Use of the Maintenance Error Decision Aid (MEDA) to Enhance Safety and Reliability and Reduce Costs in the Commercial Aviation Industry

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INTRODUCTION

Cost competition in the commercial aviation industry has increased greatly in the past few years putting the squeeze on air carrier profitability. In order to reduce costs, Engineering and Maintenance organizations are being challenged to improve maintenance efficiency to reduce costs while maintaining or increasing safety and reliability standards. One method for helping achieve these goals is a structured maintenance error investigation process to reduce human errors that have costly outcomes, e.g., air turnbacks, gate returns, and flight cancellations (Allen and Rankin, 1995a).

Major interest in the scientific study of human error began following the Three Mile Island (TMI) nuclear power plant accident in the USA in the spring of 1979. According to Woods et al. (1995), the cross-disciplinary national and international scrutiny of human error began with the "clambake" conference on human error in Columbia Falls, Maine, in 1980 and with the publications on slips and lapses by Norman (1981) and Reason and Mycielska(1982). In addition, work in the area of human reliability, for example, by Swain and Guttman (1983) and Swain (1987), began in the late 1970s and accelerated following TMI (see Gertman and Blackman, 1994).

More recently, there has been an interest in studying human error in airline maintenance. For example, the United Kingdom Civil Aviation Authority (UK CAA, 1992) released a study on the top eight maintenance problems affecting aircraft over 5,700 kg. in weight. More recently, the relationship of pilot crew error and maintenance crew error to commercial aircraft accidents has been evaluated (see Boeing, 1993; 1995). For purposes of studying maintenance human error, maintenance error is defined as the action or inaction of an aircraft maintenance technician that leads to an unexpected aircraft discrepancy (physical degradation or failure) (Graeber and Marx, 1993).

The UK CAA (1992) study found the major types of maintenance error included:

1. Incorrect installation of components

2. The fitting of wrong parts

3. Electrical wiring discrepancies

4. Loose objects (tools, etc.) left in the aircraft

5. Inadequate lubrication

6. Cowlings, access panels, and fairings not secured

7. Fuel/oil caps and refuel panels not secured

8. Landing gear ground lock pins not removed before departure

A more recent Boeing study (1995) found that 15% (39 of 264) of commercial aviation accidents from 1982 through 1991 had maintenance as a contributing factor. More specifically, 23% of the 39 accidents had removal/installation as a contributing factor, 28% had the manufacturer or vendor maintenance or inspection program as a contributing factor, 49% had the airline maintenance or inspection program policy as a contributing factor, and 49% had design as a contributing factor. Other important contributing factors included: manufacturer/vendor service bulletins and in-service communication (21%), airline service bulletin incorporation (21%), and missed discrepancy (15%).

Even if everyone agrees that intentional malevolent behavior should not be included in the study of human error, the phrase "human error" still carries negative connotations - connotations that can hinder the in-depth study of the causes of error and error management (e.g., Woods et al., 1995; Reason, 1990; Lorenzo, 1990). This is because most people attribute the causes of human error to the person rather than to the environment. Reason (1990) discusses this phenomenon as the "blame cycle." He believes that we attribute blame to people and not situations because of the Western culture's illusion of free will and the ability to determine one's own destiny. We can break out of the blame cycle only if we:

- Recognize that human performance is shaped by the situation or environment
- Recognize that errors have multiple contributing factors
- Recognize that situations are often more easy to change than people.

Woods et al. (1995) are also concerned about the prejudicial effect that comes from labeling a cause of an accident as human error. One reason is that saying that an accident was due to human error is often seen as the causal explanation for the accident. It can restrict the true investigation that should occur, which is to determine what the interaction was between the person, the equipment, and other situational variables that lead to the error.

These situational variables that contribute to the error have also received much investigation, especially by those working in the Human Reliability Assessment (HRA) and Probabilistic Risk Assessment (PRA) field. Swain and Guttman (1983) have an in-depth list of these variables, which they call performance shaping factors (PSFs). They distinguish among these types of PSFs. External PSFs include situational characteristics (e.g., heat, lighting, supervision, and shift rotation), job and task instructions (e.g., procedures and shop practices), and task and equipment characteristics (e.g., task complexity and human machine interface issues). Examples of internal PSFs include previous training/experience, intelligence, and motivation. Stressor PSFs include psychological stressors (e.g., task speed, monotony, and distraction) and physiological stressors (e.g., fatigue, pain, and disruption of circadian rhythm).

The important thing about PSFs within the HRA/PRA framework is that they are seen as contributing to the cause of the human error. Thus, the concept of PSFs can be used to help break the blame cycle. An obvious second important aspect of PSFs is that they help indicate where changes are needed to reduce human error. Swain has estimated (see Lorenzo, 1990) that only 15-20% of workplace errors are caused by internal PSFs, while the remaining 80-85% are primarily caused by external PSFs and stressor PSFs, many of which are directly under management control.

Thus, it is not surprising that the concept of PSFs or contributing factors is used as a basis for error reduction programs. For instance, Lorenzo (1990) lists the Swain and Guttman (1983) PSFs, and then discusses many of them point-by-point as to how to enhance a PSF in order to minimize human error in the chemical industry. As another example, McDonald and White (McDonald, 1995; White, 1995a; White, 1995b) looked at the PSFs that lead to airport ramp accidents/incidents and developed a ramp safety program based on changes to these PSFs.

As noted earlier, the study of human error in aircraft maintenance is still in its infancy. Data now exists (Figure 9-1 and 9-2, appendix) to show that maintenance error is a contributing factor in aircraft accidents/incidents. There are also some data to indicate what types of errors are occurring. However, what is now needed with regard to maintenance human error is to collect empirical data on the types of errors that are occurring, their consequences, the PSFs that contribute to that error, and intervention strategies for preventing future errors attributable to the same PSFs. That is the purpose of the Maintenance Error Decision Aid (MEDA).

THE MAINTENANCE ERROR DECISION AID TOOL

MEDA was developed over a two-year period by a team of airline representatives, regulators, and Boeing maintenance human factors personnel. The objectives of MEDA are to:

- Provide a better understanding of how performance shaping factors contribute to maintenance error

- Provide maintenance organizations with a standardized methodology for analyzing maintenance error, its causes, and intervention strategies

- Provide a means of error trend analysis for the commercial airline maintenance organizations.

The MEDA tool consists of the Results Form (a paper tool used in the error investigation), a User's Guide to facilitate the investigation process, and Supplemental Assessment Information to facilitate the use of the Results Form. The Results Form consists of five major sections:

1. General
2. Events
3. Maintenance Error
4. Contributing Factors
5. Corrective Actions

The General section asks for information about the aircraft, the airline, the analyst, and where and when the incident occurred. The Event section asks for the type of ***event*** that triggered the MEDA investigations. Events include flight delay, flight cancellation, gate return, in-flight shut down, air-turn-back, aircraft damage, injury, diversion, and rework. The Maintenance Error sections asks the investigator to check the one type of maintenance error that caused the incident. The major categories of error include improper installation, improper servicing, improper/incomplete repair, improper fault isolation/inspection/testing, foreign object damage, surrounding equipment damage, and personal injury.

The Contributing Factors section is used to help guide the analyst in thinking about what performance shaping factors affected technician performance resulting in a maintenance error. There are ten major categories of contributing factors, and each category has several examples in checklist format. The major categories include: information, equipment/tools/parts, airplane design/configuration, job/task, technical knowledge/skills, factors affecting individual performance, environment/facilities, organizational environment issues, leadership/supervision, and communication issues.

The Corrective Actions section includes three sub-sections. The first sub-section asks whether existing maintenance procedures, inspection or functional checks, maintenance documentation, supporting documentation, or company maintenance policies were intended to prevent the error but didn't, and how this could be resolved. The second and third sub-sections ask, respectively, for local corrective actions and other corrective actions that can be taken.

FIELD TEST EVALUATION

In order to evaluate the MEDA tool and process before beginning implementation at customer airlines, eight domestic and international air carriers and one repair station agreed to participate in a Field Test (Figure 9-3, appendix). The Field Test training and evaluation were carried out under FAA contract over a period of eight months from November, 1994, to July, 1995 (see Allen and Rankin, 1995b). Employees from these organizations were trained to use the MEDA process in a 3 to 8 hour training session, which included a case study exercise.

Three methods were used to collect Field Test evaluation data. First, five questionnaires were filled out by participating personnel regarding work environment, causes of maintenance error, and perception of error investigations. Second, the nine participating organizations used the MEDA Results Forms to investigate maintenance error event occurrences. Seventy-four completed Results Forms were sent to Boeing for analysis during the data collection period. In addition to quantitative analysis, data from completed Results Forms were analyzed to determine whether the forms were being filled out logically and consistently. Third, meetings were held mid-point through the Field Test and approximately six weeks after the end of the Field Test to get feedback from representatives of the participating organizations.

The Field Test found a wide variation in the manner in which MEDA was implemented in the participating organizations. Two of the organizations never fully implemented MEDA. The others implemented MEDA in various ways regarding which maintenance organization carried out the investigations, what types of events triggered an error investigation, and how corrective actions were implemented.

The evaluation surveys found that respondents generally agreed that the MEDA Results Form helped them with their error investigation and that it was easy to use. A large majority of the respondents believed that MEDA will have a positive impact on their maintenance organization, although they are much less certain that MEDA will reduce punishment for making errors or that MEDA will cause new corrective actions to be taken. The experience of the erring technician in the error investigation was positive. They did not feel intimidated during the investigation, they felt that the purpose and philosophy of the process was made clear to them, and they believed that MEDA would improve their work environment. However, they were not certain whether corrective actions would be taken. Managers agreed fully with the MEDA philosophy, understood how MEDA was being implemented at their airline, felt that there was strong acceptance of MEDA by airline management and technicians alike, strongly supported MEDA themselves, and felt that it was important for other airlines to adopt MEDA and to share MEDA data.

Seventy-four completed Results Forms were sent to the Boeing team members for analysis.

(Figure 9-4, appendix) graphs the operational events that triggered the MEDA investigations. Flight delays (22), aircraft damage (17), and air turn backs (11) were the major triggering events. The 11 "other" events included workshop errors, vendor problems, and a few events that probably could have been described by the existing event types in the Results Form but were coded "other" by the investigators.

(Figure 9-5, appendix) graphs the types of maintenance errors that caused the event. Improper installation (26 errors) was, by far, the major error type, which was followed distantly by improper fault isolation/inspection/testing (11 errors), and improper servicing (9 errors). Of the 17 "other" maintenance errors, eight were related to errors that caused ground damage.

(Figure 9-6, appendix) graphs the factors that contributed to the errors. There was an average of 3.2 major categories of contributing factors selected per Results Form. Information was a contributing factor in 50% of the investigations, followed closely by communications (43%), job/task (42%), environment/facilities (38%), factors affecting individual performance (35%), qualification/skills (31%), airplane design/configuration (30%), equipment/tools/parts (27%), organizational environment (26%), and supervision (16%). It is interesting to compare these empirical data with the survey opinions of the managers and investigators concerning which of these factors was most likely to contribute to error. The managers and investigators correctly believed that information and communication were high in importance. However, they greatly overestimated the importance of supervision and qualification/skills, and they underestimated the importance of environment/facilities and factors affecting individual performance.

Two meetings were held during and immediately after the Field Test to get suggestions for improvement from the participating organizations. A major recommendation, regarding the presentations/training needed for implementation at other airlines, was that three separate presentation/training packages be developed: a senior management presentation, and investigator training package, and a maintenance team briefing.

CONCLUSIONS AND RECOMMENDATIONS

In conclusion, the Field Test evaluation determined that the MEDA objectives were met. The MEDA tool and investigation process did provide an easy-to-use standardized investigation methodology to airline maintenance organizations. However, it took the participating airlines longer to implement MEDA than first anticipated. Determining the events that will trigger a MEDA investigation, assigning MEDA administrative responsibility to an organization, selecting and training MEDA investigators, and (especially) setting up a corrective action process and feedback mechanism were time consuming and were impacted by the organizational climate.

The MEDA tool also helped uncover maintenance system deficiencies. All of the participating airlines had successfully solved maintenance error problems using MEDA.

Finally, the educational process that was used for implementation did provide maintenance personnel with a better understanding of how human performance is influenced by local and organizational factors. Trend analyses were begun by the participating airlines, although additional data are needed for these analyses to be more useful.

Several recommendations resulted from the Field Test. Air carriers should continue to promote the use of event-driven analysis tools to foster error management within their organizations. MEDA Field Test participants should continue to use the MEDA tool in its present or customized form. Industry should also continue to develop modular human factors-based training programs (modeling successful CRM concepts) to complement the use of technology-enhanced, event-driven analysis tools and to promote organizational recognition of error producing factors and the importance of team work in error management.

Issues that inhibit maintenance error reporting and analysis within individual organizations and industry-wide must be addressed by the individual organizations, where applicable, and within industry by its governing bodies. These issues include, but are not limited to:

- A uniformly accepted limited immunity policy governing technician participation in these event reporting programs, consistent with the standard established for similar flight operations programs
- Definition of an acceptable standard of organizational disciplinary action to complement a limited immunity policy and the use of event-driven analysis tools.

Also, Boeing should develop three presentation/training packages for future MEDA implementation: the first to present the concept to senior management to gain their support and to lay out the organizational model required to implement MEDA successfully; the second to train the selected MEDA investigators; and the third to present the MEDA process to the maintenance technicians and their management to allay fears regarding punitive actions, to inform them about how the investigation process is carried out, and to discuss the benefits of MEDA.

Boeing is now making the MEDA tool available to customer airlines to help them improve their maintenance operations and as a means to more efficiently communicate with Boeing about events that have design or manufacturing as a contributing factor. The Boeing Maintenance and Ground Operations Systems (MGOS) group within Customer Services Division will assist customer airlines with training and implementation of the MEDA process. Air carriers interested in MEDA may contact MGOS through their Boeing Field Service Representative.

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APPENDIX

Figure 9-1: Airlines with 500,000 - 1 Million Engine Hours

Figure 9-2: Airlines with over1 Million Engine Hours

Figure 9-3: Field Test Participants

Figure 9-4: Operational Events

Figure 9-5: Maintenance Error Types

Figure 9-6: Contributing Factors