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 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 deemed human as the central part of the aviation system [4]. The emphasis on 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 the aircraft maintenance and inspection activities. As a part of this evaluation, surveillance of maintenance and inspection activities is conducted in a rigorous fashion. The objective of these activities is achieved through an 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 industry which influence the safety and airworthiness of the aircraft. Thus, the surveillance and auditing activities are of foremost importance in ensuring adherence to the quality assurance requirements and also maintaining a consistent level of supervision over maintenance operations. Given this, surveillance and auditing activities exact the need to develop a system that ensures superior performance of these activities. This system is required to perform the following functions: (a) Seek input from diversified sources; (b) Proactively identify contributing factors; (c) Promote a standardized format for data collection, data reduction and data analysis within and across the maintenance industry and lastly, (d) Generate trend analysis for problem areas (causal factors within and across organizations).

The objective of this web-based surveillance and auditing tool (WebSAT: http://www.ces.clemson.edu/~jsg/hcsl/) is to proactively capture maintenance errors. The system captures and records errors that occur during maintenance and inspection and analyzes these findings. The specific objectives of this research are to:

(1) Identify an exhaustive list of impact variables that affect aviation safety and transcend across various aircraft maintenance organizations.
(2) Develop data collection/reduction and analysis protocol to analyze errors for the identified set of impact variables.
(3) Use the results of the aforementioned activity develop and implement an application in performing surveillance/monitoring tool so that a consistent level of oversight is maintained.

The primary step of this research is to identify impact variables. In order to do so it is important to understand the current maintenance, surveillance and auditing processes. This necessitates the need to employ 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 [18]

investigation on 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 [9], 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 way of using the term "needs" in ergonomics, business and design engineering literature is, to consider it as being used to establish some connection between a user and an artifact [5, 6, 7, 10, 19]. 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 about improvements in the existing design [20]. The purpose of data gathering is to collect sufficient, and relevant, data so that a set of stable requirements can be produced [13]. This activity is typically applicable before the design process begins. The information gathered using these data methods allows us to understand what the system should look like. Trials, surveys, focus groups and, observations are some of the ways of gaining this information [11]. One of the most powerful ways of getting 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 [15]. Observation is the cornerstone of usability testing and an important strategy in evaluating library websites [16]. Alan et al., [1] identify various factors which distinguish different evaluation techniques to allow one to make an appropriate choice. Rudman and Engelbeck [17] describe how they used different techniques to establish the requirement 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 of 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 users on paper. In some cases, questionnaire is administered at a distance. Well-designed questionnaires are good at getting answers to specific questions from a large group of people, and especially if that group of people is spread across a wide geographical area, making it infeasible to visit them all. Questionnaires are often 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 don't 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 a human encourages people 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 on its own 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: as 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, getting 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 highlighting areas of conflict. It also allows 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

Humans 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 method 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 everyday practices may augment them and 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.

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 could be used to selecting one or many data gathering methodologies to allow collection of precise data.

3. Choosing a Data Method

Choosing the appropriate set of techniques for a project is crucial as it affects the requirements identified for the design process. Olson and Moran [12] suggest that choosing between data-gathering techniques rests on two issues: the nature of the data gathering technique itself, and the nature of the task to be studied. Data methods differ in two main respects: the amount of time they take, and the information being sought. The following factors for choosing a data method were considered to identify other aspects of design such as information detail, knowledge base, and design detail.

3.1. Phase Factor

The first factor to affect the choice of data method is the stage in the project at which the data gathering is required. 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 feed the development of a physical 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. Applying data methods at the design stage tends to involve design experts only and be analytic, whereas collecting user feedback and evaluation of the implementation later on in the developmental phases of the project brings in users as subjects and is experimental.

3.2. Data Gathering Environment

The environments in which the studies are conducted vary from laboratories or 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. Ideally, the data method should include both styles of data gathering, with laboratory studies dominating the early stages and field studies conducted with system implementation.

3.3. Subjective vs. Objective Data Methods

Some methods rely heavily on the interpretation of the investigator, while others would provide similar information regardless of who is performing the data method. Thus, data 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 methods. 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 methods. 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 reduce the negative effects of each data gathering method.

3.4. Qualitative and Quantitative Measures

The type of measurement provided by the data method is an important consideration. There are two types: quantitative measurement and qualitative measurement. Quantitative measurements are usually numeric and can be easily analyzed using statistical techniques. Qualitative measurement are non-numeric and is 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 level of information required may also vary. The information required by the investigator at any stage of the project may range from low level information to higher level information. Some data methods, such as controlled experiments, are excellent at providing low level information; an experiment can be designed to measure a particular aspect of the interface. Another example for low level information method would be a well designed survey which would allow the audience to compare certain variables without being provided too much information 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 the system.

3.6. Response Time

Another factor distinguishing the data 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, subjects, context, and 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 people's experiments to avoid having to conduct new experiments.

4. Selection Matrix

The research team created a matrix to accommodate all the factors. The goal of this approach was to create a tool which can be used to select one or many methods based on the project criteria. The tool is referred to as the Selection Matrix (See Table1). The general approach adopted in the creation of this matrix was to consider the various factors mentioned above from the Choosing a Data Method section and bring it down to simple responses- Yes/No or High/Medium/Low. The team realized that this may not be possible in some cases such as time, equipment etc. They also realized that to make this matrix helpful the values in the cells should be precise. There are numerous data gathering methods available. However, these methods (such as cognitive walkthroughs and Blackout methods) are not classic data gathering methodologies and apply to unique design situations.

Table1. Selection Matrix shows a comparison of the various data methods
where 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
Measure	Both	Both	Both	Both	Both
Info Detail: H=High, M=Medium & L=Low	H	H	M	H	M to H
Response Time: H=High, M=Medium & L=Low	M to H	H	H	L to M	L
Time as Resource: H=High, M=Medium & L=Low	L	L	H	H	H
Equipment as Resource: H=High, M=Medium & L=Low	L	L	L	L	L
Expertise	L	L	L	H	M

4.1 Application of Selection Matrix for WebSAT

The following factors were considered for gathering impact variables (requirements):

- The general objective of this research will be to identify an exhaustive list of impact variables that affect aviation safety and transcend across 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 adds its own complications to gather information.
- The participants are senior managers in the surveillance and audit department, maintenance personnel, and FAA representatives. The maintenance personnel are located at the substantial maintenance department which is located in Mobile, AL. The FAA representatives (stakeholders) are located at Washington, DC.
- It is perceived that the impact variables will be qualitative in nature. WebSAT has to develop a way of quantifying these variables.
- The knowledge-gathering session has to be detailed as the research team is new to the airline industry and has to understand the basic workflow of the industry before beginning to look for variables.
- Three doctoral students, who have a good background in the field of Human Computer Interaction, are working full time on this project.
- Cost of traveling to the airline headquarters and the aircraft maintenance site is high.

5. Discussion

The Selection Matrix is an effective reference to help decide which methods to select, based on the applicable factors. This matrix can be further improved by introducing some more factors such as cost, stakeholder privacy etc. These are some of the points that are currently being looked at by the research team. The next step would be to make this matrix more quantifiable to allow for a scoring system which would allow the user to select desired methods. Our research team used this matrix to decide which data methods to adopt for the project. After careful review of the factors and keeping the selection matrix in mind, it was observed 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 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 get this information. The Low to Medium response time will not be a hindrance for this project as we have time allocated for the same.

(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 the relevant manuals.

(4) Questionnaires: We strongly believe that questionnaires should be used in the later phase of the project. They will be particularly useful if used as a web survey. This will allow us to evaluate (remotely) our selection of impact variables with the various other airline companies.

6. Conclusion

Data methods are an integral part of the design process. It should take place throughout the design life cycle to test the functionality and quality of the product and to identify any requirements early on. It can take place in the laboratory or in the user's workplace, and may involve active participation on the part of the user. Interpreting user needs before any implementation work has started is an efficient way to minimize the cost of early design errors. The identification of the impact variables will help understand the problem areas. This will let the aviation industry prioritize factors that transcend across industry to systematically reduce or eliminate potential errors.

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