Usability Issues within Technical Data Management Systems

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Abstract

The purpose of this thesis is to explore and study the usability issues within Technical Data Management Systems (TDMS). The research has been conducted as a single case study at the gardening and landscape maintenance company Husqvarna. The inductive research led to conducting 10 interviews, 2 expert focus groups and a observational study. An artefact was produced during the research to emulate a potential system. During the research, the researchers identified ten heuristic usability issues within TDMS. Furthermore the functional and non-functional needs of Husqvarna have been identified. The artefact was created, based on existing usability guidelines, addressing the usability issues and the needs of Husqvarna. The artefact was used to answer if the applied guidelines have solved the identified usability issues. The conclusion was set, that the applied guidelines had solved the identified issues.

With the research being conducted with a single case study, the result may lack generalisability. Future researchers are encouraged to conduct a multiple case study to further identify issues within the research area.

Keywords: usability, usability issues, usability guidelines, data management systems, technical data management systems, user interface design
Summary

Data management systems (DMS) have the purpose of providing support for maintaining large quantities of data. TDMS refers to a DMS which handles technical data. Technical Data is data which is produced in an engineering process, e.g. prototype testing results. TDMS has risen in use within the industrial market, as the trend for collecting and analysing this data has become a necessity for companies to stay competitive. With the big amount of data, the data evolves to become more complex. As the complexity rises, the usability for these systems tends to drop. The purpose of this thesis is to study the usability issues in TDMS. The research has been conducted with a case study at the gardening and landscape maintenance company, Husqvarna. It was elected they are currently using multiple TDMS. Due to the lack of research in this area, a case study approach was chosen. The thesis was set out to answer two questions.

• What are the functional and non-functional requirements of a technical data management systems within a manufacturing company?

• How can existing usability guidelines solve usability issues for technical data management systems?

The thesis took an inductive approach to answer the questions. The 10 conducted interviews have discovered 10 usability issues and 33 functional and non-functional needs for Husqvarna. The issues were, "Lack of standards of manual data input", "Incompatible with other necessary systems", "Difficult generate general overview", "Lack of version control of the data", "Compromised high-lighted important sections", "Workflow flexibility", "Lack of data visualisation", "Intuitive UI" and "Inefficient Search". The needs have partly emerged from the issues but are also specific for Husqvarna. An artefact was produced to emulate a potential system where the guidelines are applied on. It was created, based on the applied 174 usability guidelines; As well as on the 10 usability issues. Two focus groups were conducted to confirm the findings of the interviews and partially answer the second question. The observational study was conducted, with the artefact, to answer if the applied guidelines had solved the usability issues. The conclusion of the study was that the guidelines had solved the issues and the requirements were confirmed. 83% of the participants were able to complete the tasks set in the study. Which showcases that the usability guidelines had solved the issues.
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1. Introduction

The motivation of doing the research in the area of usability in technical data management system is presented firstly. It introduces the intention of the paper and why research in this area is needed. This chapter is followed by stating out the purpose and research questions. Since not every aspect of the chosen research can be perfectly covered, the delimitation of this paper are outlined at last.

1.1. Motivation

The need of usability in software has been established over the past few years [22]. The main purpose of a software, beside the main functionality, is that the software has to be used by the users. Without a good usability the application can not be used to it’s full potential and therefore can not fulfil it’s purpose.

Data management systems (DMS) have been around for several years. DMS have the purpose of providing support for maintaining large quantities of data. For example maintenance planning, product development and product testing in a company [14]. At the same time these systems, facilitate the job-tasks of the personnel which is in charge of the data management in a company. Registering current and completed tasks or getting the description of maintenance’s tasks, are examples of the functions where a DMS can support the company’s personnel [22]. The system serves as a central hub of communication within project management, data management and task management [14]. DMS is a collective term for software which acquires data, stores it, retrieves it and also in general controls the access to the data [16]. Technical Data Management Systems (TDMS) are in general systems which handle technical data. Technical data refers to data which is used by engineers. TDMS store information about functions which are used in/by machines and about the personnel [5]. Technical data is usually collected in enormous quantities, and the data has multiple relationships. This makes managing the technical data a very complex task. Therefore TDMS will aid engineers with their tasks [5]. With that trend, automation and with the possibility of facilitating the process of maintenance management, the computerisation of these systems has severely increased [22]. Computerised maintenance management systems (CMMS) is another kind of TDMS which focuses on project maintenance and product management within companies.
Currently CMMS and with that TDMS in general, are facing many usability issues such as, having the trend of having user interfaces which are too difficult to use. The systems are usually too complex for the users and have too much manual input. The manual input becomes a negative outcome, as the data becomes inconsistent. It varies from the user’s level of motivation, knowledge of the system and the user’s workload during the input. This leads to a lot of the data within these systems becoming corrupt, creating issues within the companies using TDMS.

As of now, there do not exist standardised usability guidelines for TDMS. This creates a continues issue for future systems since the same usability issues will plague future similar software. Currently a lot of researched usability guidelines exist within software. These guidelines could be potentially used for TDMS or potentially be modified to solve the current usability issues within TDMS.

1.2. Purpose and Research Questions

The purpose of this thesis is to firstly fill the research gap of usability guidelines in technical data management systems. Secondly to provide a solution for a TDMS in a company. The case study will take place in the company Husqvarna. Husqvarna operates in the field of forestry and garden/landscape maintenance. The company does not has a centralised TDMS for their data maintenance at the moment. The case study will be conducted in the Research & Development (RD) department of Husqvarna. They currently maintaining their data through several individual files and programs due to the lack of a usable TDMS. During the case study, research will be conducted on the current used systems by the Husqvarna RD department and defining the current usability issues. An artefact of the proposed new system will be created based on existing software usability guidelines in research. The artefact will then be tested with the Husqvarna’s RD employees. The testing process of this artefact will support in answering if the existing guidelines are able to solve the current usability issues within TDMS. This leads to the first research of:

- What are the functional and non-functional requirements of a technical data management systems within a manufacturing company?
Answering this question and conducting the case study will bring up several usability issues to the surface. To create a connection and to bring a profit for research about usability in TDMS, current usability issues which occurred in the industry and in research will be presented. How to overcome those issues is the questions which arises directly. Therefore the second research question this paper wants to answer is:

- How can existing usability guidelines solve usability issues for technical data management systems?

To overcome these issues we are going to use existing guidelines which have been discovered by several researchers in the usability area. To be able to measure and say how they can be solved, those guidelines will be used while developing an artefact in our case study. Summarising, the two research questions this thesis is aiming to solve are targeted on the usability in technical data management systems.

1.3. Delimitation

As there are many different data management systems, which face usability issues, we decided to limit the research to only study the usability issues within technical data management systems. Since TDMS do have previous academically confirmed usability issues. This helps us to identify the issues in a more focused manner. Which helps to answer if the existing usability guidelines can provide an aid in solving the existing usability issues. Further delimitation we have set for this project was within the case study and with the research participant we choose. As we are using a industrial case study for creating a industrial software, the research participants were chosen to fit within the context. Using participants which are experienced users of the system helps to focus more deeply into what the issues are within this system. Furthermore it helps to identify a solution to the issues. Choosing participants within the company which are not inexperienced users of this system would have created irrelevant issues. The third delimitation we have taken for the project is that we used a qualitative research approach, by collecting data through semi-structured research methods. This was once chosen to collect a more focused view on the issues from an expert point-of-view. If a quantitative research approach would have been taken, we would not have been able to go deeply into the issues and would rather confirm the issues from previous research. The result would be too general and too broad for a data result. If unstructured methods would have been applied for collecting
the data, the view would be too scattered for the issues. This would provide the same problem as the quantitative approach, by having a too broad range of a data result. Using semi-structured methods helps with diving deep into the issues and understanding them, but still focusing on a structure to follow along. Another aspect which limited the research is the circumstance that the whole project was conducted by two researchers. This has some effect on the analysis and interpretation of the data.

2. Theoretical Background

The following chapter provides the necessary academical knowledge about the usability in technical data management systems (TDMS). Therefore TDMS will be introduced and defined. The definition of TDMS is split in three different parts to allocate a rounded view on these systems. Since the usability in those systems is researched, usability as itself has to be defined. The presented definition of usability takes was viewed from three different angles.

2.1. Technical Data Management System (TDMS)

Technical Data Management Systems (TDMS) are systems which handle technical data. The different tasks and aspects of such a system are part of the definition and will be further clarified in this chapter. Since TDMS are not acknowledged in the academic world, but in the industrial, different definitions exist. Therefore, the systems are differently viewed. Especially in the academic world there are several perspective on data management systems. They have to handle with technical data which is partly entered manually and/or automatically with the computer. In the first sub-chapter we will present several views which correspond to the system of the case study. This will provide a common ground and clarify what the meaning of technical data management system is. Due to the circumstance that the case study is conducted in a industrial company, the need of giving a industrial definition is indispensable. Since especially in the industry a clear difference from the academical view of those systems exist. In the last sub-chapter a deeper definition in combination of both former definitions created. This supports to tailor it more the topic of the thesis and the case study.
2.1.1. Academic Definition

Technical Data Management Systems are a kind of data management systems (DMS) as the term as itself reveals. In general the act of managing data includes a broad range of activities like for example acquiring the data, storing it, retrieving it and also in general controlling the access to the data [16]. Having a software or system which handles the management of the data, is a data management system. The definition of the Oxford Dictionary for Computer Science defines DMS as following: ”A class of software systems that includes database management systems and file management systems.” [9]. Therefore a data management system has a database as base for handling the amount of data. For the purpose of this thesis, the data which is handled in the TDMS is technical data. Technical data is in the literature often referred to engineering data [5]. It is a specific kind of data which increases in quantity enormously daily and includes information about functions and people. As well does it has different components in technical data, multiple relationships to each other or different data. Which leads to having different version of the data. All these aspects make it difficult to manage the data. And therefore specific systems for technical data exist [5]. As above mentioned a lot different perspectives have been taken on TDMS in the academic world. According to the former definitions of technical data and data management systems, Computerized Maintenance Management Systems (CMMS) and Product Data Management Systems (PDMS) are included in the term of technical data management systems.

CMMS are data management systems which have the purpose of maintaining data [22]. With the trend of data mining, automation and with that the possibility of facilitating the process of maintenance management, the computerisation of these systems has severely increased [24]. It manages the information about the person who plans or schedules maintenance of machines as well as the actual information about it. This includes several versions of costs, information tracking or the assigned personnel. Which falls under the term of technical data since several relationships between the different information. Therefore there exists multiple versions of it.

Product data management systems have the purpose on handling data which is about specific products. These systems are mostly computer based. They electronically provide the management of technical data, activities and docu-
ment, as well as changes which are in relation to the product. The intention of PDMS’s is to improve and maintain the quality of the supervised products and the related processes to it \[5\]. The same arguments, as for CMMS, can be taken to identify it as a technical data management systems, since the same kind of data is handled. This has to be kept in mind for the upcoming content in the paper. The usability issues, which will be discussed, emerge generally from technical data management systems. They can have their actual origin for example of the above mentioned specific systems (i.e. CMMS or PDM). Since they are TDMS their issues can be mirrored for technical data management systems issues.

2.1.2. Industrial Definition

In the industrial world technical data management systems are used daily. The market for these systems has been already discovered and several companies are selling software with the purpose of managing technical data. Trix \[23\] or CSoft \[11\] are examples of companies who have taken the technical data management from a niche to a mass market level. Trix or CSoft are companies which are selling specific application for technical data management. They define data management as a process which manages data in an consistent way, which provides a software to access data and a database to be able to store the data. They highlight the importance of technical data management in the issue of the rising amount of data and that managing the data manual can not be processed efficiently anymore. They define technical data in the same way as the academical world. It is data which can be related to the product and is the output of an engineering process. Within the definition from Trix, the fact of which business procedures and users are included in the technical data management process, are pointed out as well. Workflows to design, revision and change control as well as communicating and security are examples of the procedures. The users which are pointed out are Engineers, Technicians, Data Controllers or for example Project Managers \[23\]. Those are all aspects which have importance for defining TDMS.

Another aspect to mention for the industrial definition of TDMS is that there is a definition of it on Wikipedia. Even though Wikipedia is not a trusted source for academical research and there will not be relevant references from it for this paper. It is still important to mention here, that there is an entry of technical data management systems on Wikipedia. This indicates that the term and the systems as itself do have an importance in the industry.
The article mentions different references which strengthened the quality of it relatively. Nevertheless, the broader definition of Wikipedia corresponds with the ones from Trix and CSoft. This substantiates the view of industrial definition in this thesis.

The case study is held in the industrial company Husqvarna. Their definition of technical data management system is on the same level of profoundness as the academical definition. They perceive the system mostly as general data management system even though technical data is processed by it. What kind of systems are in use currently in Husqvarna and which ones do have importance for the thesis will be explained in Chapter 4.1 Use Case: Husqvarna

2.1.3. Thesis Definition of TDMS

The former given academic and industrial definition have several similarities but also differences. Therefore we will take a closer look at the common factors. Gathering together the commonalities and creating an intersection of them to create a definition of TDMS for this thesis. Furthermore it will unite both worlds and create a new perspective on these systems. Figure 1 shows the similarities intersected to define technical data managements systems.

Figure 1: TDMS Definition
There are three main components for defining TDMS. To be able to manage data, data is needed. Since data can be anything and can occur in every area of research or the industry we have to take data which comes from engineering and technical processes. That is the first commonality which both definitions have. The second component is a system which manages something. Combining management systems with technical/engineering processes an engineering management system results. In this aspect the industrial and academic perspective agree and both of them are using the term in the same way. Intersecting the data part with technical/engineering processes results into technical data. Combining the specific kind of data, technical data, with the technical/engineering management systems leads to the overlapping of technical data management systems. The individual definition of data, managements systems and technical/engineering processes are corresponding in most part in a researcher and practitioner way. For the definition of TDMS we have taken the similarities of the intersections to create a well-balanced definition.

For the academic and industrial world TDMS’s occur in different forms. As above mentioned they can be called for example computerized maintenance management system (CMMS) or product management system (PDM). There are lot of versions of those systems which differ in some aspects but they all do handle partly or mainly technical data.

2.2. Usability Definition

The usability of a product/an application has been defined by many researchers. Therefore several definitions do exist, which take slightly different approaches. For this paper we will introduce three different definitions. A standard definition has been made by researchers. We are going to introduce this one firstly. The definition which is written down in the ISO standard from 1998 is worded as follows: ”the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use” [1]. Examining this definition leads to the key words of effectiveness, efficiency and satisfaction in relation to a user achieving a goal in a specific utilisation context. The definition was made over 20 years ago and is still revised every five years and therefore valid and used by several researcher. Even though the specification of the word ”usability” has not included the specific area of software, it can still be applied to the context of using a software. This specification of the word
"usability" has been seen of a user perspective and helps this paper to include the users view while defining usability.

The second definition which coincides for the use of this thesis, is the definition from Nielsen. Nielsen [20] refers to qualitative factor which appraises how easy a user can use the interface of an application as the definition of usability. More over is "usability" according to him a method which is used during the process of designing a software to enhance the "ease-of-use" [20] of the design. The definition from Nielsen of usability includes five elements: learnability, efficiency, memorability, errors and satisfaction. The learnability in context of the usability of a design, answers the question on how easily a user can solve a tasks on their first time being faced with the design. The efficiency on the other hand is defined as how fast a user can achieve the goal of a tasks when he/she has acquired the design. For the memorability in the usability, Nielsen reckons the users ability of re-establishing the attainment of being proficient of the design after being absent from it. Another component of usability is the amount of errors a user makes and how grave they are, and if the user can recover from them easily. Lastly, the overall satisfaction i.e. the pleasure of the design matters for the general usability definition from Nielsen. He sees the definition from a design perspective and with having the area of the "world wide web" in mind. This leads to be able to apply this definition not only to web applications but to applications in general. Furthermore, has Nielsen influenced the usability guidelines later on in this chapter. Therefore his definition of usability is indispensable for this paper.

Definitions of the user’s and designer’s perspective have been given. Benyon [7] examines usability more as the "quality of the interaction in terms of parameters such as time taken to perform tasks, number of errors made, and the time to become a competent user". His definition intersects with Nielsen’s and the ISO one but approaches it in a more measurable way. Since the usability will be researched on a specific kind of software, it is important of being able to quantify it on an application. Benyon’s definition does not only combine the two mentioned definitions but also helps to be able to identify and measure the usability of an application, which will be done in the use case of this paper. Parameters as how long it took users to achieve tasks or how many mistakes have been done while executing them will indicate to which extent the usability of a software exists. This can be based on and with Benyon’s description of usability.
2.3. Usability Issues within TDMS

The current status of usability issues in technical data management systems in the academical is complicated to define. There are different variations of how these systems which are handling technical data. Important papers which are related these systems and have been identified for computerised maintenance management systems. These are the papers from Tretten [22], Lopes[17], Wienker[24] and de Wit[6]. Other researchers who have examined technical data management systems and have undertaken several studies on the usability or user-centered approach of those systems are: de Porto Alegre Muniz and de Moraes [12], Bugaje and Chowdhury [8] and Hirz [13]. All of the mentioned researchers are agreeing on the fact that most of the current existing TDMS are currently not designed from a user’s perspective, but rather than from a requirements point of view. Therefore these systems lack in general in usability since they are handling technical data. Which can not be processed in an easy way by humans [22].

The papers which fitted most in the context were providing tangibles issues are from Tretten and Bugaje. Tretten and Karim [22] had the aim to enhance the usability in CMMS. Inter alia they have conducted a case study in the aircraft maintenance industry and split their usability issues. In general needs for the industrial and on the other hand for the aircraft maintenance industry. The following issues are the generalised industry ones Tretten found:

- Limited access to necessary documentation
- Incompatible with other necessary systems
- Too much manual input of information
- UI difficult to use
- More guidance needed
- Maintenance decision support is lacking
- CMMS was too complex

All these issues have been found in different industries but the need for them was found between all of them. One of the factors is leading the human to
enter data in a not assumed way. The issues are emerged from the lack of a suitable information architecture, complicated user interface or complex data flow. The authors invoke for CMMS, and with that TDMS, to be a easy understandable and easily navigated software. It shall provide essential information which enables the user to execute maintenance tasks, to trace the data flow and to gather and transfer data to other systems.

Bugaje and Chowdhury have been researching on user-centered research data management systems (RDM) [8]. They have more in detail examined the requirements for those systems. Research data is a part of an engineering process [8] and falls therefore in the category of technical data as well. Due to this fact, the findings of Bugaje are important for this paper. The list of requirements which have been found for RDM systems can be adapted as issues which current TDMS are lacking. The ones which are connected to the usability are:

- Users are not able to structure data
- Recognisable difference of different roles and user types in the system
- UI is not according to standards and best practices
- Lack of data visualisation
- Non-existing interaction with data sets on web-browser before download
- Allow user to save data as draft/invisible

Bugaje and Chowdhury gathered those issues from an online survey, face-to-face interviews and market appraisal and review. The listed issues are the requirements for this kind of systems, which they got from the users. They are also corresponding to several guidelines in the literature [8]. For them the main goal for a data management (DM) systems with a user-centered approach is that the system supports the user to discover data and to provide easy access and usage of the data. As well, they invoke that a DM system should help the user to enter data in an effective way. Furthermore to also use it in a way which enables the systems itself to inter-operate.

The other researchers have taken a more general approach to the usability
issues in TDM systems. They are mainly arguing that these systems have a trend of having user interfaces which are too difficult to use. The systems are usually too complex for the users or having too much manual input. Which leads the user to not use the systems full potential, as they are less willing to put effort into using the system [6]. Accordingly to them the difficult user interface and the complexity of the system lead to state of the user of needing more guidance. This leads to user producing errors in the system and eventually losing interest [22][6][17]. This results to the user needing more training than to actually use the application. With the right amount of user research the output will be, that these users do not have the need spending their majority of their time with documenting [17]. Rather will users spend time with proper issue solving and requirement testing. Hirtz [13] focused on engineering data management and is concluding as well that the challenge within this kind of information is to create usable ways to interact with the data. Another factor which Lopes, de Wit, Hirtz, Tretten and Muniz have in common is that the origin of one of the main usability issue is the data structure. With that is the flow of the data the ”behind the scences” of the application Lopes et al. [17][13][6][22][12].

The work which is represented in the thesis, is focusing on the industrial needs and how to cover them. The base for this, is the current status on the issues from the academical perspective. Therefore, are the presented researched usability issue used as the first layer for the found ones in the case study.

3. Methodology

The following chapter provides the explanations and arguments for the the research methods we used through this research project. The chapter will help establishing a good understanding why the methods we used were chosen to answer the research questions. The chapter has been split up into two sections. The first section introduces the research methods which were used for collecting the data. Every method will be explained and arguments why they fit within the research are given. The second section will introduce the methods we used to analyse the data which was collected through the research methods.
3.1. Data Collection

In this sub chapter the research methods which were used for collecting data in this research project will be introduced. Each of the methods will be provided with an explanation of the method and also arguments why this method was chosen for this specific research context. Firstly the method of the literature review is presented. The explanation of the case study followed by the interviews, focus groups and observational study follows.

3.1.1. Literature Review

A literature review supports the project to establish a stable academic ground. Critically reviewing previous literature provides an insight into the topic and creates a foundation for the research [2][25]. This is also the intention of using literature in the researching process for this paper: creating a stable academic ground of current usability issues in TDMS and usability guidelines. As there is no need to reinvent the wheel, literature review locates the trends within the field [2]. The academic ground will help in arguing for where the knowledge gap lies within usability issues within TDMS.

Dependent on the acknowledged knowledge gap, which is identified from the literature review, a research purpose will be set how the research project shall continue from previous research. Usability standards and issues within technical data management system will be reviewed.

The hermeneutic framework (illustrated in Figure 2) by Boell [3] has been applied during the literature review, to create coherency when retrieving the literature. The hermeneutic framework will create a structured way for conducting the literature review. By applying this framework it will be ensured that the different literature is critically reviewed by connecting and comparing them. Due to the risk of neglecting the important literature during the process of narrowing down the key search words, the hermeneutic framework was chosen to prevent it. The iterative process of the framework enables the researcher to validate the first results and then approach the search ones again. The framework takes an inductive approach to the literature review. An inductive approach starts with analysing the data of previous literature and then continues with creating theories which will relate to the reviewed literature [2]. The hermeneutic framework [3] (Figure 2) consists out of two iterative workflow circles. In the first circle, “Search and Acquisition”, the researcher starts with defining the keywords for the search process. The researcher use these keywords to search for relevant literature,
Figure 2: A hermeneutic framework for the literature review process consisting of two major hermeneutic circles

followed by sorting and filtering them. This is followed by collecting and reviewing the relevant literature. If relevant literature findings are not found, the researchers use the found literature to identify and refine additional keywords to search for. If relevant literature is found the researcher continues into the second workflow circle, which will be explained in the chapter 3.2.1.

The literature review consists of academic articles, journal articles, conference proceedings, books and internet resources. The literature was located from the academical search engines Primo and Google Scholar. Their retrieving content from the academic databases Emerald Insight, Elsevier, ACM Digital Library and IEEE Xplore Digital Library. During the search, the literature was filtered by "peer-reviewed". The relevance tree by Saunders [2] (Figure 3) displays the keywords for the literature search which were used and redefined during the first hermeneutic framework workflow circle. To emphasise the combination of the different searches a circle has been chosen to fulfil the iterative process proposed by Boell [3]. Figure 3 showcases how the keywords have been combined during the search. Each of the boxes in the figure displays the keywords which have been applied during the search.
Adjacent boxes to that keyword in the figure have been combined by using two of the keywords or all three together (e.g. Data Management Systems AND Usability Issues AND Usability Guidelines).

3.1.2. Case Study

The focus which has been set for this thesis is a qualitative approach. The research project will be collaborated with the Husqvarna RD team. Therefore the framework of a case study was chosen. Case study research is extensively used for finding and developing theories about a social phenomenon [25]. As this research of the social phenomenon which is being researched in its natural setting [25]. The intention with the case study is to find out the case study’s company functional and non-functional requirements of TDMS. This helps to answer the first research question of the thesis. As well it provides insights on how TDMS are used and needed in the industry.

Husqvarna is currently using a set of data management systems which are
part of the big workflow of their testing process. A case study is well fitting, as a research framework for developing and testing a theory where knowledge is limited [25]. Many of these systems are very tightly intertwined in the company and not a lot of knowledge exists outside of the company. A case study will help to understand the usability issues within these systems and how they can be solved through studying the problem close at hand. The case study will be designed as a single-case study. This was chosen for the reason of the limited time and due to the resources provided for the project. A single case study is suitable when it comes to extreme research cases. As the researcher can conduct a in-depth analysis of the area which is being studied.

A case study can also be combined with other research methods to further develop the theory of the project [25]. A base has been set for this research project to use a case study as its framework. Several other methods have been chosen to strengthen the developed theory. A selection of three sub-methods has been chosen to perform the case study. As the project will consists of a use case with Husqvarna, the goal is to develop a user-friendly technical data management artefact for Husqvarna. A major part of the case study will be conducted through user studies. Within the user studies there will be specific methods, such as interviews, focus groups and observational study. A case study will help the project to strengthen the academical findings which will be produced from the case study results. The final result of the case study will be a high fidelity prototype of a technical data management system. Focusing the research project around a case study is the most sufficient for understanding the issue at hand. Studying the area where the problem is emerging, will provide a clear understanding of these issues [25].

3.1.3. Interviews

To get a better and deeper understanding of a target group in a design project, interviews are often used to get qualitative data [25]. The intention of using interviews as a research method was to identify the issues Husqvarna are currently facing while using technical data management systems. Answering the question about how the usability guidelines can be established in a data management system will be answered partly through the interviews.

Design of the Interviews

The design of the interviews was set as semi-structured. Interviews can be divided into different styles, such as structured, semi-structured and unstruc-
tured. Structured interviews give barely any freedom. All the interviewees would have been given the same questions without deviation. This leads to a very linear results, which is not appropriate for qualitative studies [25] [26]. Unstructured interviews take the interview process to the complete opposite. The interview is more likely to be a conversation, which can lead the interview to a broader point of view. Which leads to the data being hard to compare between interviews [25] [26]. Since that would interfere with the intention of the interviews, semi-structured interviews were conducted. In total 10 interviews were held. There were two rounds of interview sessions conducted. The first round had the intention to gather the first data and to get the first insights. After the conduction of the first session, first patterns were discovered. With those in mind the second session was hold. Every interviewee was interviewed separately. To be able to gather and analyse data, the interviews were voice recorded. Every participant was asked before the interview for consent for the voice recording.

Participants of the Interviews
Interviews were conducted with employees of Husqvarna who worked closely with their in-house data management systems. The interviewees were anonymously interviewed, only revealing the position within the research and development department. A total of ten interviews were held. They are seven potential user groups of the software: Test Operator, Test Responsible, System Engineer, Test Method Owner, Project Manager, Lead Engineer and Design Engineer. These user groups were given by the responsible person of this project at Husqvarna, who started investigating in the project three years ago. Due to that reason, no further research was conducted considering the user groups. A further description of each role can be found in chapter 4.2.1. The contact with the participants was initiated by e-mail and meetings for the interviews were set. All of the participants were told that there is no need to prepare, since gathering the first impressions and thoughts of the potential users was wanted. All interviews were executed in the span of two weeks. Seven interviews were first conducted, with interviewees which represented the seven user groups. After the first seven interviews were conducted, the first analysis was performed on the data. The result of the analysis has been taking in consideration in the last three interviews to get them indirectly confirmed. During the last three interviews the user groups, Test Operator, Project Manager and Test Method Owner were interviewed. These user groups were chosen to create reliability and validity of the collected data. As
all three of these user groups have related work tasks as some of the other user groups (see chapter 4.2.1).

**Question Design of the Interviews**

Due to the design of having semi-structured interviews, only a few questions were created. In total, six questions were asked during the interviews. The exact questions can be found in the appendix (A). One question was intended to introduce the participants to the general context and to slowly dive into the topic. Based on the answer the questions of the current characteristics he/she likes and dislike about them, allows to reveal positive and negative issues. The rest of the questions were figuring out what kind of work the user does, expect and wants in an TDMS. These questions were designed in a shallow way and not deep in detail. This allows the interviewee to answer as in-detail, as they thought they to need to. Therefore the researchers are able to get insights and several facets in different kinds of extent. For example one question which was asked during the interview session followed as, "What do they expect from a test management system?". This for example helped to give the interviewee a context and topic path but being able to talk about it freely. The rest of questions asked during the interviews can be found in A. In the end of the interviews, the already existing requirements from the supervisor at Husqvarna were shown. The interviewees were asked if they agree or disagree with them and if they are important for their daily work.

3.1.4. *Focus Group*

Focus group has been chosen as the second research method. The intention of using them in the case study is to find out if the interviews have been analysed in the right way. The results of the interviews is tested with the method of focus groups. Focus group is a suitable research method to produce a larger amount of qualitative data in a short amount of time [20]. Focus groups are especially suited for exploring peoples view on experiences, ideas and products [25]. With the interviews, the aim was to identify usability issues within technical data management systems on an individual level. Therefore asking them several questions about the topic will support the process of extracting the issues. First and foremost the focus group will be used to confirm how the artefact has addressed these issues. As the artefact was created based on two factors: the usability guidelines which were found through the literature review and the usability issues which were identified
during the interview sessions. Using the focus groups, a discussion will be created around the artefact. A semi-open discussion was held which was not interrupted by the researchers. This was chosen to get an unbiased perspective on the proposed solution to the issues within TDMS [4].

Secondly the focus groups will be used to confirm the findings and the analysis result from the interview sessions. Focus groups will also help with creating a group scenario. This triggers the experts to discuss within the group where the needs and issues lies within the system. This could be potentially help within identifying further usability issues. Discussing about the topic as group will be more effective as with individuals, since data management systems are mainly used by large amount of people. Both, interviews and focus groups are aiming to get a deep understanding about a topic and can be used in a complementary way [25]. Since focus groups are well suited follow-up technique for other qualitative techniques [25].

**Design of the Focus Groups**

Focus groups were used to discuss the topic within group setting. During the session, the researcher went through different sections of the artefact. In each of the sections the focus group participants were asked two to four questions regarding the section. The semi-open questions were able to steer the participants to focus on the discussion of the artefact. In the appendix you will find the questions, with the assigned sections to them, which were asked during the two focus group. This is suitable as conditions and environments are very similar to the interviews [4]. Since the nature of focus groups, the discussions tends to spiral away. During the focus group sessions, in the same manner as the interviews, the sessions are voice-recorded. Voice-recording the session helps the researcher to focus on the asking the right questions and steering the session according to the outcome of it.

**Participants of the Focus Groups**

The two groups will consist of both a mix of previous participants (biased) and new participants (unbiased). As most of the implemented issues in the artefact were stated by the biased interviewees. In the same time bringing in participant with a ”fresh pair of eyes” on the topic, enables to create an environment of discussion and to bring new thought on the stated issues [25]. As the research is focused on testing the issues in TDMS through the company Husqvarna, we chose participants which matched with the iden-
tified user roles (see chapter 4.2.1). The thought behind it was that those kind of employees will have the most understanding and knowledge of the topic. This is a factor which is desired within a focus group [25] [4]. The participants were all contacted through email, being asked if they wanted to participate and when they would be available. The combination of the user roles were dependent on the availability of the participants.

3.1.5. Observational Study

Observational study is another qualitative research methods. The intention of the research in this paper is inter alia, to see how the user interacts with the artefact. This will help to identify if the used usability guidelines were able to solve the usability issues. Observational study is usually used to study cultures or subcultures focusing on the social aspects of the culture and the setting of the culture [25]. Observational study can also be used to study specific kinds of group settings, for example within a work environment, to understand the interactions and behaviour within that setting [25] [2].

One of the intentions of conducting a observational study is as already mentioned, to comprehend the interaction and behavioural actions of the user. With our work we are coinciding the aim of observational study of gathering and recording information with the way of working and thinking of the user. This corresponds with the goal of translating the knowledge and experience of insiders to outsiders [21]. This will help to increase the usability of the artefact. For the project, verbally isolated research techniques have been used. Verbal expression has its benefits as it can help the researchers have new concepts understood and explained in detail by the participants. It also has its drawbacks, as the participants can only discuss about what they actually perceive about the topic. Aspects which are obvious for them may slip by [25] [2]. Those obvious pieces of information may be crucial to the research. To complement the verbal research techniques, participant observation was chosen since the context of the case study has a naturalistic setting. It enables to observe the variety of actors interaction and behaviour within the setting of the researched system.

Conducting a observational study can be done in several ways since it is one of the most flexible research methods [25]. The general process of implement-
ing and adapting this method for the use case is to conduct an observation study. Being able to perform this kind of study, the kind of participant observation was chosen. Participant observation can combine several procedures like focus groups, questionnaire or interviews \[25\]. Since interviews and focus groups are used as individual methods in the papers case study, the technique of usability testing will be used for the observation study. One of the basic conditions for the method is to choose the way of observation. Due to the selected technique the "observer as participant" was chosen. As being the observer like a participant, the observer is interacting in a limited way with the individual or group of the observation. Asking questions, giving them task or hinting the participants in the right directions, are ways of the limited intercourse with the participants \[25\]. The chosen style of observation is focal \[25\]. The focal way of observing means to record all the behaviour as well as they physical properties of the participant in a selected time period.

Another aspect which has to be taken in consideration for conducting a observational study is to gain the trust and permission of the participants. The case study in Husqvarna has been conducted over a time period which lasted for months and the observational research has been chosen for being the last method for data collection. Therefore all the participants have been used to the observers and they have been gotten familiar with the topic of the research. The consent of being recorded has been obtained in the beginning of the observation.

As important as it is to get the direct feedback from the user about the usability issues, the user can not always describe where the underlying problem lies. With the observational study it is able to become the fly on the wall and see directly how the user use these systems (in this case the created artefact), without becoming influenced by the researchers questions and inputs. An observational approach will help the research project to receive the result about the usability issues from a subconscious level \[2\]. This will be achieved by testing the usability of the systems during the observational study. Since users tend towards executing tasks differently than they are describing. The above mentioned "fly on the wall" is necessary to identify if the usability issues have been solved with the created artefact.

**Design of the Observational Study**
The observational study was conducted on five different kind of users. Sev-
eral tasks, which required to use an artefact, were given to the participants. The artefact was created on the basis of the interviews and the focus groups. It is a clickable mock-up which imitates a technical data management system which is tailored to the needs of the case study’s company. Depending on what kind of user the individual participant was, different assignments have been given to him/her. The tasks were executed on the artefact in the software Figma. Figma is the software in which the artefact was created. The users executed the task in a ”viewing” mode. In this mode they were not able to change or edit factors in the artefact. While executing the tasks, the whole process of the user trying to achieve it has been voice and screen recorded. Each participant has been aware of the topic of the system and has been a participant in the interviews or/and focus groups. Before the observation started, the users have been asked for confirmation about the recording. They have been informed about the way the software in which the prototype has been implemented, works. One observation was scheduled to be two hours in conduction time. In this included, is the explanation of the tasks, the execution of them and the general retrospect feedback of the users.

Participants of the Observational Study
For the observational study, participants were recruited. As mentioned in chapter 3.1.5 it is important to have the trust of the participants which are going to be observed. All attendees were part of the interviews or focus groups and did therefore knew the researchers. This eliminated the above mentioned risk of trust issues. Test Operator, Test Responsible, Project Manager and Test Method Owner were discovered as the potential main users of the system. The Test Responsible has the same activities in the system as the Test Operator (compare with chapter 4.2.1). Therefore an additional Test Responsible was recruited to validate the actions of the other Test Responsible and Test Operator. This led in the end to five session. One representative of each user group (or two in the case of the test responsible) has been contacted through e-mail. They have been reminded about the interview or focus group they have been part of and been asked if they want to take part in testing the artefact. Different time periods for the sessions have been suggested and either accepted or changed by the participant. Each participant has been observed individually.

Tasks of the observational study
Since the observational study has the intention to examine the users be-
behaviour while executing different actions, several tasks were given to the users. The detailed level of the tasks varied from general to specific. Having only too broad or too high-in-detail tasks would restrict the user to execute the tasks in the initial way or would allow him/her total uncontrollable freedom. The tasks have been created to measure, if the usability issues have been solved. Therefore targets each task one or several issues. Table 1 shows which tasks is covering which issue. The main tasks, which every user has accomplished, were:

- Task 1: Find your last comment
- Task 2: How would you search for a specific test report?
- Task 3: How is the test result status for the test report “Sågning DTEW675”?
- Task 4: Which versions of the completed test reports of the “Jordfräs TF325” has Nils Norberg created?

These tasks are user independent and focused on the usability issues of: “Difficult to generate general overview”, ”Inefficient search”, ”Compromised highlighted important sections” and ”Lack of version control of the data”. The rest of the 16 tasks can be found in the appendix C. The Test Operator is one of the main users who are supposed to work in the system on a daily basis. This user gets assigned to tests by other users like the project manager. He/She executes tests and therefore has to enter measurement data and makes the first judgement of the result of the test. The tasks 5,6,7,8 and 9 were given to the Test Operator. Due to the work of the Test Operator and his needs for the systems the tasks were aiming to test if the usability issues of ”Lack of standards for manual data input”, ”Complicated process for manual data input”, ”Incompatible with other necessary systems”, ”Workflow flexibility”, ”Compromised highlighted important sections” and ”Complicated process for data input”. Since the tasks of this user are about editing or adding actual data, mainly the issues of the data input and workflow have been examined.

The Test Responsible acts in the same way as the Test Operator but has more rights and therefore has to capture the bigger picture of the test project/management flow. Therefore this user got the same tasks as the Test Operator but additionally tasks 10,11,12 and 13. The major difference between the
task of the *Test Operator* and the *Test Responsible* is that the *Test Responsible* got tasks which are influencing the test projects in either the beginning phase, with e.g. importing requirements, and/or in the final phase like looking up the fail/pass rates of test results.

The *Project Manager* is also responsible for different actions before and after the test execution, test project progress and test analysis process. Due to that the *Project Manager* got a slightly different set of tasks than the *Test Responsible*. The manager’s tasks were targeted on a more abstracted level. The tasks 10, 12, 13, 14, 15 and 16 were given.

Three additional tasks, compared to the *Test Responsible*, have been executed from the Project Manager. Task 14-16 are targeting the issues of ”Incompatible with other necessary systems”, ”Difficult to generate overview”, ”Lack of data visualisation” and ”Workflow Flexibility”. The user role which is feeding the system with test codes and therefore delivers the base for the test executions, test analysis and test projects is the *Test Method Owner*. He/She provides the first layer of data in the artefact his/her tasks were an intersection of all tasks (e.g. tasks 5,6,9 and 13)

The following table (Table 1) is summarising which tasks were testing which usability issues. The first row represents the actual task with the complementing number. The issue of an intuitive user interface has been tested with every tasks since the interface did not change between different users or tasks.

<table>
<thead>
<tr>
<th>Issue</th>
<th>1</th>
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<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of standards for manual data input</td>
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<tr>
<td>Incompatible with other necessary systems</td>
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<tr>
<td>Difficult to generate general overview</td>
<td>x</td>
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<tr>
<td>Complicated process for manual data input</td>
<td>x</td>
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<tr>
<td>Lack of version control of the data</td>
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<tr>
<td>Compromised highlighted important sections</td>
<td>x</td>
<td>x</td>
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<tr>
<td>Workflow flexibility</td>
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<tr>
<td>Lack of data visualisation</td>
<td>x</td>
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<tr>
<td>Intuitive UI is needed</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<td>x</td>
<td>x</td>
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<td>x</td>
<td>x</td>
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<tr>
<td>Inefficient search</td>
<td>x</td>
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</tbody>
</table>

Table 1: Task Issue Overview

**Parameters of the observational study**

Every task was measured and documented during the observation. The fol-
lowing measurements were used in the analysis to find out if the usability issues are still existing or not. These measurements/documentation factors were used:

- Time for executing the tasks
- Number and Description of confusion situations
- Pass or fail of the task execution
- Path-Documentation of the execution
- Amount of clicks

Not every measurement has been taken for every tasks. But for every tasks, the path the user took for executing the task (Path-Documentation) was documented. The situations were the user expressed confusion have been counted and written down for the analysis. How they have been analysed is reported in chapter [1.2.5]. The time an user took for executing the task has been taken inter alia as an indicator on how fast the user is able to orientate him/herself in the artefact. As well as how well the terms and the structure of the system has been chosen. The amount of situations and the actual situation were confusion was expressed by the user, have been taken to identify left usability issues and/or general issues with the concept. The users have been informed about that not they but the artefact is tested. The pass or fail of the execution of the task by the user is a valid factor of measuring if the concept is understandable for them. Since they were also several ways to pass a task a “pass with remarks” has been implemented in the analysis as well. Since the most usability issues occur due to the misunderstanding of the users way of thinking, documenting the path they took is suppose to help to understand the user better. The last quantitative measurement which was taken in consideration, was the amount of clicks the user took while achieving the task. This measurement helps on account of comparing the users among each other and to get a sharper view on how complex the system seems to be for the users. During all those measurements which have been taken during the observation or while analysing the screen- and audio-recordings, the statements the user gave during the process, have been documented and analysed as well.
### Table 2: Observation Schedule

<table>
<thead>
<tr>
<th>Path</th>
<th>Time</th>
<th>Amount of Clicks</th>
<th>Pass/Fail</th>
<th>Confusion Timer</th>
<th>Observation Notes</th>
<th>Tested Issue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task 1</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>User 1</td>
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<td>...</td>
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<tr>
<td>Task 2</td>
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</table>

**Observation Schedule of the observational study**

To create a base on the gathered data, as well as to provide and follow a structure an observation schedule for the observational study has been created (compare with table 2). Every measurement which was designed to be taken is in the observation schedule included. They serve to be the indicators on how well a usability issue has been solved. Since the issues are the main factors for the users, the guidelines which have been used to solve the issues are not included in the observation schedule. For the analysis of the observational study, they have been mapped out towards the issues. Besides the above mentioned measurements, notes which have been taken during the observation are included in the schedule as well. This helps to merge the recorded data with the actual observations from the researchers.

### 3.2. Data Analysis

In this sub chapter the methods which were used to analyse the collected data, gathered through the previously mentioned research method, will be presented. This will be done by introducing how the data has been analysed on each of the research methods. The techniques for analysing were chosen to fit to the methods which were used for the data collection. For every method which has been analysed, an inductive way has been used. The main idea behind using an inductive approach is to gather data and analyse it to examine the data, to find pattern and themes to follow up and focus on [2]. In general, the goal while analysing the data was to identify relations between the data and the research questions. Furthermore, possible theories should emerge from the collected and analysed data.
3.2.1. Analysis of Literature Review

From the first circle within the hermeneutic framework, search and acquisition, into the continuation of the second circle of "Analysis and Interpretation" (see figure 2). The first step of analysis and interpretation starts with mapping and classifying the acquired literature. Afterwards critically assessing the mapped out classified literature followed. This was implemented through reviewing how far previous literature was able to answer the research questions. The short comings of previous literature were addressed, as well as where authors explicitly mentioned where future research can continue on. How arguments and theories has been established the former research has been set as the base for the result of the assessment. If further research problems/questions would be necessary to set, a transition back to the first workflow circle in the hermeneutic circle would have been triggered. By iterating the whole process once again, sufficient arguments for the research area would be established.

During the analysis and interpretation of the acquired literature, was started with the mapping and classifying of the literature based on the set keywords (Usability issues, TDMS, usability guidelines etc. ). As the literature review was used for building the first level for answering the second research question, we critically assessed based it on that. This was performed, which was stated previously, by looking into how far the previous literature was able to answer the question based on the keyword classes.

3.2.2. Analysis of Interviews

The interviews were conducted to gather qualitative data. The intention was to get a deeper understanding about the test management process in Husqvarna and how the future users of the system work. To find the first needs of those users, the interviews have been conducted. As the inductive approach takes a red thread in the research of this paper, an inductively based analytically procedure has been used for the analysis of the interviews. The approach of the analysis method of "Grounded Theory" has been used for analysing the interviews. Since the intention is to build a theory based on the data, the process of Grounded Theory is suitable for the analysis. The theories which are being build with the interviews are to state the functional and non-functional requirements within the Husqvarna company.

To follow the Grounded Theory process of open coding, axial coding and
selective coding [2]. The first action which has been taking was to transcribe the interviews. All ten interviews were transcribed manually. The recorded sessions have been listed for each question section. The sections have been written down (word for word). Not only what the participants said, but also how they said it has been documented during the transcribing process. When an interviewee has enhanced a fact or put emphasise on it, the affected section has been put in bold letters to highlight the statement. The distinction between the interviewee and the interviewer has been made clear with adding the names in front of each the statements.

After the transcription, the process of open coding has been conducted. Open coding follows the structure as categorisation and unitisation [2]. First of all, the data has been categorised which includes the practice of developing categories and assigning them to different chunks of the data. For creating the different labels of the categories, the main statements of the different chunks has been highlighted. This helped to emerge the terms for the categories from the actual data and actually ”copying” possible terms which have been used by the participants (”in vivo” codes) [2]. While implementing the sectioning, it has always been taken in consideration, to have meaningful terms. The terms have been chosen in the manner that they are meaningful for the data but also highly-valued for the relation to the other categories. For simplistic reasons the terms have been kept as precise as possible to be able to easily visualise the data. Visualising the data is another helpful technique for analysing qualitative data. It helps to be able to see and create relationships in a more efficient way [2]. Another reason for that, was to unitise the data in a visual way. Unitising data is the method of assigning the chunks of data to their categories [2]. The whole process of open coding enabled to indicate patterns and issues, which the interviewees had and helped the researchers to focus on them. After the open coding, the researchers concluded this part of the analysis with ten different categories. Under those categories the statements which overlapped and have been mentioned by every interviewee have been assigned to. These data chunks are detailed explained in Section 4.1.1.

The result of the axial coding delivers the relation between the different categories. Furthermore, it underlines the hierarchical order of the categories [2]. While applying the method, the question of why the categories (therefore the issues) have been mentioned, has been asked. As well as how they are affecting the daily work life of the interviewee. This helped to find out the
axial relations and therefore which ones have to be higher in hierarchy. Since 
the evaluation and analysing of the interviews has taken several weeks the 
different priorities and relations have gone through several changes. This is 
described as selective coding in the grounded theory analysing method [2].

Even though the main intention of the analysis of qualitative data in the 
grounded theory is to emerge a theory from the collected data. We adapted 
the approach to our already existing research questions. The research ques-
tions didn’t imply directly a theory and therefore this method of analysing 
has been chosen to create theories to be able to answer the research questions 
with it.

3.2.3. Analysis of Focus Groups

The focus group method was used to further collect qualitative data. The 
intention of using the focus groups method was to analyse if the artefact had 
solved the identified usability issues. This was a part of the second research 
question. Continuing the red thread through this paper an inductive ap-
proach have been applied to analysing the focus group data; Same as in the 
interviews.

The analysis method of Grounded Theory has been applied again to analysis 
the focus group data results. The theories, which will be built from the data 
result, indicates how the artefact has solved the usability issues. A base of 
theories had been built during the analysis of the interviews. The analysis of 
the focus groups continues to develop those theories. Only open coding was 
used during the coding of the focus group data. As mentioned in chapter 
3.1.4, the focus groups were voice-recorded. Unlike the interviews, the focus 
groups were not transcribed word by word. The reason for this were time 
constrains within the project. The two focus group sessions were transcribed 
with a data sampling transcription method. Data sampling transcription 
was conducted while listening to the recorded sessions. Only transcribing 
and highlighting in the recorded session is pertinent to the research [2]. This 
method comes with some potential problems. Certain things may be missed 
during the process and the recordings need to be listen at least twice [2]. This 
problem has been eliminated, as during the transcription each researcher lis-
tened through the recording and transcribed the relevant sections. After 
both the researchers have transcribed the audio, the two transcriptions were 
compared and merged. Same as the in transcription the enhanced facts and
statements were put in bold to highlight the importance. Comments such as what the participants enjoyed and what they disliked about the artefact were highlighted for further analysis [4]. The distinction between the interviewee and the interviewer as been made clear with the process of putting the names in front of the statements. Highlighting enhanced facts and statements built the chunks of data.

3.2.4. Analysis of Observational Study

The observational study technique was used to test if the created artefact, which is based on usability guidelines, solves the usability issues within TDM systems. It is a technique where qualitative and quantitative data can be produced, depending on the execution of the research [25]. The data was gathered through voice and screen recording as well as taking notes during the user observation. As in the other two methods (interviews and focus groups) the voice recorded data was transcribed to be able to analyse it. Since the observation of the user was initiated through different tasks, which were given by the researchers, the analysis of the gathered data was focused on how the users perform these tasks. The analysis of the voice recorded data was conducted in the same process as the analysis of the focus groups (compare with chapter 3.2.3). The data was sampled during the transcription and to avoid the possibility of missing out content, the data sampling for each observation was conducted by both researchers. The transcription was conducted simultaneously with the screen recording. Since the participants expressed opinions about certain circumstances while using the artefact, the actual context with the comment of the user was important. The data sampling supported and commented the situation where the opinion and statements were raised.

After the data sampling part of the analysis the results were compared to find patterns. For this purpose the analysing method of open and axial coding were used [25]. This was differently used than in the two other methods before. The patterns were matched to the tasks which were given. The ideology of the coding was still follow but only matched to already existing categories. The screen recordings have been separately analysed as well. They were not only supportive for the qualitative analysis of the voice recording but also to create quantitative data. With the quantitative data the intention was to enable a quantitative way of evaluating if the artefact solved the usability issues or not. Therefore different measurement have been determined before
the execution of the observational study. The exact measurements have been explained in chapter 3.1.5. While analysing the screen recordings, those measurements have been examined and the actual values for each tasks assigned. To have validity on this data analysis, this part has been also conducted of both researchers separately. Afterwards the results have been compared, merged and arisen differences have been double checked with the original recording together.

The analysed results of both recordings have been brought together in one document. Having the results of both analysed recordings and bringing the quantitative and qualitative data together, enabled to analyse all data in the context together. Since the main intention with the observational study was to analyse if the usability issues have been solved with the created artefact, the analysed data (qualitative and quantitative) has been mapped to the issues. Since each tasks was created with the intention of testing one or several issues, the mapping process was interpretation-free and easily executed. For each issue the analysed data has been examined and based on the qualitative data supported by the extent of the quantitative result. These were crucial factors for the decision if the issue has been solved or not. When the qualitative arguments were positive and the quantitative data resembled the positiveness, the decision that the issue has been solved, was made. On the other hand, if both of the data aspects leaned towards a negative results the issue has been marked as “not solved”. If the qualitative analysis resulted in a positive way and the quantitative one in a negative (or the other way around), the issue could not be clarified as solved or not solved. Those issues were discussed and marked as ”neutral”.

4. Findings and Analysis

The findings and analysis chapter presents the content which enables to answer the research questions. The found usability guidelines are presented firstly. They have been the results of the literature review. Which ones exactly have been used and which have been sorted out is introduced in the chapter of *Applied Usability Guidelines for TDMS*. Afterwards the company and the findings of the case study are presented. This chapter is divided into the order of how the methods were conducted and allows therefore to follow the project process. Therefore firstly the interviews findings are introduced. The result of those findings (the usability issues) led to creating an artefact,
which is explained correspondingly afterwards. Followed by the findings of the focus groups and observational study the chapter ends.

4.1. Usability Guidelines

This chapter presents the usability guidelines. Different resources have been found during the literature review. The chosen guidelines and papers are presented in the discussion of the existing usability guidelines. Afterwards the usability guidelines which have been used for the created artefact in this research are introduced.

4.1.1. Discussion of existing Usability Guidelines

Usability guidelines have existed in the digital world for a long time. With the need of making user friendly software, the need of guidelines for creating such applications has risen. A guideline in the context of usability is an information on how to design an application to achieve it. Guidelines serve the purpose of giving a comprehensive view of known issues and recall them. They guide into a direction of overcoming lacking standards in design and communication. These recommendations are not rigid definitions and they should rather be discussed and refined by researchers and practitioners of the specific area. In general, guidelines are recommendations which have been discovered through issues \[15\]. With the "World Wide Web" usability guidelines spread in conferences and are discussed by scientists and researchers. Within the industrial market, guidelines have been established. It also should be kept in mind that guidelines change over the time and adapt to the users and environment needs \[15\]. While conducting the literature review guidelines were in- and excluded due to their state-of-the-art validity and their relevancy for the context of the case study. For example, guidelines which were created 20 years ago and which depended on specific out-dated hardware have been sorted out for the purpose of this thesis. Specific criteria for categorising and sorting out different guidelines will be explained later in this chapter. The applied guidelines in this paper will be presented with references and justification to ensure an academical standard.

Nielsen’s Heuristics
One of the most popular guidelines are the usability heuristics of Nielsen. Dr. Jakob Nielsen is a pioneer in the user experience world and known for his research in usability and user experience. His heuristics were published
1993 [18] and are still used today for creating application with a high usability. They are called "heuristics" and Nielsen mentions that they are more likely to see as recommendations since they don’t define specific guidelines [19]. For the use of this paper they have been considered as guidelines while bearing the explanation of Nielsen in mind and adapting it to the context of usability in TDMS. He claims that

- Visibility of system status
- Match between system and the real world
- User control and freedom
- Consistency and standards
- Error prevention
- Recognition rather than recall
- Flexibility and efficiency of use
- Aesthetic and minimalist design
- Help users recognize, diagnose, and recover from error
- Help and documentation

are appropriated to consider when a high usability application is desired [18]. His guidelines were created based on several usability issues and due to their broader range, they are applicable for several contexts [19]. In this paper, the heuristics have been considered due to their state-of-the-art status and since they are seen as one of the base columns of usability engineering.

**Research-Based Web Design & Usability Guidelines**

A collection of 209 guidelines based on several references has been created by the U.S Department of Health and Human Services [15]. Every guideline was either collected from published research articles, usability test reports, research summaries or style guides. The guidelines are targeting designer, usability specialists, managers and researchers. They aim of the book is to provide support to evaluate the usability of web pages and to guide while conceiving and designing a web page. The intention of gathering current
standards and principles together was to create one guide, arise discussion and to detect research gaps. While developing the collection, the authors have been creating a original set of principles which concluded in the end of 500 guidelines. After they reviewed the set, they eliminated guidelines which were duplicates and conflicted each other. Rephrasing of unclear principles has been conducted as well. The review process left 398 guidelines. To be able to verify the principles the authors determined the relative importance and strength of evidence. They had several reviewers and researchers recruited to rate the guidelines after the importance and evidence in papers. Afterwords, grouping and updating of the guidelines has been conducted which lead to final version of 209 guidelines. The authors have categorised the principles in eighteen different categories which for example includes the category ”Navigation” or ”Content Organisation” [15].

The paper provides guidelines for specific content/design choices of applications. Due to the fact that no specific focal area was mentioned by the authors, the guidelines were found to be adaptable for the focus of technical data management system. For the purpose of TDMS and of the case study several guidelines have been eliminated. Outdated guidelines, not applicable to TDMS, technology wise irrelevant principles, guidelines which had a lack of references (which included guidelines with one or two references older than 15 years) and duplicates were disregarded. After eliminating several principles due to the above mentioned reasons, 120 guidelines were left. The remaining ones have been reviewed and categorised under the heuristics of Nielsen [18] to create a structure and to estimate the weight of the principles.

**Usability guideline for Desktop Search Engines**

Another resource which was found during the literature review, provides usability guidelines in the context of search engines which are developed for desktops. The authors approached the development of the guidelines through the study of eight desktop search engines, Nielsen’s heuristics and with two evaluators for each desktop search engine. The result of the walkthroughs was a collection of 70 usability problems. After clustering redundant usability issues and taking the individual strengths of the different testers, a set total of 36 guidelines was gathered. Due to discussion and consolidation of the guidelines a set of 30 guidelines tailored for usability in desktop search engines were discovered. Most of the guidelines are not overlapping with already known guidelines and were tailored to their focus area of desktop
search engines. For developing and providing a better understanding of their created principles, Nielsen’s heuristics [18] were used for categorising, so that other researchers are able to understand the guidelines in a broader context as well.

Due to the circumstance that our case study may have a desktop search integrated in the TDMS, the paper has been evaluated as applicable. For adapting the guidelines for the use of usability in TDMS some of the principles were discarded. The reasons for eliminating guidelines were the same as for the other collections of guidelines which have been found, through the literature review. Three of the principles had to be eliminated since they have been tailored to desktop search engines or were made redundant due to the other collections of guidelines. In total 27 principles of the paper have been taking in consideration for the usability guidelines for TDMS.

**Customisation Usability: 46 Design Guidelines to Improve Web-based Interface and Product Customisation**

The Nielsen Norman Group is known as being an pioneer institution in the user experience and usability world. Jen Cardello the author of the book is a User Experience Specialist in the Nielsen Norman Group and conducted the study the book is about. The focus area of the study was web-based customised products. The customisation was defined for the interface of the product and the product itself [10]. Cardello conducted a usability study to create the guidelines. The study as itself was carried out as a “Thinking Aloud” study. The participants therefore commented on what they search for, what they like and dislike and if the given tasks were easily or difficult to achieve. The study was executed on customisable and non-customisable websites to compare the experience and execution on both versions. The whole intention was to raise the question if the usability increases if the user is able to customise a web page. As well as to allocate guidelines for usability in applications with customisable functions [10].

The paper was found applicable to the topic of TDMS since a lot of application are web-based and most of the users are used to web-based interfaces. Enhancing the usability of a TDMS can be achieved with adapting usability guidelines of web-based interfaces since a lot of users are confronted with those kind of applications in their daily life. Cardello’s paper [10] was reviewed at last. Due to that 15 of the 46 guidelines were added to the col-
lection of guidelines. The rest were mostly duplicates to the other discovered guidelines in the before mentioned papers.

4.1.2. Applied Usability Guidelines for TDMS

The goal of the thesis is to solve usability issues in technical data management system with current existing usability guidelines. The above clarified papers mention and suggest guidelines which can be used to achieve a good usability in software and applications. In total 197 guidelines were found applicable and useful for the purpose of this research (compare with table 3). The number of the appropriated guidelines varies from each resource. Due to the circumstance that we explored the resources one after the other, several guidelines became duplicates in the sources which have been examined later. Therefore the amount of guidelines declines for each paper in the order of examination. While analysing the resources several factors played a role for excluding some of the guidelines. The reasons were:

- Redundant due to another guideline
- Not applicable for TDMS
- Outdated (Technology-wise)
- Hardware-dependent
- Lack of evidence/resources

If the guideline was a duplicate to another there was no reasons to include it. Some of the guidelines were too specific or were tailored for a particular context which made them not usable for TDMS. Since the majority of resources have not been created in the past five years some of the guidelines were technology-wise outdated. Since the IT and digitalised world is known for their rapid change, several guidelines were not applicable for today’s technology. The same reasoning is behind excluding guideline which were dependent on different hardware components like desktop screens. The last factor which has been taken in consideration while analysing the guidelines, was the lack of resources and the lack of evidence for the guidelines. If the authors of the collection of the guidelines could not prove academically-wise that there is an explanation or need for this guideline, it was not included.

To give an overview of the collected guidelines and for further research, we
have decided to categorised the collected guidelines into the heuristics of Nielsen. Since the context of technical data management systems is rather specific the structuring of the guidelines into the heuristics supports to judge the guidelines. The heuristics as themselves have been explained in the former paragraph. The mapping of the collected guidelines into the ten heuristics was based on three key factor: the categorisation of guideline from the resource, the context and the keywords. Firstly, using the judgement of the resource itself and dividing the guidelines based on their categorisation. Secondly, looking into context in which the guideline fits. The context was determined by the keywords of the guideline. An example of the mapping process is the following: looking into an example guideline from Leavitt [15], ”Design for Working Memory Limitations”. As mentioned the keywords determine the context. The keywords which determine the context in this guideline are ”working, memory” and ”limitations”. This brings the guideline into the context of working process and user memory. The example guideline was categorised into the heuristics of ”Recognition rather than recall”, as the keyword ”recognition” in the heuristics relates to memory. Hence why the guideline was sorted into this specific heuristic.

The table is divided into the heuristics and into the three other resources of guidelines which have been found. This corresponds to the total of four usability guideline resources. The second, third and fourth columns with the abbreviations ”RWD”, ”DSE” and ”CU” stand for the titles of the resources. ”RWD” stands for ”Research-Based Web Design & Usability Guidelines”, ”DSE” for ”Usability guideline for Desktop Search Engines” and ”CU” for the title of the resource ”Customisation Usability: 46 Design Guidelines to Improve Web-based Interface and Product Customisation”. The amount of guidelines for each heuristics is based on the quantity of guidelines which has been assigned to the heuristics in the process of an inductive categorisation approach. Some of the guidelines were valid for several heuristics and have been assigned to the several guidelines.

Summarising the most guidelines have been found for the factors of consistency and standards, error prevention and recognition rather than recall. Rather fewer guidelines for the visibility of system status, match between system and the real world as well as for the two help heuristics have been discovered.
<table>
<thead>
<tr>
<th>Nielsen’s Heuristics</th>
<th>RWD</th>
<th>DSE</th>
<th>CU</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visibility of system status</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Match between system and the real world</td>
<td>5</td>
<td>3</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>User control and freedom</td>
<td>6</td>
<td>4</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>Consistency and standards</td>
<td>36</td>
<td>3</td>
<td>1</td>
<td>40</td>
</tr>
<tr>
<td>Error prevention</td>
<td>22</td>
<td>4</td>
<td>4</td>
<td>30</td>
</tr>
<tr>
<td>Recognition rather than recall</td>
<td>33</td>
<td>2</td>
<td>4</td>
<td>39</td>
</tr>
<tr>
<td>Flexibility and efficiency of use</td>
<td>20</td>
<td>4</td>
<td>1</td>
<td>25</td>
</tr>
<tr>
<td>Aesthetic and minimalist design</td>
<td>21</td>
<td>2</td>
<td>2</td>
<td>25</td>
</tr>
<tr>
<td>Help users recognise, diagnose, and recover from errors</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Help and documentation</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>197</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Collected Guidelines

4.2. **Case Study: Husqvarna**

Husqvarna is an industrial company founded in Huskvarna, Sweden with its headquarter in Stockholm. They are manufacturing products in the forestry and gardening equipment area. In their market their are known for chainsaws and lawnmowers, hedge trimmers and cutters. The research & development department is collaborating with the researchers for developing a technical data management systems for their testing process. The scope of the project for Husqvarna is to find and break down the requirements for such a system, designing parts of the user interface for the application, creating a system design for the software and give recommendations for a suitable programming environment.

To be able to achieve all the mentioned milestone, the first step is researching about the current systems on the market and in Husqvarna regarding data management and testing. The second step is interviewing future possible users of the software. This supports to find out the needs and requirements of the application. After evaluating the interviews and the competitor analysis, the process of wireframes based on the results follows. To insure that the needs of the users are met and to get feedback, the wireframes are triggers for the focus groups. The results of the evaluation of the focus groups will lead to improvements of the wireframes and enable the process of creating mock-ups. These will be tested with a observational study (i.e. chapter 3.1.5). The last step for the milestone of creating several parts of the user interface for the desired system, is to implement the results of the user testing and with
that create a low-fidelity prototype.

Due to the research phase and the iterations of creating the interface, the different requirements and needed structure for the system design will emerge. Therefore gathering the information, structuring and presenting them is needed to present a suitable system design. Otherwise will the recommendation of the programming environment be based on the former experience and the already existing programming environments of Husqvarna.

4.2.1. Interview Findings

To get insights about the needs and thoughts of possible users of the software, interviews were held. The interviews were the starting point in answering the first research question, regarding the functional and non-functional requirements in TDMS for a manufacturing company. The interviews were held in a semi-structured way. A semi-structured interview allows a freedom which can help to discover unknown issues. How they are specifically are executed and how they helped with qualitative research is described in chapter 3.1.3 Interviews.

A total of ten interviews were held. During these interviews we identified seven different user groups which had different responsibilities and tasks within Husqvarna’s different TDM systems. The user groups which were identified were: Test Operator, Test Responsible, System Engineer, Test Method Owner, Project Manager, Lead Engineer and Design Engineer. Their tasks and role have been discovered from the interviews as follows:

- **A Test Operator (TO)** gets assigned to perform several test and therefore he/she enters measurement data into the application while conducting the test. They are also the user group which delivers the first result judgement of a test.

- **A Test Responsible (TR)** has the same duties as a test operator but has additionally responsibilities. They also operate, analyse and evaluate the test results as well they are able to change the status of a test (e.g. ”in progress” or ”done”)

- **A System Engineer (SE)** is responsible for writing test requirements. He/She will enter test data and view test methods in the system.
• A Test Method Owner (TMO) has the main responsibility for the test methods and therefore they are writing test methods. Not only initiating and creating the first versions of the methods but also updating them is one of the tasks they will perform in the system.

• A Project Manager (PM) is writing test plans, assigns test responsibilities, leads different projects and reports the result to other personnel.

• The Lead and Design Engineers (LE)(DE) are looking up and using test results, intermediate steps, may view the status projects as well do they have to need to search for finding specific information.

Each of the above mentioned user roles where interviewed and for each of the test engineers, test operators and project managers, two persons were interviewed. During the interviews we identified that the main of the designed artefact the Test Operator is. As the Test Operator will enter and adjust most of the data and give the first judgement of the data within a TDMS in Husqvarna. The interview process was divided into two sections. The first seven interviews were collecting the initial data and were the base for first assumptions. After the assumptions had been set, three additional interviews were conducted to create a confirmation of the assumptions.

The method for analysing the interview data was the Grounded Theory. The method was used to create a theory which answers the research question of the functional and non-functional requirements within a manufacturing company. The process of Grounded Theory is explained further in chapter 3.1.3. It was used to code the data with open coding, axial coding and selective coding [2]. The step which had to be taken to be able to code the data, was to transcribe the interviews. The transcribing process was performed manually, by listening section-wise to the recorded interviews. By writing down word by word what was said. Extra care was taken on enhanced and emphasised statements of the interviewee. These statements were highlighted in bold during transcribing process.

The categorisation was conducted to find patterns in the data. The patterns were visualised through writing down common empathised statements on sticky notes. This was to easily create a visualisation of the data. Based on the sticky notes, categories were formed from the chunks of data which then going to be visualised. The labels of the categorisation were formed from
highlighting the similarities between the main statements. The categories
which were marked out, were Templates, Synced System, Search, Flexibility,
Usability Issues, Database, Requirements, Workflow and Issue Tracking. The
unitisation step was conducted after the categories were established. Each
sticky note was assigned to one of the 10 categories. The data was assigned in
a reversed manner to show how the categories were formed. The highlighted
statements were assigned to the category with the closest related label.

After the categories have been established, the data has been assigned to the
them. The method of axial coding was used. Axial coding was further used
to find patterns and find relations between the categories. It was also used
to create a hierarchy between the data. Which allowed to prioritise the chunks
of data better. Three levels of importance were established, High Priority,
Medium Priority and Low Priority. Based on the quantity of the state-
ments which were mentioned by the participants, the categories were placed
in one of the three priority levels. A category was mentioned by more than
six participants, the category was placed in the high priority level. Five cat-
egories fell under the high priority level (Templates, Synced Systems, Search,
Flexibility and Usability Issues). If a category was mentioned by at least
five participants it was assigned to the medium priority level. The medium
priority level categories are Database, Requirement Management and Work-
flow. If a category was mentioned by at least one participant, the category
was placed in a low priority level. The only category which was placed in the
low priority was Issue Tracking. The categories of Synced System and Flex-
ibility were merged to become the core category. The rest of the categories
were then placed as sub categories to the core category. In table 4 the result
of the coding process of the interviews are presented. Table shows which
categories were identified. It showcases example statements from the inter-
viewees as well as in which category they were placed. Which user groups
expressed statements in this category, how many mentioned things related
to this category and which priority level it was given.

The statements within these categories can be rooted back to the core
category. In the category Synced Systems the main statements which were
stated which is presented in table 4. These statements related to the core
statements in the Flexibility category. The main statements in this categories
were "All our systems are disconnected. They are not compatible with each
other" and "Everyone Works differently, there is no consistency". The state-
ment "All our systems are disconnected. They are not compatible with each
<table>
<thead>
<tr>
<th>Category</th>
<th>Example Statement</th>
<th>User</th>
<th>Mentions</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Synced Systems</td>
<td>&quot;A lot double work. A need for data version control&quot;</td>
<td>TO, TR, SE, TMO, PM, LE, DE</td>
<td>10 of 10</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>&quot;Needs to be connected to other systems, too many systems.&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Search</td>
<td>&quot;The search is extremely bad and inefficient, as almost everyone works differently and people put information in wrong&quot;</td>
<td>TO, TR, SE, TMO, LE</td>
<td>8 of 10</td>
<td>High</td>
</tr>
<tr>
<td>Templates</td>
<td>&quot;Standardised test reports is need to be able to analyse the results.&quot;</td>
<td>TO, TR, TMO, PM</td>
<td>7 of 10</td>
<td>High</td>
</tr>
<tr>
<td>Usability Issues</td>
<td>&quot;It is hard to know what fields to fill in&quot;</td>
<td>TO, TR, TMO</td>
<td>6 of 10</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>&quot;There is too much manual input&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Workflow</td>
<td>&quot;It takes a lot of time to compare data in a precise manner&quot;</td>
<td>TO, TR, SE, TMO, DE</td>
<td>7 of 10</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>&quot;I want to see the responsible person of the test project&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Requirement Management</td>
<td>&quot;I want to easily import a requirement sheet into the system and review the requirements points&quot;</td>
<td>TO, TR, TMO</td>
<td>4 of 10</td>
<td>Medium</td>
</tr>
<tr>
<td>Database</td>
<td>&quot;Have an easy overview of the structure of our test codes and test reports&quot;</td>
<td>TO, TR, PM, TMO</td>
<td>5 of 10</td>
<td>Medium</td>
</tr>
<tr>
<td>Issue Tracking</td>
<td>&quot;I want to know when there have been a change in the test&quot;</td>
<td>PM, DE</td>
<td>2 of 10</td>
<td>Low</td>
</tr>
</tbody>
</table>

Table 4: Coding of Interviews

other”, was stated by all participants. There was a clear connection between the categories. Statements such as ”All our systems are disconnected, they are not compatible with each other”, ”A lot double work, a need for data version control” and ”Needs to be connected to other systems, too many systems”; show an incompatibility with other necessary systems and a lack of version control of the data. Hence this connection between the categories, a merge of the two categories were made.

Applying selective coding to the data was the next step. The other categories remained the same, as they transformed into sub categories of the core category. Statements within these categories can be related back to the core category. The remaining three categories in the high priority level were Templates, Search and Usability Issues. The statement and issues in these categories were mentioned by the majority of the participants. One of the most commonly stated category was the Search category. The search category was the second most mentioned category (see table 4). The statement presented in table 4, showcases a connection to two other categories, Usabil-
ity Issues and Templates. As in these categories, there were also mentioned that a majority of people works differently, which generates the issue of an inefficient search. As people are not working with templates, which then creates a lot of issues of creating a efficient search engine.

The Workflow was one of the categories which got moved to the high priority level. The category’s statements overlapped strongly with the core category’s statements. These were for example: ”I want to see the responsible person of the test project” and ”It takes a lot of time to compare test results in a precise manner”. They state difficulties of a workflow flexibility.

4.2.2. Usability Issues in the Garden & Landscape Maintenance Industry

During the qualitative analysis of the interviews, not only the functional and non-functional requirements of Husqvarna have been discovered but also the current usability issues. The usability issues can be accounted as part of both, the functional and non-functional needs.

The interviews revealed the usability issues within the current used software in Husqvarna. Due to the different professions and roles of the interviewees, several perspectives on the issues have to be taken in consideration. The following table (Table 5) illustrates the issues which have been emerged from the collected data in the interviews. The issue Incompatible with other necessary systems has been mentioned by every participant in the interviews independently of the technical data management system. The users were complaining that due to the lack of synchronisation with other systems and the different kinds of file output, their daily working life suffers. Entering the same data, multiple times in different technical data management systems derives frustration and lowers the usability of the systems. Especially in industrial companies where a lot of systems are used for different purposes, they have to be synchronised to enhance the working process of the users. The same issue has been also discovered by Tretten [22] which indicates that this issue can be generalised for TDMS.

The second most important issue, is the lack of an efficient search in the used technical data management systems. Being able to find technical data with a suitable search term or ID increases the usability of the system for the user. In general, being able to create and find content, are two of the main functions such systems are providing [14]. The lack of finding specific data decreases the usability of such systems. The different user groups of the
TDMS’s in Husqvarna have different intentions of using the systems, but all of them have the need of searching for data. Therefore is this issue of high importance.

*Lack of standards for manual data input, Workflow flexibility, Lack of data visualisation* and *Intuitive UI is needed* are issues which seven of the ten interviewees have mentioned. The current input for the different TDMS’s at Husqvarna is mainly manual. It is on the behalf of the specific user how the data is entered and therefore saved in the system. Structure or standards which forces the user to enter the data in an organised way are currently not implemented. This leads to usability issues like unreadable data or data chaos in the systems. Especially for the user roles which have to enter and manage the data this usability issue is of greatest importance. Being flexible about the own workflow, as well of the general workflow of the system, is one of the third most important issues. Creating the engineering testing processes and being able to edit data afterwards in the way it fits to the working flow of the responsible person, is the main desire of the users. The other aspect of this issue is, that it is according to the participants, hard to be able to generate a general overview.
to quickly grasp the flow of the system. Therefore it is nearly impossible to create flexibility in it. The users have to adapt to a rigid structure which is difficult to understand in the first attempts of using the system. The users have to create "work-arounds" to be able to their work. Tretten discovered the same issue in his case study [22].

Humans are facing a challenge when it comes to understand and process data which is displayed in a computer-understandable way. With technical data, which is the kind of data which emerges from an engineering process, is mostly non-human friendly. TDM systems therefore are having the issue of visualising the data in a human-friendly way. The interviewees who mentioned this issue, raised the opinion that they are aware that the data has to be in this kind of form, but they are struggling with processing it.

Another usability issue which is corresponding to the literature of Tretten is the issue of not having an intuitive user interface (UI). An intuitive UI means that the software does not need any further explanation of the components in the interface. It should immediately be clear for the user how to use the interface. The interviewees were complaining that in the current TDMS’s the interfaces are not intuitive. As well that it takes several hours to understand what functions different parts of the systems are providing.

Being not able to get an overview about the data which is in the system and how the relations are between them is the usability issue of Difficult to generate general overview. Usability is, inter alia, about being able to give the user the "big picture" within the first seconds. In general, it is a big challenge for technical data management systems to provide such an overview but it is necessary to provide it partly. Currently, this is not the standard in the Husqvarna.

Some of the users felt that the process of entering data manually in the systems is complicated and confusing. This correlates with the lack of standards for such kind of input. The reasons for the confusion varied from unclear labels for the input fields to not knowing what data is actually wanted. The aspect of Lack of version control of the data is another usability issue in the system, which relates directly to the data. In contrast to the two other issues, this problem is a specific need from the users and does not relate to the lack of architecture of the data. Currently there is no function for the users which
indicates several versions of the same data. This declines the usability of the
TDMS since data may be interpreted in the false way and get processed in
the wrong way, which leads to user dissatisfaction.

Completing the list of usability issues, is the problem that important sec-
tions are not highlighted or compromised. The cognitive workload in TDMS
is a lot and therefore the need of having specific areas, like results or starting
points, highlighted and/or compromised would help the user for orientation.
And to achieve their goals quickly. The faster a user is able to satisfy the
urge of using a system, the more likely is the system perceived with a high
usability [19].

Summarising, some similarities to the study of Tretten [22] in the aircraft
maintenance area as well as in the industrial needs can be drawn. There are
specific issues within the test management area which have been discovered
during the interviews. All of them are in relation to the fact that technical
data is not easy to manage and a lot of factors are coming together. The
focus lies on solving the usability issues in table 5 with the current existing
usability guidelines in the literature.

4.2.3. The Artefact

To test if the usability issues in technical data management system can be
solved through using usability guidelines a TDMS was created. The artefact
was created with the data from the interviews and focus groups. The actual
testing of the artefact was implemented with the observational study. The
software artefact helps to identify if general usability guidelines can enhance
the usability of TDMS. Since these systems are handling data which is hard
to process for humans, the questions arises if current usability guidelines
enable the process of an increased usability in these systems. Both gath-
ered usability issues from the literature review (chapter 3.2.1) and from the
interview (chapter 4.2.1) set the base to create a TDMS which fits to the
case studys’ company. The main focus while creating the artefact was based
on the issues which were gathered from the interview. Creating a system
which tries to solve issues which are not related or have not occured for the
company, is not useful for research reasons. Which specific needs have been
identified has been explained in the above mentioned chapters.

Since the artefact has to provide a valuable service for the users at Husq-
varna, the needs of those users have been taken in focus. The needs were
the results of the interviews which have been conducted. Those included
the actual mentioned issues from the user but also the needs, which were
identified during the analysis and comparison of the interviews (i.e. chapters
3.1.3, 3.2.2 and 4.2.1). The user needs were then translated into requirements
for the artefact. The whole set of requirements was complemented with the
needs which have been identified from the research for technical data man-
agement systems.

Before the process of creating the artefact was initiated, the collected guide-
lines (i.e. chapter 3) have been listed and shared with both researchers. The
total of 197 guidelines has been examined by the researchers before creating
the first version of the artefact. The guidelines have been categorised into
the heuristics of Nielsen (compare with chapter 4.1.2).

To allow each researcher freedom in creativity and their own interpretation
of the user needs, the first versions (wireframes) were created separately. The
wireframes and the end version of the artefact, were created in the software
Figma. Figma is a prototyping tool which allows version control and real
time synchronisation within a project with several members. The tool was
chosen mainly due to the fact that it simplified the collaboration between the
researchers. Each researcher used the guidelines in a different way and also
the amount of the actual used guidelines differed for each researcher. One
researcher used 163 guidelines for the wireframes and the other one used
162 guidelines. Since the guidelines were mapped to the heuristics, each
researcher covered each heuristic with the implemented guidelines. Each
heuristic is as important to ensure a high usability in a software [18]. Due
to the circumstance that they were more guidelines for some heuristics, for
example of "Consistency and standards" or "Recognition rather than recall",
correspondingly more guidelines of those heuristics were used. The reason for
not using the total of 197 guidelines was, that the focus of created product
from the research. It dependent on which areas were going to be implemented
in the artefact. It has shifted with the emerged needs from the interviews.
Both versions of the wireframes were discussed between the researchers with
the guidelines in mind. The similarities have been adopted in the final first
version. Variations have been discussed and the reasons for including them
have been valued. Depending on the priority of the variation based on the
users needs and the guidelines, the component has been adapted or not. Ad-
ditional components have been added during the merging process. In total, the first version of the artefact included 174 guidelines. These used guidelines in comparison to the total for each heuristics were implemented as followed:

- Visibility of system status: 5 out of 6
- Match between system and the real world: 8 out of 8
- User control and freedom: 10 out of 12
- Consistency and standards: 36 out of 40
- Error prevention: 28 out of 30
- Recognition rather than recall: 31 out of 39
- Flexibility and efficiency of use: 19 out of 25
- Aesthetic and minimalist design: 25 out of 25
- Help users recognise, diagnose, and recover from error: 8 out of 8
- Help and documentation: 4 out of 4

Since the intention of the thesis is to find out if the guidelines are able to solve the usability issues, each guideline was targeted to one or several issues. For example the found issue of ”Lack of standards for manual data input” (e.g. table 4.2.2) is in relation to the guidelines which are categorised under the heuristic of ”Consistency and standards”. The mapping of the usability issues to the guidelines was conducted based on same criteria as the ones for the mapping of the guidelines to the heuristics. Having the same criteria for our mapping processes insures consistency and therefore reliability and validity for our work.

Figure 4 illustrates how the guidelines have been included in the first version of the artefact. The red marked areas are examples of how the guidelines are presented in the wireframes. For example, suggested one guideline that common icons should be used in the whole system to avoid confusion and misinterpretation of the it. If it is necessary to have a unique icon, a textual description has to be added. This guideline has been used and implemented in the way Figure 5 shows. Since there are several icons which have the meaning of uploading or importing data, a more common symbol
was used. To assure that the user does not misinterpret the icon, the actual explanation of it has been added next to it.

Several content areas of the artefact covered different guidelines, which adds up to the usage of the 174 usability guidelines in total. Summarising, did the first version consists of:

- 7 Content Areas (Test Codes, Test Reports, Test Object Catalogue, Test Result Database, Import Data, Setting, Search Result)
- 174 Usability Guidelines
- 48 Screens
This version was used in the focus groups to inter alia examine if the user needs have been met. And if the general approach of the artefact encounters confirmation of the future users.

After the Focus Group has been analysed, the feedback has been implemented into the wireframes. This was the base for the next version of the artefact. A high fidelity mock-up of the artefact was created afterwards. This version of the artefact was the second one. None of the guidelines were removed or added, rather were their appearance changed or/and moved to another screen. Furthermore were they more adapted to the user needs and have been set more in the use case perspective.

Figure 6: Artefact Version 2

Figure 6 showcases one screen of the second version of the artefact. It illustrates with the red boxes around the areas where several guidelines were used. This version consisted in the end of:

- 14 Content Areas (Dashboard, Test Project, Test Codes, Test Code Execution, Test Reports, Test Report Database, Test Result Database,
The doubled amount of content areas and the additional 88 screens had the intention to provide the user with an experience which comes fairly close to a real software. This version was used for the observational study (i.e. chapter 3.1.5). Based on the findings of the research (i.e. chapter 4.2.5), the artefact has been improved. The improvements resulted in being in the current state and only being minor. Therefore, no screens or guidelines had to be added. Screens of the final version of the artefact can be found in the appendix D. The artefact as itself has been handed over to Husqvarna as a base for implementing the system.

4.2.4. Focus Groups Findings

The intention of the focus group was to confirm two things:

- if the researchers have captured the thinking of the employees of Husqvarna
- how the artefact had addressed the current issues

Through the two focus group sessions, further issues emerged through the discussion between the participants.

There were 10 heuristic usability issues which were identified during the interview sessions. The issues were, ”Lack of standards of manual data input”, ”Incompatible with other necessary systems”, ”Difficult generate general overview”, ”Lack of version control of the data”, ”Compromised highlighted important sections”, ”Workflow flexibility”, ”Lack of data visualisation”, ”Intuitive UI” and ”Inefficient Search”. These issues which got confirmed through the artefact and new emerged issues will be presented in this chapter. As mentioned in chapter 3.1.4, two focus group sessions were conducted.

In the first focus group session there were four participants. The participants represented the user groups Test Responsible, Test Method Owner, Project Manager and System Engineer. During the session the researchers went
through different sections of the artefact’s user interface (UI). After a section had been introduced, one to three semi-open questions were presented to the group to get the conversation started. The findings of the first focus group are represented in table 6. The table is structured in the way of presenting the statements of the participants. Presenting which user role has expressed these statements and how many participants in the focus group verbally approved of the statement. As well as which identified usability issue the statements connects to. The user roles have been shorten down to their intials(e.g. Test Method Owner is TMO).

Three usability issues which were expressed by all of the participants, were the issues of ”Lack of standards for manual data input”, ”Complicated process of manual data input” and ”Inefficient Search”. Seen in table 6, on row 1 and 2 show two statements which are connected to these issues. Both of these statements were verbally agreed by all of the participants. This revealed a connection between the three issues and that they were caused by one another. Leading to the confirmation that these issue are prominent usability issues within the current systems.

Three other issues which were stated by several participants were ”Difficult to generate general overview”, ”Intuitive UI needed” and ”Compromised highlighted important sections”. Seen in table 6, from row 3 to 5, shows statements which connected to these issues. Also mentioned by the Test Operator which were a direct feedback of the artefact was, ”Today we have “not reviewed”, draft as a template, active, the one who is a maker has different kind of drafts, on-going”. Which referred to the addressed issue of ”Compromised highlighted sections”. The statements confirm that these issues are also prominent issue within TDMS. Finally the participants stated concerns about the issue of ”Incompatible with other necessary systems” and ”Lack of version control of the data”. Seen in table 6, in row 6 and 7 are statements illustrated which are connected to these issues. During the first session there were two issues which was not confirmed. These issues were ”Lack of data visualisation” and ”Workflow Flexibility”.

In the second focus group session five participants attended. The participants represented the user groups Test Method Owner, Lead Engineer, Test Responsible, Test Operator and System Engineer. During the session a shift of to specific sections of the artefact UI was introduced.
<table>
<thead>
<tr>
<th>Usability Issue</th>
<th>Statement</th>
<th>User</th>
<th>Approval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of standards for manual data input</td>
<td>Inefficient Search</td>
<td>TMO</td>
<td>4 of 4</td>
</tr>
<tr>
<td></td>
<td>&quot;[..] in the current systems, it is more or less impossible to search in it. The reason why it is impossible, we are not consequent when filling in the information.&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of standards for manual data input</td>
<td></td>
<td>TO</td>
<td>4 of 4</td>
</tr>
<tr>
<td></td>
<td>&quot;In the lab we never work with test codes and we need free text but we are also know that this is the problem when it comes to search engines. Test codes are easier to find when you know the name.&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difficult to generate general overview</td>
<td>Intuitive UI needed</td>
<td>TMO</td>
<td>3 of 4</td>
</tr>
<tr>
<td></td>
<td>&quot;[..] during testing processes, quite often we don't even know what to do.&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difficult to generate general overview</td>
<td>Compromised highlighted important sections</td>
<td>SE</td>
<td>2 of 4</td>
</tr>
<tr>
<td></td>
<td>&quot;Which lead us to then not even know if we can label the test as pass or fail. Often labelling the test as 'Investigation', which leaves it very open and not knowing how to proceed&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difficult to generate general overview</td>
<td>Intuitive UI needed</td>
<td>TO</td>
<td>3 of 4</td>
</tr>
<tr>
<td></td>
<td>&quot;Currently many parts of the our system look very different. We need to have some pages to look the same, like the landing page or search engine page.&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of version control of the data</td>
<td>Incompatible with other necessary systems</td>
<td>TMO</td>
<td>2 of 4</td>
</tr>
<tr>
<td></td>
<td>&quot;[..] connect data from Smarteam to this system. As it would help with connecting the data to be tested. Not needing to transfer it all the time&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incompatible with other necessary systems</td>
<td></td>
<td>TMO</td>
<td>3 of 4</td>
</tr>
<tr>
<td></td>
<td>&quot;Have you thought about connecting it to a Wiki? Instead of writing a help. Just to explain how does that work. &quot;Best Practice&quot; like&quot;</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6: Statements of Focus Group 1
<table>
<thead>
<tr>
<th>Usability Issue</th>
<th>Statement</th>
<th>User</th>
<th>Approval</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Difficult to generate general overview</td>
<td>&quot;A priority mark would be nice, but it would be great to have a list or another mark telling why the test hasn't been started yet&quot;</td>
<td>TO</td>
<td>3 of 5</td>
</tr>
<tr>
<td>2. Difficult to generate general overview</td>
<td>&quot;A checkmark of some sort that I have started this test project or not or that you can set that you are going to do this on Tuesday for example&quot;</td>
<td>TO</td>
<td>3 of 5</td>
</tr>
<tr>
<td>3. Difficult to generate general overview</td>
<td>&quot;You are showing completed, draft test and so on. That is very good. I would like to be updated on when the test is being started and also when the test is completed&quot;</td>
<td>PM</td>
<td>5 of 5</td>
</tr>
<tr>
<td>4. Difficult to generate general overview</td>
<td>&quot;For our department it would be important to have some other project statuses. Such as it being in reviewing my multiple people&quot;</td>
<td>PM</td>
<td>2 of 5</td>
</tr>
<tr>
<td>5. Lack of version control of the data</td>
<td>&quot;In this plan it would connect which test code is connect with which object/component&quot;</td>
<td>TR</td>
<td>5 of 5</td>
</tr>
<tr>
<td>6. Lack of version control of the data</td>
<td>&quot;[...] see between the test if it has been put as 'Retesting' and also some free text about why it was put&quot;</td>
<td>TR</td>
<td>4 of 5</td>
</tr>
<tr>
<td>7. Lack of version control of the data</td>
<td>&quot;I just like to have place where I can write the validation plan in template which the whole team can follow&quot;</td>
<td>TR</td>
<td>4 of 5</td>
</tr>
<tr>
<td>8. Lack of data visualisation</td>
<td>&quot;[...] test report as well so you can easily compare them [...]&quot;</td>
<td>TR</td>
<td>3 of 5</td>
</tr>
<tr>
<td>9. Lack of data visualisation</td>
<td>&quot;Also important to look over what is the meaning of this information.&quot;</td>
<td>TMO</td>
<td>5 of 5</td>
</tr>
</tbody>
</table>

Table 7: Statements of Focus Group 2
The most prominent stated issue from the participants during the second session was "Difficult to generate general overview". Two statements which confirmed this issue were expressed by the Test Operator. They are shown in table 7, row 1 and 2. Two other statements which covered this issue were mentioned by the Project Manager. This statement can be found in table 7 row 3 and 4. To generate a more general overview of the artefacts UI sections have been set as Dashboard views. This makes it possible for the participants to get an overview of where there are in the system and what is being shown. Another prominent issue in the interview and in this session was: "Lack of version control of the data". Other statements related to this issue had relations to another one. Two statements which covered both issues "Lack of Version control of the data" and "Workflow flexibility" were also mentioned by the Test Responsible. Finally two statements which covered the last identified usability issue, "Lack of data visualisation", were mentioned by the Test Responsible and Test Method Owner. The statement can be found in table 7 row 8 and row 9.

After the focus groups session the statements were also unitised into the existing categories from the interview. The category of "Synced System" still remained as the core category even through this two session. This confirmed the issues and categories. As well did result of the focus group confirm the results of the interviews and the issues of the current technical systems.

4.2.5. Observational Study Findings

The observational study had the intention to find out if the users are able to use the artefact and if the usability issues from the interviews/focus groups are solved. The findings of the observational study are mapped out for the issues and for which task has proven to which extent if the issue was solved or not. Based on the measurement the findings are interpreted. A summary of the finding is presented in table 8. The table shows the average value of each task, mapped out to the taken measurements. For every user the similarities where pointed out and for the quantitative data, the actual average was calculated. It resembles the structure of the observation schedule which was created for the design of the observational study.

The issue of "Lack of standards for manual data input" has been tested with the execution of two task (compare with table 2 in chapter 3.1.5). The task
<table>
<thead>
<tr>
<th>Task</th>
<th>Path</th>
<th>Time (min)</th>
<th>Amount of Clicks</th>
<th>Pass/Fail</th>
<th>Confusion Timer (Amount)</th>
<th>Observation</th>
<th>Notes</th>
</tr>
</thead>
</table>
| 1    | - Dashboard scanning  
- Checking notifications  
- Click on Test Project | 4:10 | - | Fail | 6 | Extreme confusion, User noticed comment but did not connected it with task |
| 2    | - Type/Click on search | - | 1 | Pass | 0 | Users search after: Product ID, Name, Creator, Initiator |
| 3    | - Clicks on "Test Report"  
- Clicks on specific Test Report | 1:30 | 3 | Pass | 0 | "Perfect" execution from all |
| 4    | - Clicks on "Test Report"  
- Clicks on search | - | 5 | Pass | 2 | Users felt pressured, were apologizing for own behavior, solved with search |
| 5    | - Clicks "Test codes"  
- Clicks "Add test code"  
- Fills out the test code form  
- Saves the test code | 0:15 | - | Pass | 1 | Need more research on which fields are needed, More visual help on what the fields are (guide) |
| 6    | - Clicks "Test Object"s  
- Scrolling  
- Clicks on “Jordfrås TF 325”  
- Finds the component list of "Jordfrås TF 325"  
- Clicks on “Motor CR 750”  
- Clicks SmarTeam button | 0:02 | 8 | Pass | 2 | Necessity of SmarTeam discussion |
| 7    | - Clicks "Test Code"  
- Clicks edit  
- Edits  
- Clicks save | 1:02 | - | Pass | 5 | Missing Back Button, Windows Mentality |
| 8    | - Clicks "Test Report"  
- Clicks on “Sågning DTEW675”  
- Clicks edit  
- Clicks on status dropdown  
- Clicks on pass  
- Clicks on save | 0:68 | 8 | Pass | 0 | None |
| 9    | - Clicks on "Test Report"  
- Clicks on specific Test Report | 1:03 | 3 | Pass | 1 | Discussion about available options |
| 10   | - Clicks on dashboard  
- Opens Menu  
- Clicks "Import Data"  
- Clicks "Import Requirements"  
- Selects a test object from dropdown  
- Selects files from computer  
- Clicks save | - | 9 | Pass with remarks | 3 | A lot of confusion on what/where to upload requirements |
| 11   | - Clicks "Test Reports"  
- Clicks on Sågning DTEW675  
- Scroll through | 0:16 | 3 | Pass | 0 | None |
| 12   | - Clicks Profile Icon  
- Clicks on project  
- Clicks on edit | 0:26 | 5 | Pass | 2 | Connection to Outlook idea, Windows Mentality |
| 13   | - Clicks "Test Analysis"  
- Clicks directly on apply algorithm button | - | 11 | Pass with remarks | 5 | Confusion caused due not used to working with data analysis |
| 14   | - Clicks "Import data"  
- Clicks on JIRA | 0:16 | 3 | Pass | 0 | None |
| 15   | - Clicks on search | - | 1 | Fail | 0 | Would search for: Test Project ID |
| 16   | - Clicks on dashboard  
- Clicks project page | - | 7 | Fail | 3 | Couldn’t create bigger picture with given visualisation |

Table 8: Summary of Observational Study Findings
of "Create a test code" (Task 5) and "Import a requirement from your computer" (Task 10) have been executed by every user. Task 5 has been achieved by all participants and no confusion about the data input has occurred. Some suggestions about the actual content were given, but the manual data which was required to fill in, did not cause any confusion. This task was completed by the users under a minute, which indicates that the given standard for the manual data input did not attract negative attention. Task 10 caused some confusion which lead to an average of nine clicks. Due to the fact, that the users were faced with a new software which differed in the habitual structure, they needed some time to orientate themselves. No statements or doubts were raised during the performance of the task, which leads to the assumption that the usability issue was not given anymore. In total due to the used guidelines (i.e. Standard terms for input labels) in the artefact the usability issues of "Lack of standards for manual data input" was solved.

"Incompatible with other necessary systems" was the issue which every interviewee mentioned and which was also discovered by Tretten [22]. In the developed system, this issue was supposed to be solved with the integration of other systems. And in the way the data is processed and transferred to other systems. In the observational study, this issue has been covered by three tasks, which have been completed by all users with a "pass". Task 6 (Open "Motor CR 750" in SmarTeam) has been executed in several ways (a.k.a. different paths) in a short amount of time (average of 11 seconds). And the connection to another system (SmarTeam) was clear to every participant. Task 14 and Task 17 were similar but showed the compatibility to two different systems. The other users finished the task in several seconds and with three clicks without hesitation or confusion.

One of the biggest issue the interviewees had was that they have a bad experience with generating a general overview in their current TDM systems. Four tasks were used to test if this issue is still existing when usability guidelines have been used for the system. Three out of the four tasks were failed by all participants during the observation. Even though important sections for the overview were realised by the users, they were not connected to the tasks. A lot of tasks were "solved" with the usage of the search, which indicates that the overview which was created in the artefact, was not obvious for the user. Only for one task resulted positive feedback. Since the task (Task 11) was more detailed, the users were able to break the task down, for their own
path in the system of achieving the task.

The results of the observation of the issue "Complicated process for manual data input" are only positive. During the execution all users were not confused. They were able to finish the tasks fast. Editing or creating content was not a problem for the participants in the artefact. No questions were asked during the execution and the needed time was under 30 seconds for all of the participants.

The lack of version control of the data in TDM systems is an issue which has emerged from the case study only. The two tasks (Task 4 and Task 13) which had the intention of identifying if the issue is still existing, were both high in detail. Due to the circumstance that one task (Task 13) introduced a completely new work area, the users were not fully able to "pass" this task. There was confusion on how to get to the area in the artefact. As well they were not familiar with this kind of work process. Therefore were the results for this task were carefully reviewed. When the users achieved help of the supervisor, the actual issue of the lack of version control of the data was not existing anymore to the user. No comments or confusion was caused while selecting different versions of the requested data, which indicates the filled lack. The task of telling the different versions of a report created by the same author (Task 4), was fulfilled in average with five clicks. Half of the participants used the search to get to the desired test report since they knew the different versions will be listed there.

The issue of "Compromised highlighted important section" emerged since the users were not able to find important section easily. The tasks 3,4,7,8 and 9 tested inter alia if this issue was solved in the created artefact or not. Finding the test result (task 3) was for the majority of the participant not a problem. Since it was the test result for a test report, some of the users tried to find it in the starting screen under the test projects. While analysing the other tasks for this issues it turned out that the user at Husqvarna are not used to having important sections visualised. Therefore they were able to find the compromised highlighted important sections quickly.

For every user, we have asked, it is important that the system adapts to their workflow or that their workflow is executable in the system. With the tasks of "Edit the test code "KQU833"" (Task 7), "Edit test status of the
test report "Sagning DTEW675" to “pass”” (Task 8), ”Change a member in the test project” (Task 12) and ”Set the project progress status to the next progress step” (Task 16), we wanted to see if the artefact does that. With the recording of the screen we were able to follow the users mindset and workflow. It showed especially for the tasks 7,8 and 12 the pattern every participant followed. It intersected with the way the researchers have analysed it from the interviews.

One main usability issue the researchers have found in the literature as well in the analysis of the interviews was the lack of data visualisation. Especially when it comes to technical data, the visualisation of it, is helpful to understand the actual meaning of the data. With the tasks 9 and 11 this issue was examined. The data which had to be interpreted in the tasks was visualised and the participants were able to interpret them in the prescribed meaning. They differed on the way how they got to the data, but the actual interpretation was the same for all of the users. They were able to achieve the task in a short amount of time.

With all tasks, the issue of need of a intuitive user interface (UI) was tested. The UI did not change within the different tasks. It stayed the same through the whole process. This issue has been measured through the think-aloud comments the participants gave and with the documented path. Summarising they were all satisfied with the user interface. The main issue which made it not as intuitive as it should have been, was the fact that they were used to the mental model of the operating system of ”Windows”. They were missing feature like ”a back button” even though the option of going back was always represented, since it was one of the guidelines which has been used for the artefact. But they were extremely influenced by this model and therefore the UI was not as intuitive for them.

Furthermore there were some comments about different design issues but not which had an impact on the intuition of the user interface. Balancing all tasks out and how they have been achieved 83% of the tasks have been executed with a ”pass”. This indicates that the user interface is intuitive. The search has been mainly tested with the search task (Task 2), but whenever a user used the search to fulfil another task, the search was tested indirectly. Whenever a participant made use of the search, he/she was asked what they would going to search for. This information was used in the anal-
ysis to be able to create an efficient search. This is an positive indicator that the search was accepted and used, when help was necessary.

5. Discussion and Conclusions

In this chapter the discussing and the conclusions of the findings and analysis result from the applied research methods are presented. A discussion about how the applied research methods have been able to answer the set out research questions and if the techniques were suitable for the outcome is firstly introduced. Afterwards the chapter will wrap up the research by by concluding the outcomes of the research and how future researchers can continue with the findings.

5.1. Discussion of Method

The objective of this research project was to research usability issues about technical data management system. To research the area two questions have been stated. The first question questioned what the functional and non-functional requirements of TDMS are in the company Husqvarana. The second question wanted to continue from the second question, answering how usability guidelines could solved the identified usability issues of TDM systems. The findings of the first research findings were partly used in answering the second question. This sub-chapter will be divided into six sections looking closely to each of the research methods and how they have performed in answering these questions. Finalising the sub-chapter with discussing the reliability and validity of the methods.

5.1.1. Case Study

Conducting the research within a company as a case study was well suited for recruiting relevant participants for the research. The case study was a great source of resources to produce a research result with a high validity. It enabled to conduct research within the direct context of the research area. This created a greater reliability of the end results. During the research a single case study was conducted. It was suitable for the defined scope we had set for the project. To focus on a single company using TDMS and identifying their requirements for the system. It helped to go deeper into the identified issues within TDMS and opening up a lot of theories. It was also beneficial for the set time constraint we had. For the case study the weak point of a single case study was taken into consideration .
point being that you as a researcher will receive a very one sided view of the research area. Future researchers which would research in the area could potential use a multiple case study. They could use the provided insight by us and then research in a broader scope, identify the heuristic usability issues in data management systems.

5.1.2. Literature Review

The answers of the first research question were key elements in answering our second research question. The second building component in answering the second research question came from our literature review findings. The literature review process allowed us to locate relevant usability guidelines and researched usability issues. When the guidelines were collected, it enabled us to conduct our research on how the usability guidelines could solve the known and identified usability issues in TDMS. The literature review opened up the possibility to conduct the focus groups and observational study to answer the second research question. Though the process of finding the relevant research and usability guidelines was challenging.

5.1.3. Interviews

To find out the functional and non-functional requirements, we started with identifying the users of TDMS and recruiting them for one-to-one interviews. A semi-structured approach was taken during the interviews. Taking a semi-structured approach was well suited for the intention of search. It allowed us to fully explore and collect data about the issues of TDMS. It helped us to find a lot of different data, but still keeping it structured. If we would have taken a unstructured approach the scope of the result would have been too broad. Which would have put us obstacles in the way during the analysis phase. The main issue of the findings of the interviews came from the recruitment of the interviewees. Since this was executed by the supervising person at Husqvarna. This may have coloured the choice and representation of the participants to a certain amount.

5.1.4. Focus Groups

The main intention with the focus groups was to partially answer the second research questions. The outcomes of the focus groups delivered sobering conclusions. During first session we were challenged with keeping the participants focused on giving feedback on the artefact itself. This resulted to pinpointing if the artefact addressed the identified issue from the interviews.
This session became more about confirming the analysis and findings of the interviews. This opened up further findings about issues of the current systems. Therefore they helped in developing further theories of how to answer the first research question.

As in the first session of the focus groups, challenged us to steer the participants discussion focused on the artefact itself. Which diverted the intention of the research method from answering the second research to then partially answering the first research question. Based on that, the second session of the focus groups was altered. The structure was redesigned to address the issues which occurred during the first session. A more linear approach was taken with the questions to steer the participants to talk about the artefacts user interface sections. This was achieved by sectioning the discussion limited time frames. Also through explicitly asking the questions, while having the user interface section open for all the participants to see. Which did restrict us from actually exploring and identifying further about the needs and issues. Which fitted into the intention since the focus groups were about to discuss if the guidelines could solve these identified issues. The linear approach did help marginally, but it did not stop the participants moving off the topic. The main cause that we identified during the two session was the "Dominator Effect" [25].

The "Dominator Effect" refers to the group dynamic of one person in the group who asserts their opinions without the regard to the other participants. Which may cause difficulties in following other participants opinions on the discussed topic. Especially during the first session we experienced this phenomenon, as one of the participant took over the discussion with dominance. This led to the session driving off topic multiple times, as the "dominator" wanted to push his concerns about the artefact. Those were unfortunately out of scope for our research. During the second session there emerge a dominate participant as well and took over most of the discussion. A third session may have resulted in a deeper and more insightful result. As we could have applied our alterations to the third session and received a more valid result. This maybe would have triangulated our focus group results.

5.1.5. Observational Study

Applying the observational study helped to fully answer the second research question. Since the focus group was insufficient to answer the question by itself and also failed to fulfil its intended purpose. The observational study was especially effective as it produced data which was not able to be pro-
duced through only verbally isolated methods. With the observational study we conducted during this project, it was the pure way of conducting it as it is described in the literature. Nevertheless it helped us thoroughly to see if the issues have been solved through the applied guidelines. We observed the participants as they traversed through the artefacts user interface by their own interpretation. By that the researchers could identify if the majority of the guidelines were able to solve the issues. The conduction of the method was performed in a natural, but still controlled environment. Which did lead to some factors, which effected the results. These factors needs to be considered during the conduction of the method. One of this factors is the "Observer Effect" [25]. The "Observer Effect" refers to the factor, that the participant of the observational study may alter the choice of behaviour if they are aware of the present of the observer. This factor has been considered during the analysis of the data produced by the method. It would have been interesting to see what results may have been produced if the method was conducted in a less controlled environment. The more controlled environment helped to keep the data more stream-lined, and not letting other factors effect the result.

5.1.6. Reliability and Validity of chosen methods

An interplay between methods have been set. This helped with the reliability and validity of the methods. The whole thesis was built around a single case study. As mentioned by Williamsson [25], a case study is great in providing a clear understanding of the issues within the research area. With the thesis being built around a case study, observational study was suitable. For the manner that observational study is effective in collecting but hard for replicating data. Observational study relies on the researcher gaining the communities trust, where the research is conducted. This usually takes two to three months. As the research area of usability guidelines in TDMS is not as widely researched. We had a difficult time to locate relevant academical literature. The iterative process of the hermeneutic framework helped us to broaden and identify literature which had connection to our research area. The connection was sometimes not a direct connection. The reviewed literature was conducted on different aspects of our research area. This helped the case study in opening up the research area even further. As case study is very suitable for when little understanding of how and why a process or phenomena occurs [25]. With the combination of the observational study we were able to gain a in depth analysis of the topic. The "observer effect"
may have caused the results of observational study result not being fully representative of reality. This was of course considered during the analysis of the observational data results. Another factor which also coloured the results and questioned the reliability of the focus group was the ”Dominator Effect.” The effect of this unfortunately coloured the results of the method. This ultimately effected the validity and effectiveness of the method, as most of the data from the first session was represented by one participant. The ”Dominator Effect” was not as prominent in the second session, as with the set constraints there was not room for the domintor to take full control of the discussion.

5.2. Discussion of Findings

All findings, which emerged from the methods which were used to answer the research questions, for this paper have been evaluated and interpreted by the researchers. They are the decisive indicators for answering the question and to make assumptions for further research. The methods of the interviews and focus groups were mainly conducted to be enable to answer the first research question (the requirements of a manufacturing company). The findings of these methods will be explained firstly. Secondly, the discussion of how the methods were able to answer the research question which aims to fill the research gap follows. In both chapters the main findings will be discussed and the interpretation of them are presented.

5.2.1. What are the functional and non-functional requirements of a technical data management systems within a manufacturing company?

After the analysing of the interviews the first requirements were found. The main findings which emerged from them were that Husqvarna needs a TDMS which provides: flexibility, a good search, a database, templates for manual input, workflow adaptation, a high usability and a system which is synchronised to other systems. The need of having systems working together and contracting each other was the main requirement. This indicated for the researcher to include in the artefact other systems. For that, researching which information from other software are necessary, was one of the main task to ensure that this requirement was included in the artefact. It is worth considering to question, if creating a new system, when the issue is caused by having/creating systems, solves the main need or is rather increasing the issue. Another process which was executed while analysing the findings of the interview was to set priorities to the different requirements. The need for
**Synced System** and **Workflow** were one of the high priority needs, since they were mentioned by everyone. But especially these two findings are extremely subjective and differ in extent from user to user. In the perspective of the case study it differs even more from department to department in Husqvarna. The focus groups were contributing to the findings of the interviews and not a lot of additional requirements were found. Rather have the priorities changed or/and sub-requirements were placed differently. Due to the fact that focus groups have the intention to cause discussion and to discover the bigger picture, not creating new needs was predictable and acceptable. The need of having a software, which allows the user to understand the general overview of a project and the test data was highly discussed in the focus groups. As well as having the test data and technical data visualised. The results of the focus group revealed that also issues like the security of a new TDMS has to be taken in consideration, especially in the case of big industrial company. The findings of the interviews and focus group were tested in the observational study. It was used to confirm the findings but also to discover if other needs will be exposed. Mainly was the observational study used to test if the usability guidelines were able to solve the usability issues. This is presented in the chapter 5.2.2. Since they were no comments about the requirements in the observational study, the assumption that the researchers were able to define the functional and non-functional needs of Husqvarna in the ratio of the R&D Department, can be made. The total list of the need are listed in the tables in appendix E.

### 5.2.2 How can existing usability guidelines solve usability issues for technical data management systems?

The usability guidelines have been used for and while creating the artefact. The first version of the artefact has been used in the focus group and the final one in the observational study. The findings which have been emerged from the focus group were helpful for the content the artefact is providing. The participants in the focus groups where concerned about which aspects of the test process the artefact should include. Furthermore were they guiding the researchers for the first impression of the artefact. As well as if the usability guidelines are in general a good option for creating a TDMS. Since the participants in the focus group did not raised any concerns about user interface of the artefact itself, the silence on the topic was taken as a positive feedback. If any components in the user interface would have engenders comments and feedback, the comments had to be analysed if they were positive...
or negative. They were no components, which were created by the guidelines, which have risen negative attraction. Since the findings of the focus group were not directly about the visualisation of the guidelines, the questions of how existing usability guidelines can solve usability issues for TDMS was more able to be answered with the findings of the observational study. The results of the analysis for the observational study were the pivotal factors of answering the second research question. Before discussing the highlights of the findings the fact that the participants were nervous during the observation needs to be mentioned. During the observation all of the users commented, that they do not want to do something in a wrong way and that they have to become inured to the artefact. After several confirmations and reminders from the researchers that the system and not the participants get tested with the observation, they seemed to had quieten down after a while. Since all of users had different disciplines and worked in disparate areas, the motivation while executing the tasks was varying. With every task, an issue and several guidelines were examined. When the participants used the intended way on achieving the task, the issue and guidelines were marked as solved. That means for the issues that they were exist anymore. Since the issues were resolved with the usage of the guidelines, the appropriate conclusion that the guidelines are able to solve usability issues can be drawn. In total were 83% of the tasks successfully achieved. The tasks which were not completely successful were the tasks which targeted the usability issues of:

- Generate general overview
- Workflow flexibility

The associated guidelines with those issues were partly positively confirmed with other tasks. In general due to the 83% positive percentage the two rather negative resulted tasks were taken in consideration, but have not been a decisive factor, since every tasks has tested several guidelines at once. Therefore can be said that the guidelines were mainly able to solve the usability issues.

5.3. Conclusion

In this chapter the main points of the research will be briefly presented in the first chapter. It reviews the methodology as well as the findings. Afterwards suggestion of how the work can be further developed are given.
5.3.1. Summary

The paper is about to research on technical data management system in combination with, if current usability guidelines can solve the usability issues within those systems. TDMS are in general not well defined in the research world. A definition which takes aspects from most of the common definitions, was the action which was taken to set a base. In the end, the used definition in this paper is: TDMS are data management systems which handle technical data. Finding papers and research article which handle the same kind of system was a complex component of the paper. Since a lot of facets of TDMS exist, the course of action which was taken during the literature review had to be thoughtful. This way was chosen to ensure a high diversity view on a topic which lacks research. Therefore a qualitative approach was taken. With qualitative data theories are built which can be later validated or unendorsed with quantitative data. Since not many theories exist in the area, creating qualitative data was the option to try to fill the research gap. Especially with the chosen research questions, qualitative methods like interview, focus group and observational research were suitable for them. The interviews were the base and the main method for answering the first research question about the functional and non-functional needs of a manufacturing company. Several potential users were asked about their current work process, used systems and issues they have regarding the test process management. Based on the findings of the interviews, the first version of an artefact of an TDMS was developed. Several usability guidelines were used to be able to test in the end, if they help to increase the usability of TDMS. The focus group method was then applied. It had the main intention to confirm the general direction of the artefact. To be able to find out if the usability issues are still existing with the use of usability guidelines, the observational study was conducted. With the observational study, the researchers were able to see how the users are using the artefact. Since there is a difference in behavioural and attitudinal research, it was necessary to gather behavioural data as well to be able to answer the research question. The findings of this method were mainly positive and only a few minor changes had to be implemented in the artefact. The artefact resulted in a click-able prototype and serves Husqvarna as a requirement visualisation.

5.3.2. Prospects

The presented research in this paper must be repeated and generalised to be able to confirm the theories. Since only a few case studies in different
industry areas have been conducted for TDMS, further continuation is necessary. The case study can be further developed in the sense of that more departments at Husqvarna are going to be involved. With more involved departments, more usability issues in their current TDM systems are likely to be discovered. This would be supporting to fill the research gap on usability issues as well. Focusing on the continuation of answering the question if usability guidelines are able to solve usability issues, the question of which usability guidelines are useful has to be questioned. Since the software world is changing extremely fast, so do the standards for them. This includes also the design standard and therefore the guidelines for designing software. Some guidelines have been existing for several years and are used, but with new technologies, new guidelines are created and have to be tested. This, plus the fact that technical data management systems have to handle more and more data in the time of "Big Data", leaves the researchers a complex challenge when it comes to usability guidelines in technical data management systems.
Bibliography


Appendices

A. Interview Questions

- What current system are you using in context of testing?
- What do you like about these systems?
- What do they dislike about these systems?
- How do you use the systems in your working process? (From point a to point b)
- What do they expect from a test management system?
- Which functions are the most important for you/do you wish for in a test management system?

B. Focus Group Questions

- Category: User Dashboard
  - Which test projects do you want to be updated on?
  - Should test projects have priority marks/stamps
  - Other marks on the project?

- Category: Test Conduction
  - What information should be displayed in the active tooltips for the test conduction?
  - How would you import the requirements?
  - Different test conduction pages dependent on the department? How will that benefit your workflow?

- Category: Test Object
  - Which filter categories?
  - Which involvements of the test objects do you want to see?
  - Component view: How would like to look? Tree-structure, List?
• Category: Test Code
  – Changing test code method during the test conduction or other preferred way?
  – Which version is preferred for the view of test codes?
  – Which version is preferred in relation to the filter-first-the-category view?

• Category: Database
  – What information is wanted to be displayed in the KPI algorithm output?
  – What filters for the reports/data has the algorithm to run on?

• Category: Test Report
  – Is the pass/fail for a report beneficial?
  – Export to PDF necessary?

• Category: Data Import
  – What data would you want to import?

• Category: Test Project Overview
  – Are statistics for comparison wanted?

C. Observational Study Tasks
• Task 1: Find your last comment
• Task 2: How would you search for a specific test report?
• Task 3: How is the test result status for the test report “Sågning DTEW675”?
• Task 4: Which versions of the completed test reports of the “Jordfräs TF325” has Nils Norberg created?
• Task 5: Create a test code
• Task 6: Open "Motor CR 750" in SmartTeam

• Task 7: Edit the test code "KQU833"

• Task 8: Edit test status of the test report "Sågning DTEW675" to "pass"

• Task 9: Find the test result status for the test report "Sågning DTEW675"

• Task 10: Import a requirement from your computer

• Task 11: Find the pass/fail rate for test result version 2 in the test report "Sågning DTEW675", which was created 14/04/19

• Task 12: Change a member in the test project

• Task 13: Apply the KPI Algorithm for the time period of DD/MM/YY to DD/MM/YY

• Task 14: Import Data from JIRA

• Task 15: What would be the next step to take in the Test Project "TDR436"?

• Task 16: Set the project progress status to the next progress step
D. Artefact

Home Screen of the Artefact
Test Project Screen with Menu of the Artefact
Test Object Screen of the Artefact
Test Analysis Output Screen of the Artefact

E. Functional and non-functional requirements of Husqvarna
<table>
<thead>
<tr>
<th>Requirement</th>
<th>Functional Need</th>
<th>Non-Functional Need</th>
<th>Origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>The system shall provide templates for test execution</td>
<td>x</td>
<td></td>
<td>Interviews, Focus Group</td>
</tr>
<tr>
<td>The system shall allow free text input in the test form to accommodate for unexpected outcomes</td>
<td>x</td>
<td></td>
<td>Interviews, Focus Groups, Observational Study</td>
</tr>
<tr>
<td>The system shall be able to record and store numeric and text data for a large amount</td>
<td>x</td>
<td></td>
<td>Interviews</td>
</tr>
<tr>
<td>The system must allow the user to use the system in his/her own work pattern through modularity</td>
<td>x</td>
<td>x</td>
<td>Interviews, Focus Groups, Observational Study</td>
</tr>
<tr>
<td>The system shall provide an efficient search through a well-structured information architecture</td>
<td>x</td>
<td></td>
<td>Interviews, Focus Groups, Observational Study</td>
</tr>
<tr>
<td>The system shall illustrate data in a human processible manner</td>
<td>x</td>
<td>x</td>
<td>Interviews, Focus Groups, Observational Study</td>
</tr>
<tr>
<td>The system must have a structured interface to allow the user to understand the system intuitively</td>
<td>x</td>
<td></td>
<td>Interviews, Focus Groups</td>
</tr>
<tr>
<td>The system shall use standard terms and expressions</td>
<td>x</td>
<td></td>
<td>Interviews, Focus Groups, Observational Study</td>
</tr>
<tr>
<td>The system shall include graphical versions of the test data processes which are handled in the system</td>
<td>x</td>
<td>x</td>
<td>Interview, Observational Study</td>
</tr>
<tr>
<td>The system shall transfer information to other systems</td>
<td>x</td>
<td></td>
<td>Interviews, Focus Groups, Observational Study</td>
</tr>
<tr>
<td>The system shall store data in long term (&gt;10 years)</td>
<td>x</td>
<td></td>
<td>Interviews</td>
</tr>
</tbody>
</table>

Table 9: Functional and non-functional requirements
<table>
<thead>
<tr>
<th>Requirement</th>
<th>Functional Need</th>
<th>Non-Functional Need</th>
<th>Origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>The system shall allow custom calculation on measurement data</td>
<td>x</td>
<td></td>
<td>Interviews, Observational Study</td>
</tr>
<tr>
<td>The system must use consistent and self-explanatory IDs</td>
<td>x</td>
<td>x</td>
<td>Interviews, Focus Groups, Observational Study</td>
</tr>
<tr>
<td>The system shall be able to create test requests</td>
<td>x</td>
<td></td>
<td>Interviews</td>
</tr>
<tr>
<td>The system shall synchronise different versions of the same data</td>
<td>x</td>
<td></td>
<td>Interviews, Focus Groups, Observational Study</td>
</tr>
<tr>
<td>The system shall allow different user roles</td>
<td>x</td>
<td>x</td>
<td>Interviews, Focus Groups</td>
</tr>
<tr>
<td>The system shall allow different edit rights, dependent on the user role</td>
<td>x</td>
<td>x</td>
<td>Interviews, Focus Groups, Observational Study</td>
</tr>
<tr>
<td>The system shall be able to import requirements into test methods.</td>
<td>x</td>
<td></td>
<td>Interviews</td>
</tr>
<tr>
<td>The system shall be able to record and store numeric and text data for a large number of parallel test conditions, specified both dynamically as well as in pre-defined test methods</td>
<td>x</td>
<td></td>
<td>Interviews, Focus Groups, Observational Study</td>
</tr>
<tr>
<td>The system shall be able to update requirements in test methods</td>
<td>x</td>
<td></td>
<td>Interviews, Focus Groups, Observational Study</td>
</tr>
<tr>
<td>The system must provide an overview about the test data processes</td>
<td></td>
<td>x</td>
<td>Interviews, Focus Groups, Observational Study</td>
</tr>
<tr>
<td>The system shall allow the ability to show different UI elements dependent on user roles</td>
<td>x</td>
<td></td>
<td>Interviews, Focus Groups, Observational Study</td>
</tr>
<tr>
<td>The system shall enable the user to be comfortable with the system less than a month</td>
<td>x</td>
<td></td>
<td>Interviews, Focus Groups</td>
</tr>
<tr>
<td>The system shall provide a database for test objects, test reports, test codes</td>
<td>x</td>
<td></td>
<td>Interviews, Focus Groups</td>
</tr>
</tbody>
</table>

Table 10: Functional and non-functional requirements Continuation