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Classification and Analysis of Errors Reported in Aircraft Maintenance Manuals

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Abstract

Previous research has identified maintenance information as one of the primary causal factors of maintenance error. Incorrect maintenance information has also been cited as a contributing factor in a number of recent aircraft mishaps. To date no one has studied the types of errors found in aircraft maintenance manuals published by manufacturers. The purpose of this research is to analyze Publication Change Requests (PCRs) to document the most frequently reported types of errors found in aircraft maintenance manual, to identify how errors vary across Air Transport Association (ATA) chapters, and identify the corrective actions required to address the cited problem. The most common request was for additional procedural information followed by requests to add or change the language to improve clarity. The results show that the majority of PCRs (42%) cited procedures found in Chapters 27 (Flight controls), 32 (Landing gear), and 71 (Powerplant).

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In 2003, Air Midwest Beechcraft 1900D with 19 passengers and 2 crew crashed shortly after takeoff. The National Transportation Safety Board accident investigation (NTSB, 2004b) revealed that the airplane's elevator control system was incorrectly rigged during a maintenance check restricting the airplanes elevator travel. The report cited Air Midwest's maintenance procedures and documentation as one of four probable causes of the accident. Eight months later, another fatal mishap involving a Beechcraft 1900D occurred due to an incorrectly rigged elevator trim. The National Transportation Safety Board determined (NTSB, 2004a) that the probable cause(s) of the accident were as follows:

> The improper replacement of the forward elevator trim cable, and subsequent inadequate functional check of the maintenance performed, which resulted in a reversal of the elevator trim system and a loss of control inflight. Factors were the flight crew's failure to follow the checklist procedures, and the aircraft manufacturer's erroneous depiction of the elevator trim drum in the maintenance (p 2).

The two accidents illustrate the critical role of maintenance practices and of the supporting maintenance documentation to flying safety. These maintenance related accidents are not isolated events. Analyses of major commercial aircraft accidents that occurred between 1959 and 1983 reveal that maintenance and inspection deficiencies account for 12% to 15% of commercial mishaps and are the fourth leading cause of accidents (Sears, 1986). Maintenance deficiencies account for a similar proportion (e.g., 17%) of naval aviation mishaps resulting in the loss of an aircraft or fatality (Ricci, 2003).

Causal Factors of Maintenance Error

Maintenance errors have a variety of causes and these causes can be organized into three broad categories. There are errors that 1) represent a failure to properly execute a correct plan of action; 2) errors resulting from the execution of an inadequate plan and 3) intentionally choosing a course of action that is a violation of formal rules and established procedures or that deviates from unofficial norms or standard practice (Reason & Hobbs, 2003). In the first case, an error may result from a misidentification of a signal or the failure to detect a defect during inspection. An Aviation Maintenance Technician (AMT) may misread an instrument or fail to detect a crack due to poor lighting or an interruption while performing a visual inspection. In the second case, errors typically arise from the misapplication of a useful rule or the application of a bad rule. For instance, a maintainer may develop a rule regarding what the standard torque values or tolerances for an aircraft component may be but fail to identify exceptions to the rule thereby leading to an error. Alternatively, a maintainer may adopt a habit that becomes part of their routine when performing a maintenance procedure but which has unintended consequences. In the late 1970's at one airline it became standard practice to use a forklift to support the engine/pylon assembly on DC-10s when replacing the assembly (NTSB, 1979). The use of the forklift in some cases caused unintended structural damage that resulted in a subsequent engine separation on takeoff and the loss of one aircraft, its passengers, and crew. Unlike the first two cases, a distinguishing characteristic of violations is that they are often intentional, not with the aim of bringing about bad consequences but rather to circumvent maintenance procedures. These procedures might be incorrect, lacking sufficient detail, unduly complicated, and/or burdensome. In addition, organizational and situational factors including short staffing, lack of appropriate tools, and situational considerations (i.e., on time departure and arrival) may predispose AMTs to engage in such behavior.

Several recent studies have sought to identify and classify the causal factors that contribute to maintenance error (A. Chaparro, Groff, Chaparro, & Scarlett, 2002; Hobbs & Williamson, 2003; Marx & Graeber, 1994; Patankar & Kanki, 2001; Ricci, 2003). Lattanzio, Patankar, and Kanki (2008) analyzed reports from AMTs submitted via the Aviation Safety Reporting System (ASRS) using MEDA (Maintenance Errors Decision Aid), a tool used to investigate and identify contributing factors to maintenance incidents (Rankin, Allen, & Sargent, 1998). The MEDA analysis identified 458 ASRS reports describing a procedural error that were defined as “information not understandable,” “information incorrect,” “information not enough,” “information not used,” and “information unavailable.” They performed a content analysis of the 458 ASRS reports to identify and characterize the top 10% of reports that were most representative of the larger set. This analysis indicated that maintenance information (i.e., procedures in the Aviation Maintenance Manual (AMM), task cards, job cards, service bulletins, etc) was a significant causal factor of maintenance error. Table 1 shows the most commonly reported document deficiencies cited in the reports.

Table 1
The most frequently cited maintenance deficiencies cited in maintenance related ASRS reports.

Document Deficiencies	% (N=46)
Missing information	48
Incorrect Information	19
Difficult to interpret	19
Conflicting information	19

The results of Lattanzio et al. (2008) are in accord with other published findings. McDonald, Corrigan, Daly, & Cromie (2000) conducted a survey on the use of maintenance manual procedures as part of a larger study on organization aspects of safety. Thirty-four percent of their respondents reported performing routine maintenance tasks in ways different from those outlined in the documentation. The two most frequently cited reasons for not following the manual were that there was an *easier* and there was a *faster* method of performing the procedure. Similarly, a survey of Australian maintenance technicians (Hobbs & Williamson, 2000) found that 47% of respondents reported having opted to perform a maintenance procedure in a way they felt was superior to that described by the manual.

Maintenance technicians also cite problems with unclear or confusing procedures. Sixty percent of respondents in one survey (Hobbs & Williamson, 2000) reported continuation of an unfamiliar task despite not being sure if they were performing it correctly and 67% reported they had been misled by maintenance documentation. Chaparro, Groff, et al. (2002) found that 18% of the respondents reported parts being damaged, 20% reported assembling a component incorrectly, and 25% reported having adjusted or rigged a system incorrectly because of unclear or misleading procedures.

Maintenance Manual Regulatory Requirements

Federal Aviation Regulation (FAR) Part 25.1529 (FAA 2008a) outlines the obligation of manufacturers to provide the technical instructions necessary to support continued airworthiness of the aircraft. The manuals must include information about all equipment installed on the aircraft, including equipment made by third party manufacturers. Manual content requirements are also outlined for system descriptions, maintenance and inspection procedures, required scheduled maintenance, and information about system tests and service points.

The organization of the maintenance manual is specified by the Air Transport Association's Information Standards for Aviation Maintenance (Air Transport Association, 2008) which defines the organizational structure of the AMM and the subject matter to be covered in each chapter. For instance, Chapters 27, 32, and 71 only contain information related to Flight Controls, Landing Gear, and Powerplants, respectively. While the Air Transport Association (ATA) format specifies a high level of organization of the AMM, the formatting, content and level of detail found the chapters differs amongst the manufacturers. Although the FAA requires the manufacturers to provide maintenance manuals, precise requirements regarding the content of the manuals are not defined. The manuals must be accepted by the FAA as part of the aircraft's maintenance program, but the procedural content within the manual itself is not approved by the FAA.

According to FAA regulation FAR § 43.13 (FAA 2008b), an AMT is required to follow procedures outlined in the aircraft maintenance manual. However, there are occasions where situational factors may conspire against strict adherence to the AMM. There can be considerable pressure on AMTs to minimize aircraft down time and return it to service (Hobbs & Williamson, 2000). Under these circumstances, mechanics may be more prone to *workaround* an inadequate procedure rather than contact a manufacturer's technical support for clarification of the maintenance procedure. Unlike maintenance errors that results from the incorrect execution or interpretation of a maintenance procedure the term *workaround* refers to situations where a mechanic is *aware* of a problem with an existing maintenance procedure and then relies on their knowledge and experience or that of their coworkers to identify a means of accomplishing the task. Using the terminology of error analysis the *workaround* is a *violation* because it represents a deviation from standard safe operating practices (Reason & Hobbs, 2003) but unlike other types of violations, they are a response to perceived problems with maintenance documentation.

Research Purpose

The majority of corrections to maintenance manuals are made after their publication (A Chaparro & Groff, 2001). Typically, errors are identified by an AMT performing the procedures who may either contact a manufacturer's customer service engineer for correction/clarification or attempt to identify how to perform the procedure. In the former case, the customer service engineer will verify the error, identify a solution, and decide where to submit a Publication Change Request (PCR) to the technical publications department.

PCRs represent an important source of information regarding the quantity, frequency, and distribution of errors found in the AMM. PCRs can offer insight into why AMTs intentionally deviate from the AMM. PCRs are also likely to be more representative of the errors found in maintenance documentation than analyses based on reports of incidents or accidents. The purpose of this research is to analyze user feedback in the form of PCRs, to document the most frequently reported types of errors found in the AMMs, to identify how errors vary across Air Transport Association (ATA) chapters, and identify the corrective actions taken by the OEM. These data could provide valuable information for the development of interventions to improve maintenance documentation and related causal factors in maintenance errors.

Method

Four aircraft manufacturers, including two general aviation business jet manufacturers and two commercial aircraft manufacturers, agreed to provide PCRs for analysis. Manufacturers were asked to provide a chronological sample of up to 200 PCRs. In one case, this sample represented all of the PCRs pertaining to one aircraft model. As part of the agreement to provide PCRs, which are proprietary documents, the manufacturers were assured anonymity. As such, neither the manufacturers nor the aircraft models are associated with the results. Analysis of this data includes the classification of the types of errors reported, the corrective action requested, and the ATA chapter codes of the requested changes. Only PCRs pertaining to the AMM were included in the analysis.

PCRs were classified using an error taxonomy developed previously (A. Chaparro, Rogers, Hamblin, & Chaparro, 2004). The taxonomy classifies each change request into one of four error types (Technical, Language, Procedural, and Graphics) and 15 error reasons (see Table 2). The associated corrective action made to the manual (i.e., add, delete, or change information) was also recorded for each change request.

Table 2
Error taxonomy used for PCR analysis

	Error Type				
	Technical	*Language*	*Procedure*	*Graphics*	*Effectivity*
Error Reason	Tools	Typos	Step(s)	Part diagram	
	Values/ Tolerances	Grammar/ Terminology	Order	Dimensions	
	Parts	Clarity	Alternative method	Caption/Text	
		Incorrect information	Check/Test/Inspection		
			Caution/Warning		

Four researchers coded the comments contained in the PCRs using the error taxonomy. A Cohen's Kappa (κ) of .78 was calculated on a sample of 25 PCRs reflecting an excellent level of consistency between the coders. Values between .40 and .75 represent fair to good, above .75 as excellent, agreement beyond chance (Fleiss, 1981).

Results

A total of 467 PCRs were analyzed. The PCRs contained multiple change requests and each request for change served as a data point. The result was 879 requests for changes, a mean ratio of 1.88:1 (range 2.7 to 1.6:1) change requests per PCR. Due to the unequal number of PCRs collected from each manufacturer, results will be shown as a percent of total by manufacturer. One manufacturer had sufficient requests related to aircraft effectivity, which warranted the creation of a new category. Effectivity pertains to the applicability of a procedure to a specific airplane. For example, a procedure may be applicable for some aircraft of a given model but not others due to customer modifications or engineering changes implemented in later production aircraft.

Table 3
Breakdown of Error Type for each manufacturer

SOURCE	Error Type (%)				
	Procedural	*Language*	*Technical*	*Graphic*	*Effectivity*
Manufacturer A	44.5	26.0	14.5	15.0	0.0
Manufacturer B	34.7	28.1	17.4	7.9	12.0
Manufacturer C	42.7	41.2	14.7	1.4	0.0
Manufacturer D	48.2	24.3	19.5	8.0	0.0
M =	42.5	29.9	16.5	8.1	n/a

Table 3 shows the types of errors reported in the PCRs and table 4 shows a summary of the corrective actions (Add, Change, and Delete) requested in the PCRs broken down by manufacturer. Procedural and language errors were the most frequently reported problems; in fact, for all of the manufacturers, procedural and language requests comprise an average 73% of all PCRs (range 62.8% to 83.9%). Almost 90% of the requests involved the change or addition of information to the AMM (see Table 4).

Table 4
Breakdown of corrective actions for each manufacturer

SOURCE	Correction (%)		
	Add	*Change*	*Delete*
Manufacturer A	64.6	33.0	2.4
Manufacturer B	48.8	39.3	12.0
Manufacturer C	41.7	43.1	15.2
Manufacturer D	47.8	43.8	8.4
M =	50.7	39.8	9.5

Procedural Errors

The most frequent requests were within the Procedural category. Common procedural errors were categorized as Step(s), Ordering, Alternate method, Check/Test/Inspection, Caution/Warning. Step(s) refers to a request for individual steps within a procedure to be added, changed or deleted; whereas, when a specific type of step(s) was referred to in the PCR, i.e., request for Alternate Method, Check/Test and Caution/Warning, it was recorded. Ordering refers to requests for a change in the sequence of steps by separating, combining, or reordering individual steps.

Table 5
Percentage of corrective actions and types of procedural error requests (PCRs) by manufacturer.

Procedural Errors (%)					
ERROR REASON	Manufacturer	Corrective Action (%)			
		Add	*Delete*	*Change*	% of Total
Step(s)	A	26.0	0	3.0	29.0
	B	20.7	4.2	2.8	27.7
	C	18.0	9.5	2.4	29.9
	D	21.7	5.3	8.8	35.8
	M =	21.6	4.8	4.3	30.6
Order	A	0	0	0	0
	B	0	0	2.3	2.3
	C	0	0	0.5	0.5
	D	0	0	0	0
	M=	0	0	0.7	0.7
Alternative	A	1.0	0	0	1.0
	B	1.9	0	0	1.9
	C	0	0	0	0
	D	0.4	0	0.9	1.3
	M=	0.8	0	0.2	1.1
Check/test	A	7.5	0	0.5	8.0
	B	5.2	0.5	0.5	6.1
	C	4.3	0	1.4	5.7
	D	3.5	0.4	2.7	6.6
	M =	5.1	0.2	1.3	6.6
Caution/Warning	A	5.0	0	0.5	5.5
	B	1.4	0	0	1.4
	C	0.5	0	0	0.5
	D	2.7	0	0	2.7
	M=	2.4	0	0.1	2.5

As shown in Table 5, the most frequently reported Procedural errors were found with the Step(s) category (m = 30.6%). The second category was Check/ Test step(s) (m = 6.6%), followed by Caution/Warning step(s) (m = 2.5%).

Language Errors

Language errors found in the PCRs included typographical errors (Typos), grammatical errors (Grammar), a need for clarification of the information (Clarity), and inaccurate information within a step (Incorrect).

Table 6

Percentage of corrective actions and types of Language request reasons via PCRs from each manufacturer.

Language Errors					
ERROR REASON	Manufacturer	Corrective Action (%)			
		Add	Delete	Change	% of Total
Typo/grammar	A	0	0	0	0
	B	0	0	0	0
	C	0	0	0.5	0.5
	D	0	0	0.9	0.9
	M=	0	0	0.35	0.35
Clarity	A	13.5	1.0	5.0	19.5
	B	15.5	0	2.3	17.8
	C	13.3	1.9	16.1	31.3
	D	9.7	1.3	8.4	19.5
	M =	13.0	1.1	8.0	22.0
Incorrect information	A	0	1.5	5.5	7.0
	B	0	1.9	12.2	14.1
	C	0	3.8	11.8	15.6
	D	0.4	0	4.9	5.3
	M =	0.1	1.8	8.6	10.5

As seen in Table 6, the most frequently reported Language error was Clarity (m = 22%) with users most often requesting additional information (m = 13%) or changing information (m = 8%) to improve clarity. The second most frequent Language error was Incorrect information (m = 10.5%) with users requesting either a change (m = 8.6%) or deletion (m = 1.8%).

Analysis by ATA Chapter

The ATA chapters were also recorded during classification. Analysis shows that the distribution, types of errors reported and requested corrections were similar across the four manufacturers. The most frequent errors reported were found in the chapters related to Flight controls (Chapters 27), Landing gear (32), and Powerplant (71).

Chapter 27 (Flight Controls) was faulted most often followed by Chapter 32 (Landing Gear), both consisting primarily of Procedural and Language errors while most of the errors in Chapter 71 (Powerplant) were Technical. Errors in Graphics were rarely reported. In Chapters 27 and 32, corrective actions to add information were approximately twice as frequent as requests for changes. A small number of requests for deleting information were found in all chapters.

Discussion

We examined the PCRs provided by four aircraft manufacturers to identify the types of errors most commonly reported in AMMs, their distribution across ATA chapters and the types of changes required to address the comments submitted by users. Submission of PCRs was discretionary and consequently may not provide a complete picture of the difficulties experienced by the users. Whiles PCRs do offer insight into the types of errors found in AMMs they provide little insight into the role of organizational culture or situational factors that contribute to errors or the number or types of errors found in other forms of documentation that AMTs use. The study of PCRs complements other types of investigations thus providing a fuller picture of the underlying causes of maintenance error.

Most Commonly Reported Types of PCRs

The results of this study show that the majority of PCRs represent requests for additional procedural information followed by requests to add or change the language to improve clarity. These findings suggest that AMMs may not provide sufficient detail and fail to consider the task from the perspective of the AMT. It is common that an AMT is unable to perform a procedure as described in the manual due to interference from aircraft structures or systems that are not acknowledged in the procedure. Usability testing or proofing by the user population would aid in identification of ambiguous phrasing, poor sequencing of steps, or missing procedural information. Likewise, task analyses would help ensure that procedures exist for tasks commonly performed in the field. AMTs spend much of their time troubleshooting discrepancies on the airplane (e.g., erroneous fuel pressure indicators or inability to control cabin temperature); however, manuals may not include procedures for the sorts of problems that commonly occur during regular aircraft operations (Chaparro et al., 2004).

Errors by ATA Chapter

The majority of PCRs cited procedures found in ATA Chapters 27 (Flight controls), 32 (Landing gear), and 71 (Powerplant). It is interesting to note that the NTSB report of the Air Midwest accident cited procedures in Chapter 27. The rate of occurrence of errors in these chapters may be due to several factors including: 1) a potential reporting bias due to the safety implications of errors in these procedures; 2) the larger number of individual procedures related to these systems and 3) the overall complexity of these systems. As a case in point, consider chapter 71 (Powerplant), which includes maintenance tasks pertaining to electronic sensors, hydraulic & pneumatics, environmental and fuel systems.

Filtering of PCRs

PCRs report discrepancies in the AMM, which AMTs and customer service engineers believe warrant revision of the manual; however, the frequency and distribution of discrepancies found in this study likely represent a conservative estimate. AMTs with more experience or access to experienced co-workers may workaround known errors. Furthermore, AMTs are not equally likely to submit PCRs. This is corroborated by the findings of Chaparro and Groff (2001) that approximately 50% AMTs reported only occasionally, rarely or never reporting errors in the manual. AMTs cited several reasons for not reporting errors including the lack of feedback from manufacturers regarding submitted PCRs and their observation that errors persisted in the manual even after submitting PCRs. Potential PCRs are further culled by customer service engineers, on-site manufacturer representatives, and systems engineers who decide whether a PCR warrants a change in the manual. PCRs, which identify issues that affect safety and technical errors (e.g. incorrect part numbers, settings, clearances etc), receive the highest priority. This emphasis may explain the paucity of PCRs citing the clarity of procedures, spelling errors or typos.

Relationship between Rule Violations, Incidents, and PCRs

The relationship between discrepancies in the AMM and maintenance error is not a direct causal one. In most cases, the discrepancies found in the maintenance manual prompt requests for clarification that delay completion of maintenance tasks. Inspections of work and post maintenance functional tests reduce the likelihood of a maintenance error going undetected. Nevertheless, as recent maintenance related accidents demonstrate, the safety net can fail as the result of the random collusion of factors including a poorly written maintenance procedure, an inexperienced mechanic, time pressure, and failure of the supervisor to review the work and perform functional tests. Improved AMMs would eliminate a source of problems that contribute to errors and mishaps observed downstream.

Figure 1 illustrates the possible outcomes of the executing of a maintenance procedure by an AMT and summarizes the types of rule-related behaviors that may result and where PCRs and incident reports (e.g., report of incident filed in a database MEDA, HFACS-ME, ASRS) are likely to be generated. This figure was adapted from an earlier figure by Reason and Hobbs (2003). Beginning at the top left of the figure the AMT must first identify whether the AMM contains a maintenance procedure for the task. If a maintenance procedure exists then completion of the task will depend on the degree to which the procedure is complete, clear, and correct. The AMT has two choices should no maintenance procedure exist: they may contact the manufacturers' technical support for assistance thus generating a PCR or attempt to accomplish the task by relying on their expertise or that of their peers. The latter choice has several possible outcomes: the task could be performed correctly (i.e., a correct improvisation); alternatively, the task could be performed incorrectly and is detected during functional tests (i.e., a mistake) and an incident report is filed; or finally the task is performed incorrectly and is not detected until a later date (i.e., latent error).

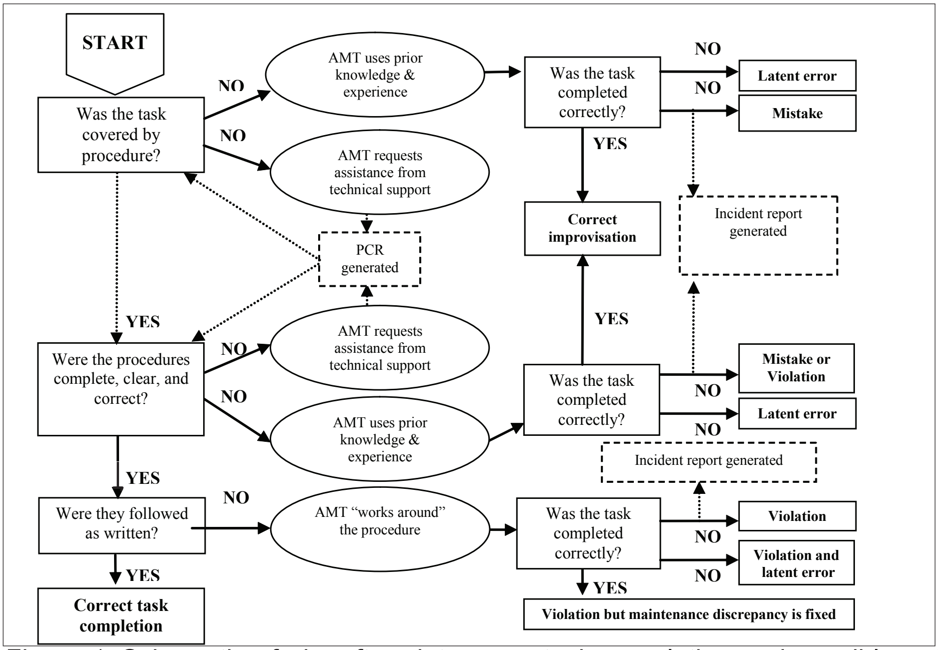

Figure 1. Schematic of aircraft maintenance task completion and possible outcomes.

As shown in Figure 1, a maintenance procedure may still fail to meet the needs of the AMT if it is difficult to follow or cannot be executed as described. A maintenance procedure may identify the wrong access panels or fail to take into account physical obstructions that prevent the removal of a component. Again, the AMT may contact technical support or attempt to identify an alternative solution. Finally, there are instances where the manual is technically correct but not followed by the AMT resulting in a *workaround*. *The FAA officially discourages Workarounds* as a maintenance procedure is supposed to be followed exactly as written. This may not always be possible. Technical writers report instances where functional tests described in the manual are technically correct but are not well suited to the task performed by the AMT. One representative example is a case where an AMT was replacing a part of a larger system. The functional test provided in the manual described a complex, time-consuming functional test for the entire system as would occur during assembly of the aircraft. However, no procedure was available for functional testing after the removal and replacement of one subcomponent as is common in the field.

Critical incident reports and PCRs serve several valuable functions. Critical incident error-reporting systems are in place to initiate corrections to the maintenance process within a maintenance facility (i.e., repair station), whereas, the PCR error-reporting system is in place to make corrections to the AMM. PCRs differ from incident reporting systems in the following ways: 1) PCRs are generated at an earlier stage of task completion; 2) PCRs generated by a AMT are filtered at one or more levels within an organization before a change is made to the AMM; 3) the information contained in a PCR is specific allowing for a more fine-grained analysis of problems in the AMM; and 4) PCRs may capture deficiencies in the AMM that may become critical incidents, as well as those that may cause latent errors.

Human Factors and Technical Writing

The problems reported in AMMs are expected given that draft procedures are not evaluated by users; rather, they are reviewed by other writers and engineers. Usually, the technical writer, in consultation with an engineer, writes a draft of a maintenance procedure using engineering drawings, system descriptions, and operational functional tests. The procedure is then circulated amongst members of the technical writing team and system experts for proofing (Chaparro, Rogers, Hamblin, & Chaparro, 2004). However, the emphasis is on technical correctness rather than usability of the procedure. This is evident in the relatively low number of technical errors reported in PCRs. Unfortunately technical correctness does not ensure usability. Some of the problems with maintenance procedures also derive from the fact that they are often based on assembly instructions used on the manufacturing line and consequently do not adequately address typical problems of maintaining an operational aircraft including troubleshooting systems to identify defective components or replacing single components rather then entire systems.

Recent Developments

Following, the Air Midwest accident, the NTSB made two recommendations specifically addressing human factors related issues in maintenance documentation.

> Recommendation A-04-13: Require that 14 CFR Part 121 (FAA 2008c) air carriers and aircraft manufacturers review all work card and maintenance manual instructions of critical flight systems and ensure the accuracy and usability of these instruction so that they are appropriate to the level of training of the mechanics performing the work.
>
> Recommendation A-04-16: Require that 14 CFR Part 121 air carriers implement comprehensive human factors programs to reduce the likelihood of human error in (Federal, 2008c) aviation maintenance.

A summary of the FAA response to the NTSB recommendations can be viewed on-line at http://www.ntsb.gov/safetyrecs/private/QueryPage.aspx. In the case of recommendation A-04-13, the FAA responded that the term “critical flight systems” was ambiguous and the FAA would work with the manufacturers to clarify the meaning of the term and develop appropriate procedures. Also, that upon the resolution of another safety recommendation, the FAA would “issue a Fight Standards Information Bulletin (FSIB) to inspectors to ensure air carrier maintenance manuals address the maintenance procedures on critical flight systems.” The FAA responded to safety recommendation A-04-16 by stating, “Rulemaking activities will be initiated for 14 CFR 121.375 to require that air carrier maintenance training programs be approved by the FAA.”

The NTSB classified both responses as unacceptable noting that in the case of A-04-13 that the “FAA’s plan to issue an FSIB does not adequately address the intent of this recommendation, which is to establish a program to ensure that procedures for flight-critical systems described by airline work cards and maintenance manuals are both accurate and usable.” Likewise, the safety board expressed some concern that the FAA did not understand the intent of safety recommendation A-04-16. The board noted that many human factors issues in aviation maintenance including the “availability of proper technical reference documents and guidance, availability of proper and appropriate tools and fixtures, and procedures related to continuation of work from one shift to the next are not related to training” and that a program limited to training would not address these issues. The FAA has not responded to the last round of NTSB comments dated October 12, 2005.

Summary

Analysis of PCRs revealed that the cited problems with the maintenance documentation stem largely from incomplete maintenance procedures and ambiguous phrasing and that these problems are comparable across manufacturers and aircraft size (FAR Part 25 and 121). The problems reported in PCRs are similar to problems cited in previous studies of critical incident reports and surveys.

Previous research has shown that use of user-centered evaluative methods in developing aviation maintenance documentation is effective in revealing potential errors prior to publication of the maintenance manual. These methods may be preferable to the current process that relies on other technical writers, design engineers, and customer technical support engineers in lieu of AMTs. AMTs offer a unique perspective including their familiarity with work place constraints and extensive task-related knowledge that may not be represented by the other groups referenced in the technical documentation development process. This analysis of PCRs reveals similarities in the types of errors reported by users and those found using evaluation techniques including cognitive walkthrough, single-user and co-discovery user performance testing(A. Chaparro et al., 2004).

A breakdown of PCRs as a function of ATA chapters showed that procedures in Chapters 27 (Flight controls), 32 (Landing gear), and 71 (Powerplant) were found to have the highest percentage of PCRs. Given the additional cost of evaluating procedures, this information can be used to develop selection guidelines as to the most critical procedures to evaluate.

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Author note

Bonnie Lida Rogers is now employed at Cessna Aircraft and Christopher Hamblin is employed at Honeywell Corporation.

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