THE MAINTENANCE ERROR DECISION AID (MEDA) PROCESS

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Maintenance and inspection errors have been the primary cause of six percent of aircraft accidents and have contributed to an additional nine percent of the accidents from 1982 through 1993. What can maintenance organizations do to reduce these types of errors? This paper discusses the development and evaluation of a maintenance error investigation process--the Maintenance Error Decision Aid (MEDA). MEDA was developed based on the following philosophy: maintenance technicians do not make errors on purpose; errors result from a series of related contributing factors, and; these factors are largely under management control and, therefore, can be improved to prevent future, similar errors. The MEDA process was field tested at nine maintenance organizations. After a one-day training course, airline personnel were able to carry out a successful MEDA investigation to determine and correct contributing factors to error. An average of 3.4 contributing factors was found per error. Since the end of the field test, Boeing has provided MEDA implementation support to over 120 aircraft maintenance organizations around the world. Feedback suggests that all organizations using MEDA have found cost-effective solutions to maintenance error.

INTRODUCTION

Airplane maintenance errors have safety and economic costs. A study by Boeing and the U. S. Air Transport Association members (Boeing/ATA, 1995) found that maintenance error was one factor, typically among a series of factors, that contributed to 39 of 264 (15 percent) commercial jet aircraft hull loss accidents from 1982 through 1993. These 39 accidents resulted in 1,429 on-board fatalities. Additionally, maintenance error was the primary cause of 6 percent of the worldwide commercial jet hull loss accidents (Boeing, 1998).

Combined results from a Boeing internal study and a study by one engine manufacturer, discussed by Rankin and Allen (1995), estimated the percentage of specific engine events caused by maintenance error and the economic costs of those events to the airlines:

- 20 percent to 30 percent of engine in-flight shutdowns at an estimated cost of US$500,000 per shutdown,
- 50 percent of engine-related flight delays at an estimated cost of US$10,000 per hour of delay,
- 50 percent of engine-related flight cancellations at an estimated cost of US$50,000 per cancellation.

Boeing analyzed engine in-flight shut down rates on Boeing airplanes due to maintenance error (comparing fifteen different air carriers with over 1,000,000 hours of engine operation). The study found that the rates differed by a factor of sixteen between the lowest (0.0005 shutdowns per thousand hours) and highest (0.008 shutdowns per thousand hours) rates. Clearly, some airlines manage these types of maintenance errors better than others do.

Given that maintenance error can have safety and economic impact, what can be found in the literature regarding errors and error prevention? Major interest in the study of human error began following the Three Mile Island (TMI) nuclear power plant accident in the spring of 1979. The study of human error in aviation maintenance began with the publications on slips and lapses by Norman (1981) and Reason and Mycielska (1982). In addition, work in the area of human reliability (e.g., Swain and Guttman, 1983; Swain, 1987), began in the late 1970s and accelerated following TMI (see Gertman and Blackman, 1994). The studies dealing with factors that lead to error lend themselves to the development of a process for investigating errors and determining what actions need to be taken to prevent or reduce the likelihood of future, similar errors.

However, in order to move in this direction, it is necessary to overcome the negative connotations about human error, which can hinder the in-depth study of the causes of error and error management. Woods et al. (1995) are concerned about the prejudicial effect that comes from labeling a cause of an accident as human error. One reason is that attributing an accident to human error is often seen as the causal explanation for the accident. This can restrict the true investigation that should occur, which is to determine what interaction between the person, the equipment, and other situational variables lead to the error.

These situational variables have also received much investigation, especially by Swain and Guttman (1983) in their development of human reliability analysis tools. They called these situational variables performance shaping factors (PSFs), and they analyzed how PSFs affected human error estimates. They list three major types of PSFs within their framework: 1) external PSFs, 2) internal PSFs, and 3) stressor PSFs.

Swain (see Lorenzo, 1990) and Bird and Germain (1996) believe that only 15-20 percent of workplace errors can be controlled by individual employees, while the remaining 80-85 percent are under control of management. One important aspect of PSFs is that they are seen as contributing to the cause of 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.

Thus, PSFs are used as a basis of most error reduction programs. Lorenzo (1990), in discussing a human error reduction program for the chemical industry, lists the Swain and Guttman (1983) PSFs and then discusses ways to enhance a given PSF in order to minimize human error. McDonald and White (McDonald, 1995; White, 1995a; White 1995b) looked at the PSFs that lead to airport ramp accidents and incidents and developed a ramp safety program based on changes to these PSFs.

MEDA PROCESS DEVELOPMENT

Boeing staff, along with representatives from British Airways, Continental Airlines, United Airlines, the International Association of Machinists, and the U. S. Federal Aviation Administration, met over a period of 18 months to develop the Maintenance Error Decision Aid (MEDA) process for investigating maintenance errors. Two associated products were developed: a Results Form and a User's Guide.

The main investigation tool is the MEDA Results Form. The Results Form consists of five sections: 1) General Information, 2) Event, 3) Maintenance Error, 4) Contributing Factors, and 5) Error Prevention Strategies. The General Information section contains spaces to report such things as airplane identification information, engine type, the MEDA investigator, and dates of the error and of the error investigation.

The Event section contains a listing of potential events, which, if caused by maintenance error, would initiate a MEDA investigation. The events selected by the development team include flight delays, flight cancellations, gate returns, in-flight engine shut downs, air turn backs, aircraft damage, flight diversion, rework, and injury to maintenance technicians.

The Maintenance Error section lists the errors that could occur and lead to an event. The major error headings include: improper installation, improper servicing, improper/incomplete repair, improper fault isolation/inspection/testing, actions causing foreign object damage, actions causing surrounding equipment damage, and actions causing personal injury.

The Contributing Factors section contains situational variables that could contribute to maintenance error. The contributing factors were based on the Swain and Guttman (1983) PSFs, but the PSFs were recategorized and presented in a manner recognizable and easily usable by airline maintenance personnel. Ten categories were developed:

1. Information—written or computerized source information used by maintenance technicians to do their job, e.g., maintenance manuals, service bulletins, and maintenance tips
2. Equipment, tools, and parts
3. Airplane design and configuration
4. Job and task
5. Technical knowledge and skills
6. Factors affecting individual performance—e.g., physical health, fatigue, time constraints, and personal events
7. Environment and facilities
8. Organizational environment issues—e.g., quality of support from other Maintenance and Engineering organizations, company policies and processes, and work force stability
9. Leadership and supervision—e.g., planning, organizing, prioritizing, and delegating work
10. Communication—e.g., written and verbal communication between people and between organizations.

The Error Prevention Strategies section requires the investigator to list the existing procedures, processes, and policies in the maintenance organization that were intended to prevent the error, but did not [see Reason's (1990) barriers to error]. A second section provides space for writing in potential improvements to the contributing factors so that the factors do not contribute to future, similar errors.

The eight-step MEDA process is shown in Figure 1. A few comments are needed about this process. First, an event must occur in order to start a MEDA investigation. Second, although it is necessary to determine who made the error since a MEDA investigation is dependent upon an interview with this person (or persons), the MEDA Results Form does not include a place for the maintenance technician's name (the philosophy is "blame the process, not the person").

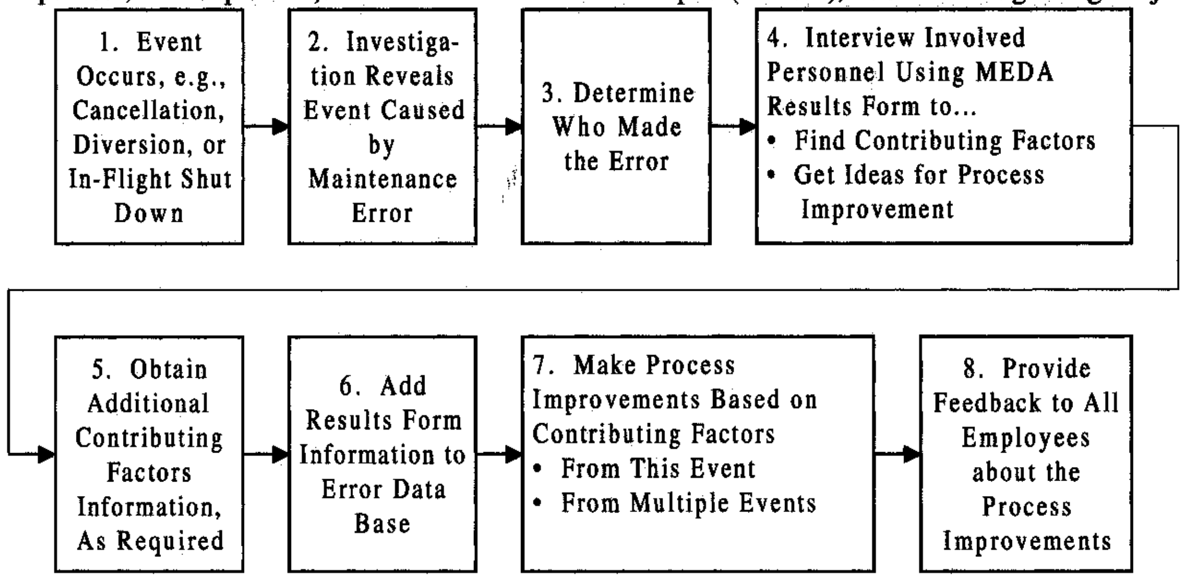

Figure 1. Maintenance Error Decision Aid process flow.

A User's Guide was developed to explain how to carry out a MEDA investigation using the Results Form and to provide numerous examples of contributing factors to the investigators. Finally, MEDA presentations were developed to inform airline maintenance management about the process and to train MEDA investigators.

The MEDA process was field tested at eight airlines and one repair station. An evaluation was conducted to determine whether the process was useful to the maintenance organizations.

FIELD TEST RESULTS

Seventy-four completed Results Forms were sent by the field test participants to Boeing for analysis. The frequency of the Operational Events that were investigated were: flight delay (22 events), aircraft damage (17 events), air turn back (11 events), flight cancellation (7 events), rework (5 events), in-flight shutdown (4 events), gate return (3 events), injury (2 events), and other (11 events). The other events included workshop errors, vendor problems, and a few events that probably could have been described by an existing event type, but were coded as "other" by the investigators. The number of events added to more than 74, since more than one event could be caused by the error (e.g., in-flight shut down followed by an air turn back).

The types of errors that lead to the operational events included: improper installation (26 errors), improper fault isolation/inspection/testing (11 errors), improper servicing (9 errors), improper/incomplete repair (3 errors), actions causing foreign object damage (2 errors), actions leading to personal injury (1 error), other (17 errors), and no maintenance error reported (5 errors). Of the 17 other errors, 8 were related to errors that caused ground damage. The no maintenance error recorded was an incorrect use of the Results Form.

The MEDA philosophy is that errors are caused by a series of contributing factors. The field test results supported this theory. For the 74 error investigations, information was a contributing factor to 37 of the errors, followed by communications (32), job/task (31), environment/facilities (28), factors affecting individual performance (26), technician knowledge/skills (23), airplane design/configuration (22), equipment/tools/parts (20), organizational environment (19), and supervision (12). Thus, there was an average of 3.4 major categories of contributing factors per error event (250 contributing factors divided by the 74 error investigations).

After the final field test meeting in August, 1995, improvements were made to the MEDA Results Form, User's Guide, and implementation process based on the airline representatives' comments. Then, Boeing announced its willingness to help customer airlines implement the process (Allen and Rankin, 1995; Rankin and Allen, 1995, 1996). Since October, 1995, Boeing has provided implementation support to over 120 additional aircraft maintenance organizations. These organizations have been encouraged to modify the MEDA Results Form and/or process in order to make it most useful to them. In January, 1997, the authors obtained feedback on maintenance organization use of MEDA in order to determine future implementation efforts. The results of the feedback (Rankin, Allen, and Sargent, 1997) determined that approximately two-thirds of the organizations were using MEDA or their modified version of MEDA.

These organizations all received some positive benefits. Examples of individual airline benefits included: decreasing flight departure delays due to mechanical problems by 16 percent; reducing operationally significant events by 48 percent over two years; improved maintenance processes and reporting of maintenance discrepancies; improved landing gear lock/unlock procedures; customization of human factors awareness training for mechanics; changing discipline policies with regard to mechanic error, and; sensitizing maintenance management to the causes of error.

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