Why is it that aircraft maintenance technicians sometimes do not use their maintenance documents: towards a new qualitative perspective

H. Zafiharimalala[ab], D. Robin[c] and A. Tricot*[a]

[a]*CLLE CNRS - Work and Cognition Laboratory, University of Toulouse, Toulouse*
5 allées Antonio Machado
31 058 Toulouse cedex, France
+33 562 252 223

[b]*Airbus Group Innovations ,*
18 rue Marius Terce, BP 13050
31300 Toulouse, France

[c] Altran
4 Avenue Didier Daurat
31700 Blagnac, France

andre.tricot@univ-tlse2.fr
malala.herimanana@gmail.com
David.tharsis@yahoo.fr

*Corresponding author

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Abstract

The aim of this article is to present an explorative study aiming to understand the use of the maintenance documentation by the technicians in the aircraft maintenance context and why they do not systematically use it, and to establish a global model based on the results. Previous studies can provide us with an understanding of why sometimes aircraft maintenance technicians do not follow the requisite procedure. Here we use these empirical data and psychological models as a framework, and consider the use by an aircraft maintenance technician of a document specifically as an information-seeking task and as a secondary task. A qualitative survey involving 13 maintenance technicians was conducted, with observations and semi-directed interviews. The survey gives first results about why, when and how technicians use their maintenance documents, and why they sometimes do not use them although they are required to do so. Thus, the decision by an aircraft technician to use or not use a prescribed document in a maintenance operation should be viewed in terms of a conflict between three priorities: namely safety, legality and efficiency. However, the explorative nature of the study involves the need to deal with the issue in depth. It could allow to validate or not the conflict of the three priorities. The results presented here could be the basis for further study to this purpose.

Applications

To increase aircraft safety linked to maintenance document use (and not use), one possible way is to reduce the conflict between maintenance technicians' main priorities: safety, legality and efficiency. It is possible to increase document efficiency by decreasing the cost linked to information seeking and processing, for example buy providing digital documents during task achieving, on the aircraft. It is also possible to better take into account cognitive, physical, social and external resources that impact document use.

Keywords: aircraft maintenance; procedure; errors; documents; decision.

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Introduction

Maintenance operations are critical to the reliability and safety of the airline industry. Kanki and Hobbs (2008) claim that maintenance errors are a major factor in causing flight delays and cancellations as well as flight accidents; and Chaparro, Rogers, Hamblin and Chaparro (2004) report, on the basis of different studies, that 6%, 12%, 17% or as much as 40% of aircraft accidents are related to maintenance issues (see also Boeing Airplane Group, 1996; CAA, 2002; Hobbs, 2000; Marx & Graeber, 1994; Ricci, 2003). One kind of maintenance error arises from the fact that sometimes maintenance technicians do not seek to follow the established procedure and/or do not read the maintenance documents even if they are required to do so, thereby increasing the risk of committing a clear breach in procedure. The aim of this article is to investigate why maintenance technicians sometimes make a decision to not use the prescribed maintenance documents.

The maintenance documentation for an aircraft is composed of different manuals noted in the table 1.

[table 1 about here]

The documentation that the technician must use to perform the maintenance task is established from the different manuals. It consists of different parts of information: warning and caution messages, information for the preparation of the task, information required for the successful performance of the task, the procedure to perform the task, and information about actions to be performed at the end when the task is finished.

Hobbs (2008) argues that there are six types of error that can arise in the area of maintenance. His typology includes three types of maintenance errors (perception error, memory lapse and a wrong assumption on the part of the technician) that are not directly related to our topic. However, the other three errors bear a direct relationship to the use (or not) of maintenance documents. These three types of error can be summarised as follows:

- *Technical misunderstandings*: these are errors that occur when technicians do not possess the necessary knowledge to accomplish a specific task, or lack an awareness of where to find the information they may need. This type of error is most likely to occur when technicians are performing an unfamiliar task, or else when they are facing non-routine situations.
- *Slips*: this type of error arises from the absent-mindedness of the technician when performing a familiar skill-based action at a time or in a place where in fact the action was not intended to be performed. Many maintenance tasks involve routine activities such as checking air pressure, opening and closing cowls, and lockwiring. Once these actions have been performed many times they start to involve automatic skill sequences that are outside conscious awareness. Slips occur when such routine activities lead to a lapse because the skills to be applied have become automatic, they are often fragments of routine behaviour or simple task-based actions that are performed simply in the wrong context.
- *Procedure violations*: there are two kinds of breaches of procedure. First routine violations consist of everyday deviations from the established procedure that have nevertheless become part of the normal way of working. Common examples of such routine violations include not referring to approved maintenance documentation, abbreviating procedures, or referring to informal sources of information such as 'black books'. In the case of our study of 13 airline maintenance personnel about half of them reported having used a 'black book' in the last six months. In many cases, airline management is aware that routine violations are occurring, but tolerates them because they help to get the work done efficiently. This is not applicable to the second kind of breach: exceptional violations are less common than routine violations, and they tend to be responses to unusual circumstances. They often arise from well-intentioned attempts by the technician to keep working in a given situation despite problems such as missing documents, a shortage of parts, or schedule pressure. One of the most common reasons for the occurrence of exceptional violations is management pressure on employees.

Reason and Hobbs (2003) reviewed the main causes for maintenance errors to occur, and found them to be linked to issues regarding the following areas: documentation (poor information, ambiguous procedures); time pressure (maintenance technicians, for example, can deliberately not perform a required functional check when facing time constraints); housekeeping and tool control; coordination and communication problems; tools and equipment (the right tools are not available); fatigue; lack of knowledge and experience; poorly designed or inadequate procedures, and faulty procedure usage (the personnel concerned choosing to not use written procedure). Subsequently Hobbs and Kanki (2008) have matched the typology of errors with the causing or contributing factors as well as with the incident outcomes. For instance, errors due to "procedure violations" are strongly associated with the following outcomes: required service not performed, unapproved or improper repair being undertaken, and problems with the documentation. Such "procedure violation" errors are also associated with a number of contributing factors, namely issues relating to management and supervision, and to norms. In contrast, errors falling in the category of "technical misunderstandings" (which are referred to by Hobbs and Kanki as "knowledge based errors") are strongly related to the use of personal knowledge and/or experience instead of the use of appropriate documentation. They are often caused for instance when maintenance staff are not aware that their knowledge has been superseded in view of the latest developments (for example a referent has changed since the last time they performed the same task).

It seems clear therefore that some aircraft maintenance errors are strongly linked to the issue of documentation, its content and its non-use. Sometimes maintenance technicians do not use the appropriate maintenance documents and they do not even refer to them when they accomplish the task; at other times, they choose to breach the procedure deliberately and to disregard the maintenance documents; and on other occasions still they may commit a slip, i.e. they perform a familiar action at the wrong time or place, or they misunderstand the context and use their own knowledge instead of seeking to refer to documents in which the established procedure has been outlined..

The documentation used to guide maintenance tasks is the highest-ranking cause of maintenance errors (Chaparro et al., 2004). These authors report that 64% of the maintainers declare that they found their own way to implement procedures. McDonald et al. (2000) report that 34% of maintainers acknowledged that their most recent task had been performed in a manner that contravened the formal procedures. In another ten percent of the cases maintainers indicated that they had followed the manual but without consulting the manual before task execution. Within the same European project (ADAMS), Van

Avermaete and Hakkeling-Mesland (2001) report a survey that resulted in a similar figure: 26% non-compliance and 9% not consulted. According to Hobbs and Williamson (2002), 80% of maintainers reported they did not use the procedures at least once last year and 10% agreed to do this often or very often.

Lattanzio, Patankar and Kanki (2008) reviewed procedural error in maintenance. They distinguished two main types of errors causes: (a) inadequacy of procedure and documentation; (b) procedural deviation, in which the mechanics and inspectors failed to follow published technical documentation. Then they identified five contributing factors: information not understandable, information incorrect, information not enough, information not used and information unavailable. Their analysis is coherent with others (e.g. Ricci, 2003 who distinguished missing procedural steps, incorrect sequence of steps, inadequate procedures for inspection and troubleshooting, incorrect technical information, and incorrect diagrams; see also Hobbs and Williamson, 2003). This analysis leads Lattanzio et al. (2008) to describe scenarios involving document deficiencies or user errors. Four of these scenarios relate specifically to maintenance personnel committing the following errors, the first two of which specifically concern document use:

- Didn't read/follow
- Lost/didn't retrieve
- Made an required inspection item error
- Made a logbook error

Why is it, then, that aircraft maintenance technicians sometimes do not use their maintenance documents? The literature about human factors and error analysis provides us with an accurate overview of how and why human failures and errors occur, but it does not provide us with any adequate explanation as to why maintenance personnel on any number of occasions may deliberately decide not to use their prescribed documents. Embrey (1998) submitted a questionnaire to 400 airline operators and managers about their procedural culture, and the answers he obtained show that procedures are deliberately not followed sometimes because of the following factors:

- Accuracy: they are inaccurate (21% agreeing); they are out-of-date (45%).
- Practicality: they are unworkable in practice (40%); they make it more difficult to do the work (42%); they are too restrictive

(48%); too time consuming (44%); they were followed 'to the letter' the job couldn't get done in time (62%).

- Optimisation: people usually find a better way of doing the job (42%); they do not describe the best way to carry out the work (48%).
- Presentation: it is difficult to know which is the right procedure (32%); they are too complex and difficult to use (42%); it is difficult to find the information you need within the procedure (48%).
- Accessibility: it is difficult to locate the right procedure (50%); people are not aware that a procedure exists for the job they are doing (57%).
- Policy: people do not understand why they are necessary (40%); no clear policy on when they should be used (37%).
- Usage: experienced people don't need them (19%); people resent being told how to do their job (34%); people prefer to rely on their own skills and experience (72%); people assume they know what is in the procedure (70%).

Reason and Hobbs (2003, p. 73) made a summary of Embrey (1998) survey. They reduce to four the principal factors to choose not to comply with the procedures, i.e. the four most frequent answers:

- If followed to the letter, the job would not get done.
- People are not aware that the procedure exists.
- People prefer to rely to their own skills and experience.
- People assume that they know what is in the procedure.

Our aim in this article is not to understand why maintenance personnel do not sometimes follow the prescribed procedure. As shown above, the literature on this question provides ample data, which enables us to understand the phenomenon, its mechanisms and outcomes. The aim of this article rather is to understand why maintenance technicians do not read and/or use the procedure document, even if (a) the requirement exists for them to read and to follow the procedure and (b) not reading and/or following the procedure can cause an error. The perception that a significant number of maintenance operators have of document failures in terms of (i) the difficulties perceived in using them (their low utility), together with (ii) the difficulties of putting them to use to find pertinent information and to be able to easily locate that information (their low usability), no doubt impacts on their decision to not read and/or use the procedure document

(Davis, 1989; see also Venkatesh, Morris, Davis, & Davis, 2003). The hypothesis that we present here is that if maintenance technicians decide to not read/use their maintenance manual, this may not be because they are convinced that they do not need it or because they have decided to deliberately breach the procedure. Instead, they could decide to not use the document simply because in their estimation the benefits/costs balance of using the document is, at that particular moment in time, unfavourable. Our argument is that the perceived benefits/costs balance is intrinsic but also extrinsic to the document, because internal as well as external factors impact on the benefits of using the document and equally on the costs of doing so. If our hypothesis is correct, then the decision on the part of a maintenance operator not to use the maintenance documents could be the cause, and not the consequence, of a procedure violation.

Background

According to the rational analysis of human cognitive activity (Anderson, 1991), human cognitive system is constantly attempting to optimize the adaptation capability of its organism by altering its behaviour. That is, when performing a task, our human cognitive system tries to maximize the benefits of the behaviour we adopt to perform the task, and at the same time it attempts to minimise any costs that may be associated to that same behaviour so as to produce maximum expediency. In order to fully understand an individual's behaviour while performing a task therefore, first the task itself must be described (i.e. its goal, its context, its resources and its constraints), the cost(s) entailed by the behaviour should then be analysed and should be followed by an analysis of the individual's previous knowledge about the task and about the context, and finally the actual goal of the individual in adopting that particular behaviour (which can be different from the prescribed goal) needs also to be taken into account. In this way it becomes possible to understand why humans frequently make suboptimal decisions: they cannot foresee all the consequences of their decision, they have to manage conflicting priorities or goals, and their cognitive capacity may be overloaded particularly when they have to deal with physical, social or emotional interferences (Beilock, 2010).

Task analysis: maintenance as a dual-task

According to Hobbs and Williamson (2002), for much of the time they are on duty, aircraft maintenance personnel do not handle the actual airplane but do their work using mainly fiche readers, technical logs,

task cards and maintenance manuals, or else they are busy signing off on other tasks. A maintenance procedure is twofold and involves two main tasks: preparation and execution. Each of the latter involves sub-task. The main task consists of the technical intervention itself (inspection, repair, etc.), which is the goal of the maintenance procedure, while the sub-task is the use of documentation so as to search for and read the relevant information about the main task. The sub-task is therefore a support for the main task; we consider the sub-task to be an information-seeking task.
The preparation main task is directly related to maintenance (e.g. the ordering of spare parts) while the preparation secondary task is the consultation of documentation (e.g. consulting the documentation so as to find the appropriate parts' identification number). The execution main task refers to the actual technical task that is required, i.e., the procedure to be performed on the aircraft, on one of its systems or on a component. In the same manner, the execution secondary task consists of using the documentation in order to implement the technical task (e.g. reading the procedure step by step). Some examples are given in table 2 below to illustrate this categorization.

[Table 2 about here]

In view of the above we would like to outline the risk that follows: as the use of documentation is a secondary task, whether at the level of preparation or of execution, there is a potential conflict of priorities, especially when the two main tasks of preparation and execution are concomitant and need to be managed simultaneously.

Information needs and information-searching

Most of the time when humans search information, it is because they lack the knowledge that is necessary either to understand a situation or to solve a problem. This lack of knowledge, when it is conscious, results in a need for information. In this section we deal with the crucial issue of information needs and of information searching when undertaking a maintenance procedure and when performing its associated tasks in the aircraft industry.

For aircraft maintenance technicians, as indeed for all individuals who perceive that they may lack some knowledge in a particular situation, the process of information searching can become a necessity. In that case they will begin a quest to find the answers to their questions. However, this quest will occur only if they expect the searching effort to lead to information containing a benefit (utility) which is higher than the total cost attached to the quest or to the searching process itself (Pirolli & Card, 1999). If the cost is deemed to be too high, information-searching may not occur. The costs of information searching are various and linked to the time spent, to the cognitive effort involved and sometimes to any monetary loss that may be incurred. The cognitive effort involved in information searching can, on its own, be assessed in terms of the costs involved in defining an information goal, in subsequently planning a strategy to reach this goal, in implementing this strategy, and finally in understanding the results and in evaluating them (Case, 2002). This cognitive cost alone is sometimes so high that, after just a few minutes of information searching, we often forget our information goal; this goal is too costly to maintain in working memory (Rouet & Tricot, 1996).

When the cost of information searching appears to be too high, humans also sometimes choose to fill the gaps in their knowledge by other methods: they can try to solve the problem or to understand the situation by themselves, by using a strategy of trial and error for example, or else they can search to obtain more information by asking other humans for help. For instance, when a maintenance technician is facing a problem such as an unexpected finding and becoming aware that she or he cannot solve it by applying the standard procedure, she or he “must” ask help from an expert. In sum, information need comes from a situation where knowledge is lacking; and the information need as well as the situation both evolve directly as a result of information searching (see e.g. Fu & Gray, 2006).

From the empirical data we have about information searching *behaviour*, we are able to gain a solid understanding of what determines an individual’s assessment of the expected utility of potential information, i.e. of the processes involved in transforming their lack of knowledge into an information need (Tricot & Raufaste, 2007). Indeed, information need is a paradox: a person must have knowledge of the need in order to be aware of his or her lack of knowledge. In fact the more knowledge someone has about a particular task or situation, the less they lack pertinent knowledge and so the less they need information to perform that task or to understand that situation. On the other hand, the more knowledge someone has about a particular task or situation, the more they are able to recognize their lack of knowledge, with even greater accuracy and relevance, thus the more they need information to perform that task or to understand that situation.

Information needs are influenced by such factors as expertise (yet non-monotonically); environment (warnings; affordances; marks of relevance i.e. the information system sometimes displays information ranked according to the degree of their relevance); emotion (anxiety, stress, psychological suffering); engagement (if he or she is strongly engaged with a particular opinion or decision, a person is likely to feel less the need for any information that contradicts that opinion or decision). It is possible, on the basis of the above factors, to define five kinds of information needs:

(1) Need to obtain new knowledge.
(2) Need to confirm existing knowledge.
(3) Need to complement existing knowledge.
(4) Need to be in conformity with the situation (e.g. implicit goals, rules, procedures).
(5) Need triggered by the detection of relevance marks in the situation: for example when a word is underlined, it is perceived as more relevant than when it is not underlined.

In the area of aircraft maintenance, Barnard, Moal and Tapie (2007) have identified four types of documentation uses that match these different information needs very closely. In terms of information-searching, these four documentation uses as identified by Barnard et al. in aircraft maintenance are as follows and aim to:

(1) Find specific information on a specific subject: the technician searches only accurate information that is missing in order to perform the task.
(2) Check if nothing important has been forgotten: the technician knows the procedure but wants to ensure that she or he has followed the procedure described in the document so as to make sure that the task performed corresponds to the prescribed task.
(3) Learn about a task or a system: here the maintenance technician uses the documentation to learn more about the procedure relating to a task or system on which he is working.
(4) Apply and carefully follow all the prescribed steps: here the technician refers to the documentation and follows step by step the procedure described in the documentation so as to accurately execute his maintenance task.

Barnard et al. didn’t outline information need corresponding to “detection of relevance marks” in aircraft maintenance, probably because it is so common in this domain that it is integrated everywhere as warnings within the maintenance manuals and on the aircraft.

In aircraft maintenance therefore, information searching has the aim of meeting any one of these four different goals. Consequently, there may quite possibly be different reasons for a technician to not use the maintenance document. She or he may judge the use of the document to be a task that is too costly (being time consuming and cognitively demanding) given, as explained above, that it is secondary. Sometimes maintenance personnel have to search information even when they do not lack any knowledge: they just have to be seen to be in conformity with the procedure. We now focus on this paradox of the aircraft maintenance task, namely that one of its fundamental aspects is that the information need is not supposed to decrease as the personnel's expertise increases.

Psychology of expertise and the paradox of maintenance tasks demands

Hobbs (1997) interviewed experienced maintenance mechanics who either had been involved in or had been witnesses of aircraft accidents (n=86). Half of the incidents were recognized as being due not to a first-time maintenance error but to one that had occurred previously. Furthermore, in the majority of those cases the mechanics were confident that the same or a similar error could occur again.

Most of us when at work learn to achieve our daily tasks with more and more efficiency: working more rapidly, with more accuracy, with less error and with less effort. The evolution of work performances can be best described as a form of expertise acquisition (Ericsson, 1996), a process whereby many skills become automatisms, involving more efficiency but less control (Cellier, Eyrolle & Mariné, 1997). Becoming an expert is also linked to the fact that skills and automatisms become more and more personal: at a high level, every expert is unique in the way he or she becomes able to achieve a task. Thus expertise is also linked to creativity: an expert is able to innovate, to solve new problems and to imagine new solutions. Consequently two types of expertise can be distinguished: basic expertise, which based on exact replication or the ability to perform exactly the same task in the same way, and flexible expertise which is based on the ability to reach a solution when faced with an unknown situation (Ericsson, 1999).

This is why lack of control is a major cause of experts' errors in many different areas, including troubleshooting (Besnard & Bastien-

Toniazzo, 1999) and medical diagnosis: one of the most important differences between the super expert's flexible expertise and that of basic experts (exact replication) is the ability of the former, unlike the latter, to entertain doubts about the way she or he understands a situation and/or performs a task, i.e. to control her or its own understanding and performances. Raufaste, Eyrolle and Mariné (1997) have provided clear evidence that basic experts, or experts using their basic expertise, may be unable to face a new situation even if they possess the skills to do so: they just do not think of using their skills to reach a solution when faced with an unknown situation, because of their lack of control over the use of those skills.

Thus it becomes understandable that in risky situations some maintenance procedures are used deliberately to force experts to achieve their daily tasks in a way that is highly controlled and standardized, in order to decrease the possibility of errors and to improve safety. In other words, for safety reasons, some maintenance procedures are set in such a way so as to deliberately ignore and indeed curtail the development of the aircraft maintenance technician's increasing expertise and efficiency. This type of constraint is very specific to such work. On the other hand, aircraft maintenance is also an area of work where the staffs spends normally between 15 and 20 per cent of their time performing assignments that they have never performed before (Hobbs & Williamson, 2002). Hence established procedures are also tools for them to use when facing new situations.

Why then would any maintenance technician, whether a basic or a flexible expert, choose to ignore their maintenance documentation? Since breaches of procedure are often deliberate acts, Reason and Hobbs (2003, p. 71) have characterised the results obtained by Battmann and Klumb (1993), as discussed below, as a mental balance sheet determining whether or not a person will breach a procedure. This is a simple computation whereby the perceived benefits and costs of using a document are offset against each other, but it is a process which makes it difficult to interpret procedure violations as being intrinsically linked to any automatism and a lack of control (see table 3). On the contrary, if the use (or non-use) of a document is the result of a deliberate calculation of the relative benefits and costs of doing so, then it can safely be assumed that the technician is (and has been) in full control of the decision at all times, and that he is making a fully conscious decision to use or not to use the document.

[Table 3 about here]

We would like to outline the following risk: because the status of maintenance expertise is paradoxical, thus there is a risk of lack of perceived usefulness of documents, a risk of over-confidence, even if the super-experts are generally cautious.

The aim of the survey presented here is to explore the reasons why maintainers don’t use documentation as a decision making process. As we considered information searching task as a secondary task, we particularly hypothesised that this secondary task can sometimes becomes a concurrent task. The basic assumption of our method is that a good way to understand why people do not do something is to understand also why they sometimes do it.

Method

Participants

The aim of the survey presented here was to explore the reasons why maintenance personnel in the aircraft industry do not always use their prescribed documentation as a tool in their decision-making process. Thirteen maintenance technicians participated in the study, one female and twelve males aged from 22 to 50. Eleven were technicians working in different specialties: electricians (operators in charge of the inspection, identification of electrical component to be repaired or replaced, etc.), electronics (operators taking care of maintenance of electronical systems by inspecting, identifying broken component and replacing of this one, etc.) and cells mechanics (operators specialists of the installation, the adjustment and the removal of hydraulic, electrical and mechanical accessories; the identification of anomalies such as corrosion, shock, wear). Technicians were joined by a team manager and also a quality manager. The participants had individual work experience that ranged from four to thirty years.

The study took place in three maintenance centres in Toulouse, France. The first is a centre for maintenance and repair parts of the ventilation system for different types of civil and military aircraft. The workstation is situated in a workshop where each maintenance technician has a chair and a bench on which he installs the parts and systems to repair and maintain. The technicians handle parts and/or systems that are detached from the aircraft and so they do not work directly on the aircraft. They have a computer that they use to search information in electronic format, and also a shelf on which filing cabinets are arranged containing the paper version (hard copy) of their electronic documentation. The second service centre is dedicated to improvement, maintenance and modification of business aircrafts. Although the centre is specialized in the modification and tailoring of aircraft according to customer demands, the centre also performs regular maintenance work on business-type aircraft. The maintenance operations generally take place within a hangar. The third centre is a normal service centre where the maintenance operations (tests, for example) take place in a shed or in the open.

Procedure

We used a two-phase procedure: the first phase consisted of an observation of a maintenance task; the second phase took the form of an interview with the observed technician.

Observations

The observations concerned the whole maintenance task: preparing the maintenance task, performing it, and verifying it. As the duration of maintenance tasks is variable (a joint replacement takes much less time than removing a screw, for example), the duration of the observations was also variable, ranging from ten minutes to one hour. All participants were requested to perform the maintenance task assigned to them exactly as they are accustomed to perform it, regardless of our presence.
Before each observation and interview, it was made clear to the participants that our goal was not to evaluate them on their work or their personal use of the documentation but really to gather information on the use of maintenance documentation. The maintenance personnel under observation tended to vocally describe the actions they were performing. These vocal descriptions were recorded as well as any other oral communications that occurred between them and us (such as a reformulation, a request for clarification or an explanation).

Interviews

Our semi-directed interviews followed a basic structure of two questions, the first question being:

1. Do you use the documentation in a systematic way?

    IF YES: 1.1 For what purpose do you use it?

1.1.1 Do you use it before the task or during the task, or after the task, or all the time?

1.1.2 Do you use it for all tasks?

1.1.3 How do you use/read it? (e.g. Do you read everything from start to end every time?)

IF NO: 1.2 Why not?

1.2.1 If you ever use the documentation, return to 1.1

The second question was as follows:

2. What would be your suggestions to improve the maintenance documentation? (The answers to this second question are not processed here).

Due to the small sample size and the exploratory character of our study, we did not analyse our results in a quantitative way. We attempted instead to highlight the extent of the diversity in the participants' individual behaviour and also in their answers, building categories when at least two elements seemed very similar.

Results

Observations

The observations allowed us to collect information on the actions of the maintenance technicians during those maintenance tasks that are related to the use of maintenance documents.

When taking up the assignment, the maintenance operator receives a job-card from the team leader. This is a card that outlines the work to be done during the shift. It also contains some information about the aircraft, the location of the task, a list of materials and tools required to perform the task, and the estimated duration of the task. The operator then proceeds to go on the computer so as to search then to gain an overview of the maintenance documentation pertaining to the maintenance task. Once the documentation has been found online, it is printed and brought to the workstation. At the workstation, she or he files the documentation nearby and checks the availability of materials, tools and parts needed. Sometimes, the parts, tools and materials are collected by a preparer. Some operators then follow the documentation step-by-step in order to complete each action, while others only read it when they are in doubt about an individual step or when the result of an action does not match what was expected. Thus one operator that we observed checked the parts list and discovered that while a part (in this case a joint) had to be replaced during the operation and had originally been included in the parts list, yet the joint as listed did not match the system (so the operator could not replace it). The problem, as it turned out, was an error in the reference number assigned to the joint. What is relevant for our purposes here is that the operator did first check the printed documentation, and that subsequently he left his work area in order to use the computer's electronic documentation to check the procedure and also the list of documents related to the task. This consultation with the documentation was thus held during the task and aimed to do away with any doubt. The operator also sought advice from a colleague who worked beside him.

We also observed the end of a shift, when for instance an unqualified operator who had finished his work began cleaning the workstation. Besides his concern to maintain cleanliness, the procedure enabled him to verify that nothing had been overlooked when installing a system. This maintenance technician went to another technician to certify his task. He explained that not being a qualified operator, he could not give himself certification. The qualified maintenance technician then checked the compliance of the task and asked the maintenance technician who was conducting the task if no incidents had disrupted his task. The documentation is itself used as a support to certify compliance of the task.

Interviews

We present below some of answers obtained to the questions asked in this study. Each operator is referred to as "M" followed by their identification number during the study.

Do you use the documentation in a systematic way?

For this first question, we obtained two types of answers: (a) Yes, systematically: "Yes of course, I use it. It is mandatory for anything. You are obliged to search the reference. Even though I already know the task. There are so many different things" (M12). "Yes, I use the documents all the time" (M13). (b) Not systematically: "Normally, the documents, we must have from the beginning to the end of the repair. We must have them all the time. I use the documents, but not always" (M1). To this, the quality manager added: "With experience, some people will just break free of regulatory constraints and will allow themselves some freedom because they know their job and do not need rely on documentation. And this can lead to a lot of problems due to human factors"

For what purposes do you use the maintenance document? Do you use it for all tasks?

The operators distinguished two main categories of purpose: tasks and information. They use the documents for certain maintenance tasks and also for information. Their answers constitute a close match with the categorizations proposed by Barnard et al. (2006) and outlined above in section 2. 2. Here is a summary of the answers the interviewees gave as to what their purpose would be for using the maintenance documentation:

- To find specific information on a specific subject: "I will need to consult all that torque value, refer to attached or equipment, equipment use, cleaning, all that I cannot remember. I can remember the important knowledge and procedure – how to do it like that – but I do not want to learn all that concerns components, torquage values and so on"(M10). "I use it all the time to look for the tools" (M5).
- To check if nothing important has been forgotten: "I also look at the end to the test." (M9) "I use it all the time for testing" (M4). "We also look for the test. Sometimes not"(M9).
- To learn about a task or a system: "I use the pages that present a whole view of a system" (M7).
- To carefully follow the prescribed steps: "Documentation? In fact I use it for disassembly and reassembly" (M7).

In conclusion here now is one answer that presents a global overview of the different purposes of document use: "We see what interests us, we look at the diagrams that are readable when it [...] We use the test section, Section on disassembling, chapter on specific tools, the values of torque, the graphics in the end..." (M1).

Do you use the maintenance document before the task, or during the task, or after the task, or all the time?

The answers received to this question mentioned the three times (before, during and after) with the same frequency.

- "When something is not known and is very specific, we read the documentation before, somewhere quiet. Otherwise, if it's a routine thing, I consult only in cases of doubt. Sometimes we do not look at the documents for the test [...] I rely on the documentation for the task to remove any doubt and also at the end to perform the test."(M9).

- “We may have planned to change parts, and in accordance with these required parts, we go back to the documentation and search again for them, in order to complete the task. Constantly, we cannot do without the documents.” (M12).
- “It is consulted before, then I print it to have it with me during the task” (M13).

How do you read the document? (Do you read everything from start to finish every time?)
From this question there were three main types of reading, depending on the task:

- Skimming: “We flew over more than we read… what we have to do normally” (M7).
- Close reading: “For a large operation, the card manufacturer's instructions are followed until the removal step and the test” (M9).
- Picking up information, for example a value, a reference.

Why do you choose not to use the documentation in a systematic way?
There were five main reasons for choosing not to systematically use the maintenance document:

- Because it is insufficient: “The documentation is not enough to achieve every task without outside help (…) There is not enough information, not enough pictures with exploded close-up views.” (M1). “Even to disassemble and reassemble the machine, the documentation is not very efficient: a novice cannot do it. Experience is needed” (M2). “There is not enough information, not enough figures. It is not easy. Users would like to have pictures of every part to use. To remedy this, one creates small files on the PC to bring photos of each piece, photos collected over the network, so as to be more clear, with colours, then we see better the location of each part, the connections, because the schema is not explicit enough, it is mentioned in the text but it is not clear or explicit. The text is not sufficient to accomplish the task. There has been much more likely to make mistakes, it requires much more effort, with the use of images retrieved from the network” (M7).
- Because it is not relevant: “In fact, it explains how to disassemble everything and then to re-assemble all parts, and sometimes we do not need all this information [...] It does not provide the various sub-tasks, the different possible repair

operations an operator can do on a device. It does not say for such a failure, refer to this part of the documents" (M2).

- Because I don't need it: "If it is something that I do regularly, then [about the task he was about to do during our visit], I do not need to consult the maintenance manual. I didn't, not even now. It's not a big maintenance task such as the removal of propeller. I know how to do it. Even knowing the task, I should have the documentation with me"(M10).
- Because it is in English: "In this case, we do not try to understand. To translate a sentence word for word..." (M3). "For us now, the first difficulty is English. The turn of phrase. We are looking in the dictionary all the time, it is information" (M5). "Already there is no colour, all in English, it could be confusing" (M6).
- Because it is not usable: "We view the technical drawings when they are readable. With technical drawings there is a greater risk of making mistakes, much more effort is required than with the use of photos retrieved (personally) on the network. In terms of ergonomics, there is room for improvement. The texts are never related to the pictures: we have to go back or forward several pages" (M1). "When there are drawings they are incomprehensible. So we wonder how we manage to fix it. Fortunately, people communicate with each other to know how to do it" (M2). "Sometimes, there are warnings on whole pages because you got the big planes. Every airline has its own warnings" (M4).
- Because it is not compatible with the job constraints: "The document is often not adapted to the context of maintenance. It does not take into account the constraints of an aircraft in operation. For example, to file a fitting spring, we had to do a bore. The document said such 'ream support' but it was really impossible to do on the plane: it was necessary to file the entire element, which generated many more hours of work, additional supplies. And all these things were not taken into account by the manufacturer in the literature" (M5). The same operator adds: "It would be nice if there was a dialogue between the maintainer and the document's designer. I do not understand how they manage to create such documentation without having any relationship with repairers. The editors are in relation to the librarian of XXX but this one is not a repair. He is familiar with the machines but is not in the workshop, he is not at the workstation where you have to remove a screw (according to the

procedure), but the documentation doesn't tell you that you have to remove this thing first, and then this one, and this one before removing the screw".

Discussion

Overview of the results

There are two types of use applicable to aircraft maintenance documents: the prescribed and systematic use of them and other, non-systematic uses. The prescribed use consists of reading the entire documentation and of using that documentation at any time for all tasks and in all conditions. Only two participants from our survey can be described as using the documents in this prescribed manner. Before the task, they always read the procedure and have an overview of it. During the task they also read their documents in order to access relevant information and to assess its accuracy (especially any information that is complex and difficult to remember), in order too to remove any doubts they may entertain about the procedure and to follow it step by step, especially when it relates to a complex task (i.e. a task which is composed of several sub-tasks). Finally, after the task, they also refer to their maintenance documents so as to check whether the procedure has been followed. This prescribed use of maintenance documents on the part of those two participants follows closely the four main purposes identified by Barnard et al. (2007).

The other use of maintenance documents correspond to the non-systematic use. The factors contributing to this non-systematic use are indicated in table 4 and can be summarised as follows:

- Lack of utility of the document: the maintenance technician chooses to focus on the main goal and the secondary goal is perceived as useless. This choice comes from the technician's self-confidence in his or her skills and their general lack of confidence in maintenance documents (for instance they may well be aware of document deficiencies).
- Lack of usability of the document: this factor comes into play particularly when the time spent to search information is too long, or else when the procedure is not easy to follow or to understand upon a first reading, so that the benefits/costs ratio does not favour the use of the document.
- Lack of compatibility of the document with the main task: using a document while performing the main task can be a heavy burden.

A document can be usable and yet not be compatible with the task.

[Table 4 about here]

In terms of our results, it is also worth noting that the perception of the lack of utility and of the lack of usability of the maintenance document, on the part of the technician who does not use the document systematically, is often reinforced by a more “social” phenomenon concerning the technician’s viewpoint about the document’s designers and the aircraft manufacturers generally. The latter tend frequently to be considered by technicians as being very removed from the reality of repairing an aircraft, and to lack an understanding of their actual schedule of duties and responsibilities in the maintenance area.

Safety, Legality, Efficiency: A dynamic and additive model of the decision to use maintenance documents

In this section, we attempt to integrate the results that we have obtained in our study with those reported by other researchers and outlined in the two first parts of this article. We also propose a more dynamic, additive model of the decision to use maintenance documents.

That aircraft safety requirements and maintenance operational goals frequently come into conflict is a standard perception of maintenance personnel in the aircraft industry (e.g. Eiff & Suckow, 2008). Our study, but also the results obtained in previous studies of aircraft maintenance, lead us to suggest that maintenance technicians have to deal with three main priorities: safety, legality and efficiency. In optimal situations, these three priorities are not in conflict: legality is perceived as a way to reach safety, while efficiency is considered to be a secondary criterion which is to be taken into account only if it does not threaten the two other priorities. However, in some specific situations, a different relationship and a different order can be seen to be at work between these three priorities. This is the case even if safety still constitutes the highest priority.

For example, legality enters into a conflict with safety when the maintenance technician has significant past experience and/or previous knowledge about documentation failures and especially about the long delays that normally occur before these failures can be rectified. The conflict between legality and safety here can be even more acute if the technician has very accurate knowledge about the system that he is currently dealing with, or with the task that he is actually performing. In this latter case, he can (and often does) resort to using a "black book", i.e. a personal booklet. From a general point of view or in regard to several aspects of his responsibilities when carrying out his job, in this kind of situation the technician's expertise can therefore lead him to develop a higher confidence in his own personal skills, and to trust these personal skills at the expense of the documentation.

Another conflict between the three priorities mentioned can occur when the documentation is perceived as being poor in its usability, the resulting perception being that much valuable time can be lost if the document is used as prescribed. In this case, efficiency is very likely to enter into a conflict with legality, particularly in situations where there is significant time pressure exerted on the maintenance personnel. Such time pressure can come not only from management but also from other factors. It may even be the case that recurring management pressure over issues of timeliness can be directly perceived by the technicians as efficiency receiving a higher priority than legality (e.g. Hobbs & Kanki, 2008). More generally, if a maintenance procedure is perceived as causing a decrease in efficiency, then efficiency tends to enter into conflict with legality.

Moreover efficiency can enter into conflict even with safety: this is possible, for instance, when the information-searching task is perceived as being concurrent with the main maintenance task.

It seems therefore that different information needs can lead to a different perception of the benefits/costs balance sheet for the use of a maintenance document. Here we list the benefits/costs balance sheet for each type of document use as indicated in section 4.2.2. above.

To find specific information on a specific subject: a perception of high utility with low cost.

To check if nothing important has been forgotten: a perception of high utility with moderate cost.

To learn about a task or a system: a perception of high utility with moderate cost.

To carefully follow the prescribed steps: a perception of low utility with high cost (for experts).

These conflicts between the three priorities can determine the decision to use or not use a document as prescribed. We therefore propose a dynamic but very simple additive model, whereby the decision taken to use a document occurs when a certain level of information need has to be met and is deemed likely to be met. As shown above and

in section 4.2.2, information needs can be of 4 different kinds and do not correspond to a simple lack of knowledge but more to the information-searching process and its related benefits and costs. Consequently, the utility/cost ratio will be different depending on the type of information need. The utility/cost ratio will also depend on the quantity of resources deemed to be required so as to satisfy the information need, e.g. temporal resources, or cognitive resources. Under normal circumstances, the safety and legality requirements are of a high enough level to ensure that the information need threshold is reached. In some situations however, with some maintenance technicians, for some tasks and for some documents, this information need threshold cannot be achieved in a straightforward manner and can lead to a fully conscious decision on the part of the technician not to use the prescribed documentation.
Below we list the main variables that come into play in such situations. When the information need threshold is not reached (because the utility/cost ratio for the use of the document is different), according to our model each maintenance technician will choose to either use or not use the prescribed documentation by taken the following factors into account:

- When temporal resources decrease, temporal costs increase.
- When the distance between the computer and the location of the maintenance operation increases, the cost of using the document also increases.
- When fatigue, noise and other interferences increase, cognitive or attention resources decrease.
- When colleagues with expertise are available then the perceived utility of documentation decreases.
- When a task is performed very often, the expertise about this task increases.
- When expertise increases, the perceived utility of a document decreases (mainly applicable in the case of Information Need 4, “To carefully follow the prescribed steps”)
- When task complexity, duration or novelty increases, the document’s perceived utility increases.
- When the document’s perceived usability decreases, temporal and cognitive costs increase.
- Experience with document failures decreases the perceived utility of the document.
- Experience with document difficulties decreases the perceived usability of the document

- The information need threshold increases when the requirement for safety and for legality increases.
- The information need threshold is reduced when the requirement of efficiency is decreased.

Figure 1 presents a summary of our model. The representation of the four main information needs tries to translate the idea that the information need threshold is low for Need 1 and high for Need 4.

[Figure 1 about here]

Conclusion

This explorative study contributes to an understanding of why, when and how maintenance personnel in the aircraft industry use the prescribed documents to carry out their various tasks, and why they sometimes do not use these same documents. Our results as well as an analysis of the previous literature on the topic lead us to suggest that when maintenance technicians choose not to use a document, as does happen regularly, this is not necessarily because they have made a previous decision to breach the prescribed procedure. We suggest instead that technicians make their decision by proceeding to evaluate their need to use a document, not just before performing a task but even while they are continuing to perform it, according to what kind of information need they face given the specific situation and the specific configuration of the maintenance operation. Other factors they bring into play for reaching a decision are the level of their own knowledge, their perception of the utility and of the usability of the documentation, and also of the conflict that they need to manage between the three priorities of safety, legality and efficiency.

Our hypothesis needs now to be challenged by empirical studies in this new field. If new results appear to be coherent with our proposed model, then it would be possible to think about the consequences. Indeed, it could be possible to consider that training and work organization should place a much greater emphasis on this conflict between safety, legality and efficiency. It could also be possible to consider in different ways the different patterns of information needs as described here, the problem of not using a document being probably much more linked to "following the whole procedure" need than the other needs.

On the basis of the results presented here, we are now studying the general hypothesis that digital document should decrease the costs of information seeking and document use. Based on this hypothesis, we are evaluating if providing digital document on tablets, which the maintenance operators should bring with them on the aircraft, is suitable for information seeking and processing, but also for task supporting. If this solution is right, then digital documents on tablets should contribute to reduce the conflict between the three priorities (safety, legality and efficiency) by improving efficiency.

References

Anderson, J.R. (1991). The place of cognitive architectures in a rational analysis. In K. Van Len, Ed., *Architectures for intelligence*. (pp. 1-24). Hillsdale, NJ: Erlbaum.

Barnard, Y., Moal, M., & Tapie, J. (2007). Ergonomie, documentation électronique et maintenance : exemple de l'aéronautique. *Forum Maintenance and Transports*, Paris, 15 May.

Battmann, W. & Klumb, P. L. (1993). Behaviour economics and compliance with safety regulations. *Safety Science, 16*, 35-46.

Beilock, S. (2010). *Choke*. New York: Free Press.

Besnard D. & Bastien-Toniazzo M. (1999). Expert error in trouble-shooting : an exploratory study in electronics. *International Journal of Human-Computer Studies, 50*, 391-405.

Boeing Airplane Group B.C.A. (1996.) *Statistical summary of commercial jet aircraft accidents, world wide operations 1959-1995*. Seattle: Boeing Airplane Group.

Case, D.O. (2002). *Looking for information*. San Diego: Academic Press.

Cellier, J.-M., Eyrolle, H. & Mariné, C. (1997). Expertise in dynamic systems. *Ergonomics, 40*, 28-50.

Chaparro, A., Rogers, B., Hamblin, C., & Chaparro, B. (2004). *A comparison of three evaluative techniques for validating maintenance documentation*. Final Report. Washington DC: Federal Aviation Administration.

Civil Aviation Authority (2002). *Human factors in aircraft maintenance and inspection*. Report No. CAP 718 London: The Safety Regulation Group.

Davis, F.D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly, 13*, 319–340

Eiff, G.M. & Suckow, M. (2008). Reducing accidents and incidents through control of process. *International Journal of Aviation Psychology, 18*, 43-50

Embrey, D. (2000). *Preventing human error: developing a consensus-led safety culture based on best practice*. Dalton: Human Reliability Associates.

Ericsson, K. A. (1996). The acquisition of expert performance: An introduction to some of the issues. In K.A. Ericsson Ed., *The road to excellence: The acquisition of expert performance in the arts and sciences, sports, and games*. (pp. 1-50). Mahwah, NJ: Erlbaum.
Ericsson, K. A. (1999). Creative expertise as superior reproducible performance: Innovative and flexible aspects of expert performance. *Psychological Inquiry, 10*, 329-333.
Fu, W.-T., & Gray, W. D. (2006). Suboptimal tradeoffs in information seeking. *Cognitive Psychology, 52*, 195-242.
Hobbs, A.N. (1997). *Human factors in airline maintenance : study of incident reports*. Canberra: Bureau of Air Safety Investigation.
Hobbs, A.N. (2000). Maintenance error, lessons from the BASI survey. *Flight Safety Australia, 4*, 36-37.
Hobbs, A.N. (2008). *An overview of human factors in aviation maintenance*. Canberra: Australian Transport Safety Bureau
Hobbs, A.N., & Kanki, B.G. (2008). Patterns of error in confidential maintenance incident reports. *International Journal of Aviation Psychology, 18*, 5-16.
Hobbs, A.N., & Williamson, A. (2002.) Unsafe and unsafe outcomes in aircraft maintenance. *Ergonomics, 45*, 866-882.
Hobbs, A.N., & Williamson, A. (2003). Associations between errors and contributing factors in aircraft maintenance. *Human Factors, 45*, 186-201
Kanki, B., & Hobbs, A.N. (2008). Maintenance human factors: introduction to special issue. *International Journal of Aviation Psychology, 18*, 1-4.
Lattanzio, D., Patankar, K. & Kanki, B. (2008). Procedural error in maintenance: a review of research and methods. *International Journal of Aviation Psychology, 18*, 17-29.
Marx, D.A. & Graeber, C.A. (1994). Human factors in aircraft maintenance. In N. Johnston, R. Fuller & N. McDonald, Eds., *Aviation psychology in practice*. (87-104). Aldershot: Avebury Technical.
McDonald N., Corrigan S., Cromie S., & Daly C. (2000). Safety management systems and safety culture in aircraft maintenance organisations. *Safety Science, 34*, 151-176.
Pirolli, P., & Card, S. K. (1999). Information foraging. *Psychological Review, 106*, 643-675.
Raufaste, E., Eyrolle, H., & Mariné, C. (1998). Pertinence generation in radiological diagnosis : Spreading activation and the nature of expertise. *Cognitive Science, 22*, 517-546.
Reason, J., & Hobbs, A. (2003). *Managing maintenance error: a practical guide*. Aldershot: Ashgate.

Ricci, K. (2003). Human factors issues in maintenance publications design. In DOD *Maintenance Symposium and Exhibition*. King of Prussia, PA: SAE International.
Rouet, J.-F., & Tricot, A. (1996). Task and activity models in hypertext usage. In H. van Oostendorp & S. de Mul, Eds., *Cognitive aspects of electronic text processing*. (pp. 239-264). Norwood, NJ: Ablex Publishing.
Tricot, A. & Raufaste, E. (2007). Information seeking computational models and information needs. *Workshop Computational modelling in information seeking: psychological and computing approaches*. Nice, France, 12-13 July.
Van Avermaete, J.A.G. & Hakkeling-Mesland, M.Y. (2001). Maintenance human factors from a European research perspective: results from the Adams project and related research initiatives. *15th Symposium on Human Factors in Aviation Maintenance*, London, UK.
Venkatesh, V., Morris, M.G., Davis, G.B., & Davis, F.D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly, 27*, 425–478.
Zafiharimalala, H. (2011). *Etude ergonomique pour la consultation sur écran de petite taille de la documentation de maintenance aéronautique*. Thèse, Université de Toulouse 2.

List of tables and figures

Table 1. Maintenance manuals (Zafiharimalala, 2011)

AC	Airplane Characteristics
AMM	Aircraft Maintenance Manual
ASM/AWM	Aircraft Schematic Manual/ Aircraft Wiring Manual
AWL	Aircraft Wiring List
CCC	Crash Crew Chart
CLM	Component Local Manual
CLS	Cargo Loading System Manual
ELA	Electrical Load Analysis
ESLD	ECAM System Logic Data
ESPM	Electrical Standard Practices Manual
FDRPL	Flight Data Recording Parameter Library
FIM	Fault Isolation Manual
CMPDS	Job-Cards Maintenance Planning Data Support
LTM	Livestock Transportation Manual
MFP	Maintenance Facilities Planning
MPD	Maintenance Planning Document
TSM	Trouble Shooting Manual
IPC	Illustrated Part Catalog

Table 2. Categorization of the Maintenance Dual Task – Examples

Maintenance Procedure			
Preparation Task		Execution Task	
Main Sub-Task	Secondary Sub-Task	Main Sub-Task	Secondary Sub-Task
Checking the availability of necessary parts	Consultation of the spare parts list	Disassembly of a system	Reading of the procedure

Table 3. Balance between benefits and costs when deciding to breach a procedure, Reason and Hobbs (2003)

Perceived benefits	Perceived costs
Easier way of working	Accident
Saves time	Injury to self or others
More exciting	Damage to assets
Gets the job done	Costly to repair
Shows skill	Sanctions / punishments
Meets a deadline	Loss of job / promotion
Looks macho	Disapproval of friends

Table 4. Why, when and how maintenance operators use documents?

Why?	When?	How?
1. To Find specific information	Before the main task	Picking up (skimming and extracting)
2. To check if nothing has been forgotten	End of the main task	Intensive reading
	During the main task	Picking up (skimming and extracting)
3. To learn about a task or a system	Before the main task	Skimming, Intensive reading
4. To carefully follow the procedure	During the main task	Intensive reading

Figure 1. A dynamic and additive model of the decision to use documentation in aircraft maintenance (red for increasing; blue for decreasing)