Data Gathering Methodologies to Identify Impact Variables in Aviation Maintenance

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Abstract

Impact variables are factors which must be taken into account to assure quality maintenance inspection. There are methodologies to collect and interpret information on impact variables. The choice of a particular methodology is based on factors such as the type of data to be gathered, the manner in which the data is applied, and the time available for data collection. The methodology employed has a direct effect on the quality and value of the information collected. This research analyzes data collection methodologies such as observation sessions, interviews, and surveys for the identification of impact variables in aviation maintenance.

Keywords
Data collection methodologies, Aviation maintenance, Selection matrix, WebSAT, Impact variables

1. Introduction
The mission of the FAA is to provide safe and reliable air transportation and to ensure airworthiness of the aircraft. The increasing number of maintenance and inspection errors in the aviation industry has motivated the need for human factors research. Maintenance error is a crucial factor in aircraft accidents. Human factors research in maintenance has deemed the human as the central part of the aviation system [3]. The emphasis on the human and his role in aviation systems results in the development of error tolerant systems. Such systems will be efficient if they closely monitor and evaluate aircraft maintenance and inspection activities. As a part of this evaluation, surveillance of maintenance and inspection activities must be conducted in a rigorous fashion. The objective of these activities is achieved through effective functioning of the auditors who perform these activities. The findings of these auditors help in the evaluation and assessment of the internal and external agencies of each airline that influence the safety and airworthiness of their aircraft. Thus, surveillance and auditing activities are of foremost importance in ensuring adherence to quality assurance requirements and maintaining a consistent level of supervision over maintenance operations. Given this, there is a need to develop a system that ensures superior performance of surveillance and auditing activities. This system is required to perform the following functions: (a) Seek input from diversified sources; (b) Proactively identify factors contributing to maintenance errors; (c) Promote a standardized format for data collection, data reduction and data analysis within and across the aircraft maintenance industry and lastly, (d) Generate trend analysis for problem areas (causal factors within and across organizations).

We propose to develop a web-based surveillance and auditing tool (WebSAT: http://www.ces.clemson.edu/~jsg/hcsl/) to proactively capture maintenance errors. The system will capture and record errors that occur during maintenance and inspection and analyze these findings. The specific objectives of this research are to:
(1) Identify an exhaustive list of impact variables that affect aviation safety and transcend various aircraft maintenance organizations.
(2) Develop a data collection/reduction and analysis protocol to analyze errors for the identified set of impact variables.
(3) Use the results of the aforementioned activity to develop and implement a surveillance/monitoring tool that assists in the maintenance of a consistent level of oversight.

The first step of this research is to identify impact variables. In order to do so it is important to understand current maintenance, surveillance and auditing processes. This necessitates the use of data collection methodologies to understand and subsequently identify the different variables. Impact variables are performance measures or requirements which would indicate the effectiveness and efficiency of the process. Taylor's [15] investigation of the

causes of Information Technology (IT) project failure, revealed that "there is no single cause of IT project failure," but requirements issues figured highly in the findings. A set of stable requirements can be defined by collecting sufficient, relevant, and appropriate data using proper data gathering methodologies.

Whether or not "human needs" are ontological facts of life [7], the extensive use of the word, and the concept it entails in various disciplines, presupposes that there exists a mutual understanding of its meaning, or of some phenomenon it represents. The most prevalent use of the term "needs" in the ergonomics, business and design engineering literature is to consider it as being used to establish some connection between a user and an artifact [4, 5, 6, 8, 16]. Data gathering is an important part of the requirements and evaluation activity as it helps us in understanding what these needs really are. The appropriate method depends on the time at which it is conducted and the manner in which information will be collected. These methods are aimed at providing information that drives improvements to the existing design [17]. The purpose of data gathering is to collect sufficient, and relevant, data so that a set of stable requirements can be produced [11]. This activity is typically applicable before the design process begins. The information gathered using these data collection methods allows us to understand what the system should look like. Trials, surveys, focus groups and, observations are some of the methods of acquiring this information [9]. One of the most powerful ways of obtaining user information that can be incorporated very early in the development process is through observation of users in their work context. Using a variety of ethnographic methods, developers who already thought they had a good idea of the users' work and needs are usually amazed at how much they learn through observation [12]. Observation is the cornerstone of usability testing and an important strategy in evaluating websites [13]. Alan Dix et al., [1] identify various factors which distinguish different evaluation techniques to allow one to make an appropriate choice. Rudman and Engelbeck [14] describe how they used different techniques to establish the requirements for a complex graphical user interface for a telephone company, and how different methods resulted in understanding different requirements. The techniques for data gathering can be combined and extended in many ways, which makes the possibilities for data gathering flexible.

2. Current Methods

The various data gathering methods that are currently used are questionnaires, interviews, focus groups and workshops, observation sessions and studying documentation. Some of them, such as focus groups, require active participation from stakeholders, while others, such as studying documentation, require no involvement at all. In addition, various props can be used in data-gathering sessions, such as descriptions of common tasks and prototypes of possible new functionality.

2.1. Questionnaires

Questionnaires are a series of questions designed to elicit specific information from their readers (participants). Some questionnaires require yes/no answers; others ask for a choice from a set of pre-supplied answers and others ask for a longer response or comment. Sometimes questionnaires are sent in electronic form, and sometimes they are given to the participants on paper. In some cases, the questionnaire is administered at a distance. Well-designed questionnaires are effective at getting answers to specific questions from a large group of people, especially if that group of people is spread across a wide geographical area, making it infeasible to visit them all. Questionnaires are often used in conjunction with other techniques. For example, information obtained through interviews might be corroborated by sending a questionnaire to a wide group of stakeholders to confirm conclusions.

2.2. Interviews

Interviews involve asking the participants a set of questions verbally. Often interviews are face-to-face, but they do not have to be. If interviewed in their own work or home setting, people may find it easier to talk about their activities and respond by showing the interviewer what they do and what systems and other artifacts they use. Interacting with people encourages them to respond effectively. In the context of establishing requirements, it is equally important for development team members to meet stakeholders and for users to feel involved. This aspect alone may be sufficient motivation to arrange interviews. However, interviews are time consuming and it may not be feasible to visit all stakeholders or pertinent users.

2.3. Focus Groups and Workshops

Meghan Ede [2] has an interesting perspective on focus groups: they are a way to get users to talk about long term issues that would take too long to study directly. Interviews tend to be one-on-one, and elicit only one person's perspective. As an alternative or as corroboration to another data collection method, placing a group of stakeholders together to discuss issues and requirements can be very revealing. Focus groups and workshops are useful to gather

a consensus and/or to highlight areas of conflict. They also allow stakeholders to meet the project team, and to express their views openly. It is not uncommon for one set of stakeholders to be unaware that their views are different from another set, even though they are in the same organization. These sessions need to be structured carefully and the participants should be selected carefully. One or a few people can dominate discussions, especially if they have control, higher status, or influence over the other participants.

2.4. Observation Sessions

People find it difficult to describe what they do or how they achieve a particular task. As a result, analysts rarely get an accurate story from stakeholders using any of the methods listed above. The techniques used in interviews can help prompt people to be more accurate in their descriptions, but observation provides a richer view. Observation involves spending some time with the stakeholders at their day-to-day tasks, observing work as it happens in its natural setting. Observation is an invaluable way to gain insights into the task(s) of the stakeholders and can complement other investigations. The level of involvement of the observer in the work being observed is variable along a spectrum with no involvement (outside observation) at one end and full involvement (participant observation) at the other. Observation help fill in details and nuances that do not come out of other investigations.

2.5. Studying Documentation

Procedures and rules are often written down in manuals and these are a good source of data. Such documentation should not be used as the only source, as practices may have been devised by those concerned to make the procedures work in a practical setting. Thus, an idealized account is given in the manuals, as compared to everyday practices.

3. Choosing a Data Method

There are no targeted rules to decide which methods are the most appropriate for identifying specific research needs. Each method has its particular strengths and weaknesses and each is useful if applied appropriately. However, there are various factors which should be considered when selecting methods. This paper considers this issue carefully to arrive at certain guidelines that can be used to select one or several data gathering methodologies to allow collection of useful data. Choosing the appropriate set of techniques for a project is crucial as it affects the requirements identified for the design process. Olson and Moran [11] suggest that the choice of data-gathering techniques rest on two issues: the nature of the data gathering technique itself, and the nature of the task to be studied. Data gathering methods differ in two main respects: the amount of time they take, and the information they provide. The following factors affect the choice of a data gathering method.

3.1. Project Phase

The first factor to affect the choice of data gathering method is the stage in the project at which the data is gathered. It would be useful to include data gathering of some sort throughout the project phases. Identifying user needs and performance measures early-on in the project provides information to drive the development of the system to be developed. This system may be anything from a paper mockup to a full implementation, but it is something concrete which can be tested.

3.2. Data Gathering Environment

The environments in which the studies are conducted vary from the laboratory to a user's place of work or field location. Laboratory studies allow controlled experimentation and observation but lose some of the naturalness of the user's environment [1]. Field studies retain the latter but do not allow full control over user activity.

3.3. Subjective vs. Objective Data Gathering Methods

Some methods rely heavily on the interpretation of the investigator, while others would provide similar information regardless of who is performing the data gathering. Thus, data gathering methods also vary according to their objectivity. The more subjective techniques, such as interviews, rely to a large extent on the knowledge and expertise of the investigator, who must recognize problems and understand what the user is doing. They can be useful if used correctly and provide information that may not be available from more objective method. However, investigator bias should be recognized and avoided. One way to decrease the possibility of bias is to use more than one investigator. Objective data methods, on the other hand, should produce repeatable results that do not depend on the persuasion of the particular evaluator. Controlled experiments are an example of an objective data gathering method. These experiments avoid bias and provide comparable results, but they may not reveal unexpected

problems or give detailed feedback on user experience. Ideally, both objective and subjective measures should be used to mitigate the weaknesses of each data gathering method.

3.4. Qualitative and Quantitative Measures
The type of measurement provided by the data gathering method is an important consideration. There are two basic types: quantitative measurement and qualitative measurement. Quantitative measurements are usually numeric and can be easily analyzed using statistical techniques. Qualitative measurements are non-numeric and are therefore more difficult to analyze, but can provide important details which cannot be determined from numbers. The type of measure is related to the subjectivity or objectivity of the technique. Subjective techniques tend to provide qualitative measures, and objective techniques tend to provide quantitative measures.

3.5. Information Detail
The information detail required by the investigator at any stage of the project may vary. Some data gathering methods, such as controlled experiments, are excellent at providing information with less detail; an experiment can be designed to measure a particular aspect of an interface. Another example would be a well designed survey which allows the audience to respond to certain specific variables without being provided the information needed to understand the system in all its detail. Higher level information can be gathered using questionnaire and interview techniques to provide a more general impression of the user's view of a system.

3.6. Response Time
Another factor distinguishing the data gathering methods is the immediacy of the response they provide. Methods such as observation sessions record the user's behavior at the time of the interaction itself. Other methods, such as interviews, rely on the user's recollection of events. Such recollection is liable to suffer from bias in recall and reconstruction, with users interpreting events according to their preconceptions. Recall may also be incomplete. However, immediate techniques can also be problematic since the process of measurement can actually alter the way the user works.

3.7. Resources
Availability of resources is paramount when selecting a data method. Resources to consider include equipment, time, money, participants, context, and the expertise of investigator. Some decisions are forced by resource limitations, other decisions are not so clear cut. For example, time and money may be limited, forcing a choice between two possible methods. In these circumstances, the investigator must decide which evaluation tactic will produce the most effective and useful information for the system under consideration. It may be possible to use results from other investigators' experiments to avoid having to conduct new experiments.

4. Selection Matrix
Table1. Selection Matrix of various data gathering methods
Q= Questionnaires; I = Interviews; W=Workshop; O= Observations; and D= Document Studies.

Criteria	Data Methods				
	Q	**I**	**W**	**O**	**D**
Phase (T= Throughout)	T	T	T	Data Gathering Phase	T
Environment: (L=Lab & F=Field)	L/F	L/F	L/F	F	L/F
Objective?	Yes/No	Yes/No	No	No	No
Qualitative or Quantitative Measure	Both	Both	Both	Both	Both
Level of Detail: H=High, M=Medium & L=Low	H	H	M	H	M to H
Response Time: S=Short, M=Medium & L=Long	M to L	L	L	S to M	S
Time Requirements: H=High, M=Medium & L=Low	L	L	H	H	H
Equipment Requirements: H=High, M=Medium & L=Low	L	L	L	L	L
Expertise Requirements	L	L	L	H	M

Table 1 represents a matrix to accommodate the factors discussed above. This matrix provides a tool which can be used to select one or several methods based on project criteria. The general approach adopted in the creation of this matrix was to consider the various factors that influence the choice of a data gathering method and addresses them with simple responses- Yes/No, High/Medium/Low, or Short/Medium/Long.

4.1 Application of Selection Matrix to WebSAT

The following factors were considered in the selection of data gathering methods to help identify impact variables in aviation maintenance;

- The general objective of this research is to identify an exhaustive list of impact variables that affect aviation safety and transcend various aircraft maintenance organizations.
- The research team hopes to identify the variables by the end of the year 2004.
- The partnering airline is located in the state of Tennessee. The geographical distance between the airline headquarters and the research laboratory in South Carolina adds its own complications to information gathering.
- The participants are senior managers in the surveillance and audit departments, maintenance personnel, and FAA representatives. The maintenance personnel are located at the substantial maintenance department in Alabama. The FAA representatives (stakeholders) are located in Washington, DC.
- It is expected that the impact variables will be qualitative in nature. The WebSAT tool may provide an approach to quantify these variables.
- The date gathering session has to be detailed, as the research team is new to the airline industry and needs to understand the basic workflow of the industry before beginning to look for impact variables.
- Three students, with a background in the field of human computer interaction, are working on this project.
- The costs of traveling to the airline headquarters and the aircraft maintenance site are high.

5. Discussion

The Selection Matrix is an effective reference to guide the selection of data gathering methods based on the applicable factors. This matrix can be further improved by introducing additional factors such as cost and stakeholder privacy. A next step might be to make this matrix more quantitative to allow for a scoring system that would assist the user in the selection of methods. Our research team used this matrix to decide which data methods to adopt for the WebSAT project. After careful review of the factors and keeping the selection matrix in mind, it was determined that the following data methods (in the order of preference) would be appropriate for this project:

(1) Interviews: This method is suitable for meeting the airline managers. This will also allow us to take a first-hand look at their work environment and will allow us to collect useful documents. The stakeholders will get an opportunity to put a face to the names they believe are involved in the project.
(2) Observation Sessions: To understand how aircraft maintenance is done, it is important to see how the maintenance personnel carry out their day-to-day work. Observation sessions would be the best method to collect this information. The medium to long response time will not be a hindrance for this project as sufficient time is available.
(3) Document Study: Since the airline industry is a highly regulated industry, it will be easier for us to learn more about it by reading relevant procedural manuals.
(4) Questionnaires: We believe that questionnaires should be used in a later phase of the project. They will be particularly useful if implemented as a web survey. This will allow us to evaluate (remotely) the appropriateness of impact variables with additional airlines.

6. Conclusion

Data gathering methods are an integral part of the design process. Data gathering should take place throughout the design life cycle to identify requirements early on and to later test the functionality and quality of the product. Data gathering can take place in the laboratory or in the user's workplace, and may involve active participation on the part of the user and the investigator. Interpreting user needs before any implementation work has started is an efficient way to minimize the commission of early design errors. The identification of the impact variables in aviation maintenance will enable the aviation industry to prioritize factors that transcend individual airlines. This information will be used to develop a tool that can systematically reduce or eliminate potential maintenance errors.

Acknowledgements

References

1. Dix, A., and Janet, F., 1999, *Human-Computer Interaction - Evaluation Techniques,* 393-400.
2. Ede, M., 2003, *Focus Groups to Study Work Practice*. Useit.com, Alertbox.
3. Gramopadhye, A. K., and Drury, C.G., 2000, "Human Factors in Aviation Maintenance: how we got to where we are," *International Journal of Industrial Ergonomics, 26,* 125-131.
4. Griffin, A., and Hauser, J.R., 1993, "The voice of the customer," *Marketing Science*, 12 (1) 1-27.
5. Hauser, J.R., and Clausing, D., 1988, "The house of quality," *Harvard Business Review*, May-June, 63-72.
6. Helander, M.G., and Du, X., 1999, "From Kano to Kahnema. A comparison of models to predict customer needs," *Proceedings of the Conference on TQM and Human Factors*, 322-329. Linkoping University, Sweden.
7. Kamenetzky, M., 1992, In Ekius, P. and Max-Neef, M. (eds), *Real Life Economics: Understanding Wealth Creation*, Routledge, London, 181.
8. Karlsson, M., 1996, *User Requirements Elicitation: A Framework for the study of Relation between User and Artefact*, Chalmers University of Technology, unpublished thesis.
9. Langford, J., and McDonagh, D., "What can focus groups offer us," *Contemporary Ergonomic*, 2002, 502-506.
10. Olson, J. S., and Moran, T. P., 1996, "Mapping the method muddle: guidance in using methods for user interface design," In M. Rudisill, C. Lewis, P. B. Polson and T. D. McKay (eds.) *Human Computer Interaction Design: Success Stories, Emerging Methods, Real-World Context*, San Francisco: Morgan Kaufmann, 269-300.
11. Preece, J., Rogers, Y., and Sharp, H., 2002, "Identifying needs and establishing requirements," *Interaction Design*, 214.
12. Susan, D., 1999, "Practical observation skills for understanding users and their work context," *Computer Human Interaction – Tutorials*, 15-20.
13. Susan, T., 2003, "Remote observation strategies for usability testing," *Information Technologies and Libraries* Vol. 22, 22-32.
14. Rudman, C. and Engelbeck, G., 1996, "Lessons in choosing methods for designing complex graphical user interfaces," In M. Rudisill, C. Lewis, P. B. Polson and T.D. Mc Kay (eds). *Human Computer Interface Design: Success Stories, Emerging Methods, Real-World Context,* San Francisco: Morgan Kaufmann, 198-228.
15. Taylor, A. (2000), "IT Projects: Sink or Swim," *The Computer Bulletin*," January, 24-26.
16. Verheijen, T., Kanis, H., Snelders, D. and Green, W.S., 2001, "On observation as inspiration for design," *Contemporary Ergonomics,* 383-388.
17. Karat, J., 1999, "User-centered software evaluation methodologies," *Handbook of Human-Computer Interaction*, 694-704.