines, but also places scrutiny ten -fold in maintenance departments within all commercial airlines.

Although maintenance-related accidents are far less frequent than accidents caused by pilot error, the end result can be just as fatal. Maintenance personnel, pilots, Air Traffic Controllers (ATC), and Flight Dispatchers are just a portion of the people dedicated to ensure a flight travels safely from departure to arrival. While there are several facets impacting the safety of a flight, it begins on the ground with the Aviation Maintenance Technician (AMT), also known as Airframe and Powerplant (A & P) mechanic.

Overarching Research Questions

1. How many aircraft accidents with at least one fatality have occurred due to maintenance error from 1996 through 2006?

2. What human factors and to what extent do human factors affect a mechanics, AMT, ability to safely conduct maintenance?

3. What are some cost-efficient solutions to decrease the effects of human factors which would result in an increase in aviation safety?

Review of Related Literature

Various Human Factors that Influence Mechanic Performance

As far back as the first powered flight by the Wright Brothers flight in 1903, humans have built and flown aircraft which means human error has always played a role in safety. However, it was not until 1988, when the skin of an Aloha airlines Boeing 737 ripped open in flight, did the FAA conduct the first official safety meeting with respect to aircraft maintenance activities (Lu, 2003). Since then, the boom in human factors research proves that researchers, along with the FAA, understand the influence human factors holds on mechanics performance.

In efforts to place top priority on human factors, in the year 2000 the FAA issued an Advisory Circular (AC) 120-72 titled Maintenance Resource Management training. Within this document, the FAA defines human factors as the scientific study of the interaction between people and machines. The FAA coined the phrase Dirty Dozen, which identifies the twelve most common maintenance-related causes of errors. The Dirty Dozen are as follows: Lack of communication, complacency, lack of knowledge, distraction, fatigue, lack of resources, pressure, lack of awareness, lack of assertiveness, stress, norms, and lack of teamwork.

A less common, yet still insightful, cognitive model of maintenance error was developed by Alan Hobbs with the Bureau of Air Safety Investigation (BASI). Mr. Hobbs research identified the following eight types of errors and the frequency in which they occurred: memory lapse, work-arounds, situational awareness, expertise, action slips, work practice, technical inaccuracy, and perceptual difficulties. The most common error, memory lapse, occurred in 24% of the 127 errors reported by maintenance personnel. Following closely behind at 23%, the second most frequent type of error was the work-around errors. These errors include an individual's knowledge of the correct procedure, but belief it would be all right this time. An example is performing a task in a more convenient manner than that specified in the maintenance manual. Pressures to complete a task within a certain time frame also influence how a mechanic does his/her job. When faced with time pressures, many AMT's decided not to document their actions and failed to perform all the necessary steps in a task (Hobbs, 2000). Unfortunately, there is no way to completely eliminate time pressures because the AMT's that can perform the tasks quickest receive the most business resulting in higher profit.

Due to the fact that human error is inevitable, organizations and companies need to move from blaming an individual worker to implementing a systemic approach to handle maintenance errors (Hackworth, Holcomb, Banks & Schroeder, 2007). In 1996, Boeing developed the Maintenance Error Decision Aid (MEDA) process to "help airlines shift from blaming maintenance personnel for making errors to systematically investigating and understanding contributing causes" (Graeber, nd) . The three principles behind the MEDA principles are: positive employee intent, contribution of multiple factors that contribute to an error, and manageability of errors. With the MEDA process, the traditional way of investigating errors by finding a person to blame is replaced with the new effective method of learning what factors contributed to the error in order to prevent further mishaps.

Methodology

Participants

During the 2008 Mid-South Aviation Maintenance seminar, an FAA official announced the purpose of the research and informed the audience the location in which the researcher was located for voluntary participation in a human factors mechanic survey. AMT's approached the researcher to obtain the survey and was instructed to drop off the survey in an assigned container. Attached to the top of each survey was a university approved consent form along with an explanation for the need of the research. In addition, contact information was provided if the participant had questions regarding the survey or the study. There were 18 surveys collected with the participant average age approximately 46 years old, ranging from 26 through 67 years old. The research process also included open-ended interviews with FAA officials in which the researcher recorded notes in a journal along with tape-record of interviews.

Design Approach and Instruments

The purpose of the study was to learn what type of human factors affect AMT's performance and to what extent have human factors impacted the safety of the aviation industry. Due to the nature of the inquiry process, the researcher determined that a qualitative approach was necessary for the study. Wiersma and Jurs (2005) describe qualitative research as an inductive inquiry process without any preconceived theories or hypotheses for the data collection. The inquiry process included: a) designing and collecting human factors AMT survey, b). conducting interviews with FAA officials, and c). collecting and reviewing the NTSB online aviation accident database. Qualitative data analysis included condensing and organizing the data sets into categories that can be analyzed and placed in emerging categories, themes, and patterns (Gough & Scott, 2000, Wiersma & Jurs, 2005). After all the data was collected, the qualitative data coding began, and the key categories, themes, and patterns are reported in the findings and conclusions of the study.

During data analysis, a triangulation matrix was utilized to ensure focus on the three overarching research questions. The triangulation matrix is listed in Table 1.

Table 1. *Triangulation Matrix*

Overarching Question	Data set	Data Set	Data Set
How many aircraft accidents with at least one fatality have occurred due to maintenance error from 1996 through 2006?	**NTSB online aviation accident database	Researcher field journal	AMT Human factors survey
What human factors and to what extent do human factors affect a mechanics, AMT, ability to safely conduct maintenance?	**AMT Human factors survey	Interviews with FAA officials	Researcher field journal
What are some cost-efficient solutions to decrease the effects of human factors which would result in an increase in aviation safety?	**Interview with FAA officials	Researcher field journal	AMT Human factors survey

*** Indicates the data set largely responsible for answering the overarching question*

Data Analysis

Survey and Interviews

Once all the data was collected, the researcher began the qualitative data analysis. Given that qualitative research analyzes words, not numbers, it is critical to carefully analyze the data and then revisit the data for further analysis for possible categories, trends, and connections between categories (Ratclilff, 2008). In order to stay on course, data was organized into categories relating to the overarching research questions. Quantitative descriptive statistics was incorporated with the analysis of the AMT human factors survey. The procedure for analyzing the data from the interviews with the FAA were also analyzed for common themes as well as any other important responses the researcher felt would address the research questions.

National Transportation Safety Board Aviation Accident Database

To determine the number of maintenance-related aircraft accidents that resulted in at least one fatality for the ten year span of 1996 through 2006, a review of the National Transportation of Safety Board's (NTSB) aviation accident database was necessary. Each maintenance-related accident was copied from the website into a computer document and reviewed for emerging themes and categories. Just because a mechanical failure occurs during flight does not indicate it was the error of an AMT. For example, there were several accidents caused because of engine failure, in-flight separation of parts, and fatigue cracks. These were not accounted for as maintenance-related accidents unless the report specifically cited the fault of maintenance, such as improper or inadequate maintenance.

Findings

Synopsis of Research Findings

With the extensive research of the National Transportation of Safety Board's (NTSB) aircraft accident online database, the most accidents and fatalities occurred within part 91 General Aviation operators. From 1996 through 2006, there were 141 accidents resulting in a tragic 215 fatalities. This should serve as a warning that general aviation needs to improve aircraft maintenance programs. While there were 132 fatalities in part 121 Air Carrier operator, this occurred in only five accidents over a ten year span. Unfortunately, when a part 121 aircraft has an accident the results are generally more severe because of the large number of passengers on board.

Data analysis of the three data sets revealed there were common themes emerging from twelve categories. The top four mechanical errors with the highest number of fatalities in order were: a).failure to properly complete tasks, b).improper maintenance, c).improper installations and d). failure to detect or identify problems that occurred over an extended period of time. The following are the four most common categories of errors along with the attributes assigned for each category:

- I goofed : Accidents that fall under this category listed the probable cause or contributing factors as *failure* to properly complete the maintenance task. This category includes failure to properly torque, lubricate, attach, secure, tighten, adjust, rebalance or balance, and failure to install various parts.
- Failure to maintain: Indicates an accident occurred due to improper maintenance by maintenance person(s) or person acting as a mechanic such as owner/builder. Attributes for this category are as follows: improper maintenance, improper replacement ,misrouting of fuel lines, improper assembly, improper construction ,improper shimmying, misalignments, improper modification, and improper repair.
- Who needs directions?: Accidents that occurred from improper installations indicates the maintenance instructions or directions were not properly followed by the mechanic. A few examples include: improper installation of cylinders, fuel line, oil pump, and magneto contact points.
- Detective needed: The researcher discovered there were several accidents that occurred from failure to detect or identify problems that occurred over an extended period of time. While these issues are not always easy to detect, failure to notice these often subtle issues during inspections can lead to serious repercussions. The accidents occurred from failure to detect or identify fatigue cracks, corrosion, erosion, worn cables, and fretting in propeller blade.

Table 2 lists the categories along with the number of fatalities and type of operations for each category, and Table 3 provides number of accidents for various types of operations along with the associated fatalities.

Table 2. *Number of fatalities and type of operation for each accident category*

Categories	Number of fatalities	Type of operation
I goofed	**123**	Part 91 General Aviation Part 121 Air Carrier Operator Part 135 Air Taxi & Commuter Part 137 Agricultural
Failure to maintain	69	Part 91 General Aviation Part 121 Air Carrier Operator Part 135 Air Taxi & Commuter Part 137 Agricultural
Who needs directions?	53	Part 91 General Aviation Part 135 Air Carrier Operator
Detective needed	43	Part 91 General Aviation Part 121 Air Carrier Operator Part 133 Rotorcraft External Load Part 135 Air Taxi & Commuter Part 137 Agricultural

Table 3. Number of fatalities within the type of operation

Number of fatalities	Type of operation	Number of accidents
215	Part 91 General Aviation	141
132	Part 121 Air Carrier Operator	5
25	Part 135 Air Taxi & Commuter	10
5	Part 137 Agricultural	4
2	Part 133 Rotorcraft External Load	2

The human factors that were most prevalent among the attitudes of both AMT's and the FAA officials were demanding deadlines, environmental and personal distractions, and lack of proper use of maintenance manuals or instructions. According to the AMT human factors survey, the top four distractions are as follows:

- 66% Cold/hot hangar temperatures
- 66% Interruptions while performing a task
- 44% Disorganization (having to track down proper manuals, tools, etc.)
- 38% Lack of resources

The most frequent stresses experienced at work are as follows:

- 61% Demanding Deadlines
- 50% Sick while at work
- 50% Tension among employees and/or employer
- 38% Excessive workloads

Combing the survey results and FAA interviews, the researcher discovered AMT's are not always following the appropriate manuals and rather performing tasks my memory. When asked how frequently do you perform a task from memory if it is a familiar task these were the responses:

- 61% Yes, I perform a task from memory if it is a familiar task.
- 16% No, I do not perform a task from memory even if it is a familiar task.
- 22% On occasion I perform a task from memory if it is a familiar task.

Suggestions for Improving Practice

All of the aforementioned human factors, as well as any other human factor that affects a mechanic's ability to safely perform tasks, must be taken seriously by mechanics, supervisors, FAA and NTSB officials, the United States government, and the general public. Safety should longer be compromised because of the desire to make profit. Maintenance safety training should no longer be voluntary, but rather made mandatory by Federal Aviation Regulations (FAR's). Why do certain errors seem to repeat themselves in the aviation industry? Perhaps errors occur because of pressure from management to complete a task and release the aircraft to the owner, or the AMT has some type or personal distraction that takes his focus off of correctly installing a part. The NTSB accident database does not report what caused the mechanic to make the error, but rather reports the specific error linked to the accident. Simply put- because mechanics are human there will always be human factors affecting their performance. The more awareness and training a person receives the more likely they are to recognize when human factors are affecting performance and take proper action to handle the situation.

References

Federal Aviation Administration. (2002). Advisory circular 120-72-*Maintenance Resource management training.* Washington, DC: Author.

Gough, S., & Scott, W. (2000). Exploring the purposes of qualitative data coding in educational enquiry: Insights from recent research. *Educational Studies, 26*(3).

Graeber, C. (n.d.) *The role of human factors in improving aviation safety.* Retrieved April 16, 2008, from http://www.boeing.com/commercial/ aeromagazine /aero_08/human_textonly.html

Griffin, D., & Bronstein, S (2008, March 7). *Records: Southwest flew 'unsafe' airplanes.* Retrieved April 5, 2008 from http://www.cnn.com/2008/US/03/06/southwest.planes/

Hackworth, C., Holcomb, K., Banks, J., & Schroeder, D. (2007). A survey of maintenance human factors programs across the world. [Electronic version]. *International Journal of Applied Aviation Studies, 7,* 212-229.

Hobbs, A. (2000). Maintenance human factors: Learning from errors to improve Systems. *Proceedings of the Fourth Australian Aviation Psychology Symposium*: *Vol. 2. Aviation Resource Management* (pp.347-355). Vermont: Ashgate.

Levin, A. (n.d.). FAA to check maintenance at all airlines. *USA Today*, Retrieved April 8, 2008, From Academic Search Premiere database.

Lu, C. (2003). An inductive study regarding nonregulatory maintenance resource management (MRM) training (Dissertation, The University of Nebraska at Omaha, 2003 UMI No. 3087733)

National Transportation Safety Board (NTSB). (2000). *Annual review of aircraft accident database. U.S. General Aviation, calendar year 2000*. Retrieved March 8, 2008, from http://www.ntsb.gov/publictn/2004/ARG0401.pdf

National Transportation Safety Board (NTSB) website. (n.d.) Accident database and synopses. Retrieved from http://www.ntsb.gov/ntsb/query.asp

Ratcliff, D. (2008, April/July). Qualitative data analysis and the transforming moment. *Transformation, 25.2 & 3.*

Wiersma, W., & Jurs, S. (2005). *Research methods in education. An introduction (8th ed).* Boston: Pearson Education, Inc