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Investigating a Method for Capturing Actionable Knowledge in Manufacturing Engineering

Dan Li
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Department of Product and Production Development
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MASTER'S THESIS

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Typeset in LaTeX
Printed by Chalmers Reproservice
Gothenburg, Sweden 2015

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Abstract

In order to be successful in future product development projects, knowledge needs to be reused effectively. Effective knowledge reuse requires excellent knowledge management methods. This thesis aims to investigate the appropriateness of an existing method for reusing knowledge by testing its suitability in manufacturing engineering at the case company. The purpose is to analyze if specific engineering knowledge can be captured and be made actionable. This actionable knowledge should be both relevant and easy-to-use for the intended knowledge user, who is put in focus with the method.

A qualitative approach was applied for finding relevant information, both through interviews with Technical Preparation Engineers (TPE) and a literature review. These results were then analyzed by applying the Engineering Checksheet (ECS) method, and the findings were validated by more interviews. The thesis focused on how the ECS method can generate actionable knowledge, i.e. the knowledge content. The method's actual implementation format was not explored and is left for future research.

The thesis shows that it is possible to capture relevant knowledge by using the ECS method. It also suggests that it is possible to make the captured relevant knowledge easy-to-use. The overall positive response from the validation interviews can be seen as a good indicator for that the ECS method can capture and reformulate current engineering knowledge into actionable knowledge.

There exist theories on organizational learning and this thesis' contribution to research is that it studies the desired characteristics of reusable knowledge. The originality lies in that it was tested in practice, by applying a concrete method. This experience can be valuable for future knowledge management research in order to understand what knowledge to reuse and how to do it in practice.

Keywords: Actionable Knowledge, Knowledge Reuse, Knowledge Management, Engineering Checksheet, Technical Preparation Engineer, Product and Production Development.

Acknowledgements

This Master's thesis project was carried out at the Department of Product and Production Development at Chalmers University of Technology. It has been in collaboration with our Case Company in Gothenburg, during the spring semester of 2015.

Our greatest thanks go to our supervisor at the case company, Ph.D. Amer Catic, who have helped and supported us throughout the entire project. Without his guidance and shared knowledge, the project had not been possible.

We would also like to thank our examiner at Chalmers University of Technology, Associate Professor Dag Henrik Bergsjö, for his insightful advice. Finally, we would like to thank Ph.D. student Daniel Corin Stig, for his extensive feedback on our work.

Dan Li and Jens Samuelsson
Gothenburg, June 12, 2015

List of Abbreviations

DFMA - Design for Manufacturing and Assembly

DRM - Design Research Methodology

DS-I - Descriptive Study I

DS-II - Descriptive Study II

ECS - Engineering Checksheet

e.g. - exempli gratia (for the sake of example)

et al. - et alii (and others)

i.e. - id est (that is)

PS - Prescriptive Study

R&D - Research and Development

RC - Research Clarification

SECI - Socialization, Externalization, Combination and Internalization

TPE - Technical Preparation Engineer

Contents

List of Figures

1
Introduction

This introductory chapter aims to clarify what can be expected in this thesis. An initial description of the current circumstances, in both theory and practice, justifies the relevance of this thesis' purpose and problem formulation. Together with the delimitation, it creates a clear scope and a precise focus for the thesis.

1.1 Background

In a global economy, where competition stretches worldwide, the manufacturing industry is compelled to continuously develop and improve products and productions (Mital et al., 2014; Rosenfield, 2014; de Weck and Reed, 2014). In order to be competitive with new product and production development, companies need effective development processes to improve the companies' own capabilities (Wheelwright and Clark, 2012). Better development capabilities are important for satisfying customer needs, decreasing time to market and developing great products (Mital et al., 2014; Rosenfield, 2014). While proper development capabilities are necessary for staying competitive in the manufacturing industry, extraordinary development capabilities are the foundation for achieving a competitive advantage (Wheelwright and Clark, 2012).

During the last decades, it has become apparent that knowledge management is one of the key assets for organizations to achieve great success in product and production development and a future competitiveness (Laitinen et al., 2015; Rahimli, 2012). Most companies are struggling with the reuse of engineering knowledge, e.g. it is common to gather information during development projects, but many companies have difficulties in processing the gathered information and put the knowledge to use (Lindkvist, 2001; Singh, 2013). Knowledge management aims to support future projects and decisions by providing means for how to create, capture and reuse engineering knowledge (Lan, 2014). Knowledge that is created in a project and that can be useful and contribute to other projects, needs to be shared (Singh, 2013). If that relevant knowledge is not shared, companies will suffer loss of knowledge. By losing knowledge, the companies will also lose effectiveness and its competitive advantage (Lindkvist, 2001; Rahimli, 2012).

There is arguably an urgency for many organizations to improve their knowledge management capabilities, in order to retain a competitive advantage (Singh, 2013). In order to increase the knowledge management capabilities, it is desirable for organizations to manage their knowledge reuse so that it is effective from both of these two perspectives:

- The specific knowledge should be relevant for the intended user
- The specific knowledge should be simple to understand and reuse

This effective knowledge will be expressed as *actionable knowledge*. This thesis project is performed in collaboration with a case company. The case company has developed a method for reusing actionable knowledge in their product development projects. The problem lies in the difficulty to define what knowledge is actionable. This method, combined with the distinguishing of actionable knowledge has led to the formulation of the purpose for this thesis project, presented in section 1.3.

1.2 Case Company

The case company is part of a corporate group within the automotive industry. The case company represents a large part of the group's development and is responsible for the development of new products and technology for several brands in the group. The company is operating on a global market and have around 5 000 employees. The case company development process is based on projects, which follows a stage-gate process.

As described in background, section 1.1, there is a need for many companies to improve their knowledge reuse capabilities. The case company is struggling with the same problem. The thesis project has been conducted at the case company's technology division in order to investigate the possibilities to extend knowledge reuse in their development projects. The current situation for knowledge reuse at the case company is largely dependent on face-to-face communication and documentation of lessons learned. The documentation normally includes too much information to be relevant to read. The documentation of lessons learned is explained in more detail in section 3.4.2. The dependency of face-to-face communication leads to much information in the minds of the employees. A good example is one of the interviewees, who explained that:

"When I quit, knowledge that I have will be lost because there is no one else that knows what I know and it is not stored anywhere".

In order to understand the thesis' problem formulation, the Engineering Checksheet and the Technical Preparation Engineer role needs to be clarified.

The Technical Preparation Engineers (TPE) is a role at the case company that acts as an intermediate between product design and production. Their primary task is to determine if the concepts, generated by designers, can be manufactured and assembled in the production. A more detailed description of the TPE role can be seen in section 4.1.

The Engineering Checksheet method (ECS method) is an existing method at the case company. It is designed to capture actionable engineering knowledge in order to ease the reuse of knowledge i projects. The ECS method is explained in more detail in section 3.4.1.

1.3 Project Purpose

The master thesis focuses on how the reuse of engineering knowledge at the case company can be expanded by exploring how the application of the ECS method can be extended from the project focus for designers to focus on processes for TPEs.

The purpose of this master thesis is to explore if engineering knowledge can be captured by the ECS method and be made actionable for later reuse by TPEs. The result of the thesis will be completed ECS, based on TPEs' knowledge and an evaluation of whether the ECS method can be used to capture actionable knowledge and be suitable for the role of TPE.

1.4 Problem Formulation

In order to fulfill the purpose of the thesis, the first step is to formulate the problem to describe the specific issues at hand. As discussed in background, section 1.1, there exist a current interest for companies to increase their effectiveness in knowledge reuse, to improve product and production development processes. This interest is also true for the case company.

The problem at the case company is a lack of knowledge reuse. To counter this issue, the case company has developed the ECS method to help product designers to reuse knowledge between development projects. Despite the ECS method being used on a voluntary basis, it has received positive responses among its users. However, it is not well spread among the organization yet. In order to support further implementation, the case company wishes to explore if the ECS method's use can be expanded to also support the TPE role within their product development process. The product designers use the ECS to store knowledge about products and components. The TPEs will instead use the ECS for storing knowledge about how to counter issues regarding the process.

In order to extend the use of the ECS method at the case company, the problem has been decomposed into goals and research questions. While the goals are considered deliverables to fulfill the purpose, the research questions aim to create a greater understanding of the research area.

1.4.1 Goals

The goals are formulated as deliverable objectives to guide the path through the thesis in order to fulfill the purpose of this research. These goals are:

- Identify and investigate the current situation at the case company with regards to reusability and actionability of knowledge
- Apply and evaluate the ECS method in a manufacturing engineering context

1.4.2 Research Questions

The findings of this thesis will be used to investigate and possibly improve the existing ECS method for extracting and capturing actionable knowledge. In order to get a deeper understanding for the research area, it is interesting for the thesis to answer these two research questions:

1. What characterizes actionable knowledge in a manufacturing context and how is it distinguishable?
2. How can the ECS method, for capturing actionable engineering knowledge, be improved for the TPE role in a manufacturing engineering context?

1.5 Delimitation

The thesis will neither implement the ECS method, nor will it create new methods for reusing engineering knowledge, but it will rather investigate the ECS method. Hence, the thesis focuses on the content and not on the format of knowledge reuse. The thesis will not consider the appropriateness of the ECS method for other roles than TPEs.

2
Methodology

The Methodology chapter aims to provide an overall description of the research approach. It will provide the reader with theoretical explanations of the methods used for reaching the goals. It will also discuss the selection of methods and describe the methods' contribution to the thesis.

2.1 Research Approach

Since this thesis aims to investigate a specific design - the ECS method - for the TPE role, this thesis is expected to deliver evidence supporting the possibility of expanding such reuse of engineering knowledge. Therefore, a qualitative study, with focus on developing the ECS method, is especially suitable for this thesis.

The approach of this research is based on an inductive reasoning, where the analytical process is driven by collected information rather than a theoretical truth. The qualitatively collected empirical information from both primary and secondary sources form a basis, from which the analytical process produces a result that is then validated.

Based on the aim and the approach, a methodology was selected in order to accommodate the purpose of the thesis. This methodology was the Design Research Methodology (DRM). It was selected as the methodology for this thesis because it supports researchers in reflecting and selecting appropriate research methods that creates a holistic process for engineering design. This approach and methodology is reflected upon the applied research approach, described in section 2.3.

2.2 Design Research Methodology

The methodology of this thesis follows the research process proposed by Blessing and Chakrabarti (2009): *Design Research Methodology*. *Design* in this context denotes a dynamic and complex process that involves people and knowledge, methods and tools (Blessing and Chakrabarti, 2009), which the ECS method encompasses. *Design Research* refers to the development of both the understanding and support of such design.

The methodology of Blessing and Chakrabarti (2009) is represented in figure 2.1. The process starts with an elaboration of the initial understanding for the research area, a so called research clarification (RC). This basic understanding provide the means to identify the research purpose, the goals expected to be realized and the interesting questions to be answered. The process continues with a descriptive study (DS-I), where empirical information is collected and analysed. The prescriptive study (PS) aims to develop some kind of support based on findings from DS-I in order to discover potential improvement areas. To conclude, a second descriptive study (DS-II) may be conducted to evaluate the results and suggestions from the PS and possibly implement and validate these concepts. Depending on the purpose and scope, the research can range from only including RC and DS-I, or encompass all the way to DS-II, with different level of complexity, variations and iterations. Also, depending on the outcome of each stage, it is possible to redo earlier stages with same or different methods.

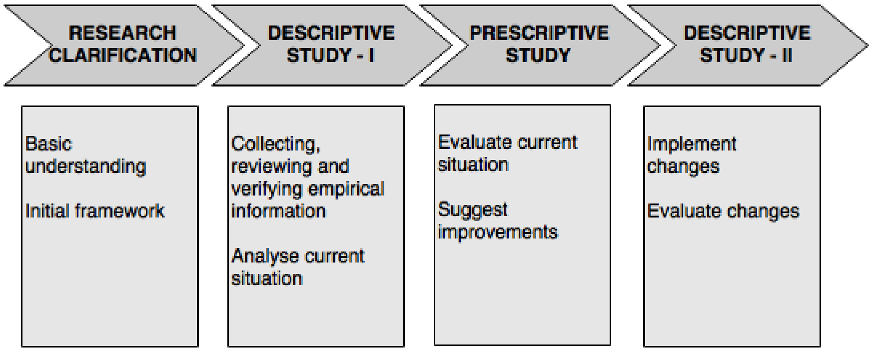

Figure 2.1: A simplified representation of the DRM framework (Blessing and Chakrabarti, 2009)

Each of the DRM stages include several different methods that are applicable in research. DRM helps the researchers to select appropriate methods based on the research purpose and approach.

Research Clarification (RC)

Blessing and Chakrabarti (2009) describe RC as the stage where the research goals are selected, based on whether it is worthwhile and realistic. Also, a type of research is selected to develop an overall research plan in order to reach the purpose of the research. Conclusively, RC tells the research problem but also creates an initial framework, from which the research originates. Such a framework can be formulated based on literature study or interviewing relevant stakeholders.

Descriptive Study I (DS-I)

DS-I is explained by Blessing and Chakrabarti (2009) as the continuation from RC. With the findings from the initial RC stage, the DS-I aims to dig deeper in the research by collecting, reviewing and verifying empirical information. The content of the DS-I can be described as an analysis of gathered information from primary sources, which creates an understanding the situation. This understanding may be formulated as a theory that is the synthesis of assumptions and experiences from the research.

Prescriptive Study (PS)

The PS stage is the stage where the deep understanding from DS-I is used by the researcher in order to suggest corrections to improve toward a desired situation (Blessing and Chakrabarti, 2009). PS can be viewed as a evaluation, which aims to investigate how factors addressed in the existing situation can possibly be improved.

Descriptive Study II (DS-II)

Like DS-I, DS-II focuses on investigating phenomena, however with a different reason Blessing and Chakrabarti (2009). The DS-II focuses on implementing the suggested improvements from the PS stage and evaluate the application of these changes. Such validation makes it possible to draw overall conclusions of outcomes.

2.3 Applied Research Approach

The applied research approach provides an understanding for how the thesis has been carried out, in chronology. It describes the methods chosen and gives a detailed explanation of the coherence of the chosen methods. The methods were chosen based on the specific recommendations from the different DRM stages. The activities of this thesis, as according to the applied research approach, is listed graphically in figure 2.2. The activities' and the report outcomes' relations to the DRM framework are also denoted. As proposed by Blessing and Chakrabarti (2009), this thesis starts with a review-based RC, which continues into a comprehensive DS-I and is concluded with an initial PS. This thesis will not further continue towards a DS-II because of the pre-defined scope of this project. The scope limits the project to end with a prescriptive suggestion for future implementation. The DS-II stage aims to describe the effects of changes after implementation. Thus, the DS-II stage was not included within the scope of this thesis.
The literature study and the interview cycle 1 resulted in the creation of a knowledge framework and an understanding of the TPE role. Here, the secondary sources of the literature study pointed towards interesting topics to investigate with primary sources. During the interview cycle 2, empirical information regarding TPEs' specific work knowledge were gathered from them. The results from these activities were then combined in the analysis to result in a completed ECS. The result from the analysis were then validated through the interview cycle 3 to confirm the expected outcome.

2.3.1 Literature Study

The main contribution of the literature study was to create a theoretical framework to support the research area. The literature study, that was a part of the RC stage within the DRM process, contributes to the selected methodology and the creation

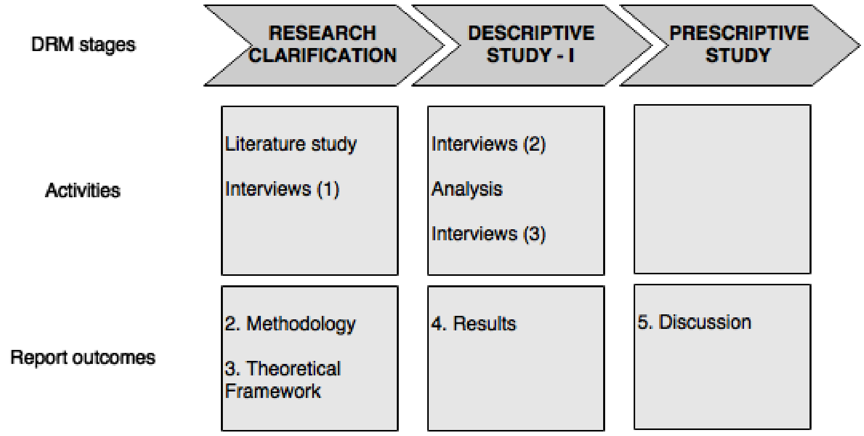

Figure 2.2: Applied research approach for this thesis, and its relation to DRM

of the theoretical framework.

The literature study method was chosen due to the large amount of accessible information within the areas of interest. What was interesting to explore in the literature study can be roughly categorized into two areas: one concerning the product and production development, and the other encompassing the domain of knowledge and its management.

The literature study was conducted by identifying relevant literature to support the research. Information were gathered from both external and internal sources. External sources in this context are books, articles, course literature and other master thesis reports with similar theoretical baseline as this project. Internal sources are information at the Case Company. The supervisor at the Case Company was consulted in order to receive guidance on searching for relevant literature. The literature was then analysed and summarized in order to create a clear view of the underlying theory.

2.3.2 Interview Cycle 1 - Exploring the Technical Preparation Engineer Role

The first cycle interviews were conducted with practitioners of the TPE role. The interviews were conducted in order to create understanding of the TPE role, which is considered as essential for contextualizing relevant knowledge. This fundamental information is a part of the RC stage of the DRM framework. The approach of the first cycle interviews was qualitative due the small amount of available TPEs. In total, 4 TPEs were interviewed at 4 occasions. The interviews varied from 1-2 hours and was performed in Swedish because it was the preferred language of the interviewees.

It was desirable to avoid answers from the practitioners based on their formal work descriptions. Instead, it is interesting to understand their actual work tasks in practise. There is a risk of the interviewees telling what they think is expected instead of their actual work tasks if using quantitative methods, e.g. surveys or questionnaires. These differences could be distinguished by interviews.

Therefore, the process of exploring the role of TPE was conducted primarily by interviewing TPEs individually. The interviews were structured with question-based topics that searched for open-ended answers. The interview results were then complemented with the internal literature and documents in order to receive an overall view of the TPE role.

2.3.3 Interview Cycle 2 - Empirical Information from Technical Preparation Engineers

The interviews of the interview cycle 2 aimed to gather relevant and detailed information from the TPEs concerning their work. This empirical information is used as input to the analysis. These interviews were the initial step of the DS-I stage, where the gathered information contributed to the analysis as input. Four interviewees were interviewed in the interview cycle 2, two of the four interviewees were interviewed twice, which in total resulted in six interview sessions. The interviews were around two hours each.

These interviews were based on the approach of iterating questions concerning issues that the TPEs have encountered. These issues were then clarified by follow-up questions in order to capture all information about the specific issue. This procedure encompassed both information regarding the issue and processes of solving them.

This second cycle interviews also had a qualitative approach in order to receive a wide range of information from the TPEs. Like the conversations of the interview cycle 1, the interview cycle 2 was also open-ended, but unstructured in order to increase flexibility of questions to illuminate different perspectives that incite the interviewees to expand their answers. During the interviews, as much information as possible were documented by writing down what was discussed. The interviews were also recorded in order to capture the information that was not written down. The recorded data was processed when there were uncertainties when reviewing the written interview notes.

A visit to the manufacturing site, where one of the interviewees showed the factory, supported improvement of the comprehension of several issues discussed in the interviews.

2.3.4 Analysis - Using the Engingeering Checksheet Method

The analysis aims to determine the relevance of information and make the relevant information easier to use in other projects. The analysis that is the central part of the DS-I is based on empirical information gathered earlier in the DS-I stage filtered through the framework developed in the RC stage, which results in completed ECS.

The analysis was done by implementing the existing ECS method. The ECS method uses the results from interview cycle 2 as input together with literature study and interview cycle 1. The method is described graphically in figure 2.3 where the numbers correspond to these performed steps:

1. The collected information from interview cycle 2, i.e. information pieces, were sorted and its relevance was assessed with regard to the TPE role as concluded from interview cycle 1.

2. The relevant information were then re-formulated to make it easy-to-use with regard to theory of actionable knowledge, based on the literature study.

3. The re-formulated information were stored in an ECS.

4. The ECS were evaluated with regard to the degree of actionability of the specific information.

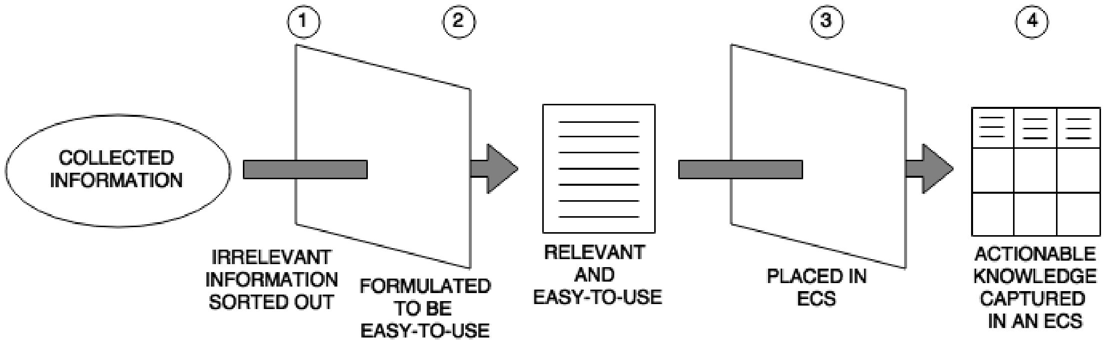

Figure 2.3: Depiction of the Engineering Checksheet method

Depending on the degree of actionability in specific information, an ECS with high degree will be ready for validation. If evaluation results in a too low degree of actionablility, more information would be gathered followed by a re-iteration of the analysis process.

After the analysis is done, a theory is developed on the validity and appropriateness of the ECS method.

2.3.5 Interview Cycle 3 - Validation of Engineering Checksheets

The third interview cycle aimed at validating the results of the ECS. Primarily with practitioners of the TPE role, but also persons with other roles were interviewed. A validation process of the results from the analysis discusses the theory of the ECS method's appropriateness.

The process of validating the ECS started with an introducing presentation of the aim and purpose of the ECS as well as a description of how the ECS will help reusing knowledge. The TPEs were also shown the completed ECS, supplemented with questions to get a response of their opinions of the suitability of the ECS method. Based on the results of these interviews, a holistic summary of the ECS method's suitability can be formulated. These results end the DS-I stage with a foundation for a development and implementation idea. Such future possible implementation is discussed and forms an initial PS stage.

3

Theoretical Framework

This chapter provides an understanding of the process of product and production development management and formulate a reference model for knowledge management. Product and production development is interesting since it creates an appreciation of a TPE's work. An elaborate framework of knowledge is important for understanding the process of creating, sharing and reuse of knowledge in a management context.

3.1 Product and Production Development

There is a current situation on the market where product and process design and technology are rapidly developed. In this competitive environment, companies are forced to make the product and process development effectiveness increase continuously. In order to stay competitive, companies needs to bring products fast to market. The products also need to meet the expectations and needs of the customers. In this environment, the development process is a key for competitive advantage (Wheelwright and Clark, 2012).

In order to create a successful development process, Wheelwright and Clark (2012) describe several areas of importance. Areas that will be focused on in this thesis are the primary areas of TPEs. These areas for increased efficiency in development are platform based products, design for manufacturing and assembly and cross-functional integration.

3.1.1 Platform Based Products

Platform based products is described by Ulrich and Eppinger (2011, p. 20) as products that are "built around a preexisting technological subsystem". It can also be described as "collection of assets that are shared by a set of products" which includes aspects regarding the product such as processes, people and relationships and knowledge (Robertson and Ulrich, 1998, p. 20). Examples of platform based products are:

- The underbody of a car or truck that are shared by different models (Michaelis, 2013)
- Apple iPhone operating system (Ulrich and Eppinger, 2011)

By implementing platform based products, companies can focus their resources on product families instead of several different products which allows them to develop new products easier and faster. If based on a platform, there are much simpler, compared to “start from scratch”, to develop new products (Ulrich and Eppinger, 2011).

3.1.2 Design for Manufacturing and Assembly

Boothroyd et al. (2002, p. 1) consider *design for manufacturing and assembly* (DFMA) as design that supports the manufacture of components and the subsequent assembly to form a product. DFMA is commonly used to provide guidance to designers for simplifying products that can reduce manufacturing and assembly costs (Boothroyd et al., 2002).

Earlier, it was common that design and manufacturing or assembly were developed apart. However, the systematic approach of DFMA improves time-to-market, quality and workplace ergonomics among others according to Boothroyd et al. (2002). The reasons for the improvements include less components and easier assemblies for the operators to manage. As the intermediate zone between design and production, Boothroyd et al. (2002) argue that the DFMA is a laudable approach in the early concept stage.

The DFMA philosophy of considering the manufacturing and assembly in early design can be practically implemented in various ways. Adler and Schwager (1992) realized early that software technologies would simplify the use of DFMA in practice. More concurrently, Barbosa and Carvalho (2014) suggest a methodology with 12 steps including both product and process design. Another example of DFMA implementation is presented by da Silva et al. (2014), where simulation and modelling of production which provide a holistic view on the impact of DFMA.

3.1.3 Cross-Functional Integration

Wheelwright and Clark (2012) describe how *cross-functional integration* can help companies increase their effectiveness in business. Cross-functional integration aims to achieve great collaboration between the major functions in a project. The major functions is described by Wheelwright and Clark (2012) as engineering, marketing and manufacturing. Engineering can be seen as closely related to designer, where the important deliverables are design, tests and prototypes. Marketing is the function for analysing customer needs and provide project plans and manufacturing is the function for calculate costs, create pilot plants and ensure the process capabilities. By integrating these functions and make them work together in an effective way, the companies can develop and deliver better products to the market within decreased time. Wheelwright and Clark (2012) also explains that companies who wants to come out on top in competitive markets, with rapidly changing technology and where time is crucial, need deep integration in order to succeed and get market shares.

The close communication is essential for making persons from different functions work with joint problems. Lindkvist (2001) describes that product success is closely related to how and what knowledge is shared. To receive integrated problem solving in projects, the shared knowledge needs to be both rich, bilateral and intensive (Wheelwright and Clark, 2012). In order for a problem solving group to be effective, one can not just "throw information over the wall". To share knowledge in an effective way, the communication needs to be face-to-face discussions, direct observations and interaction with physical prototypes or well organized computer-based systems (Wheelwright and Clark, 2012).

In order to understand the importance of knowledge sharing and what knowledge that is desirable to share in cross-functional teams, the theoretical framework will further provide explanations for how to categorize, create, share and reuse knowledge.

3.2 Concept of Knowledge

There is no singular and easy definition that encompasses all of what knowledge can be. Instead of elaborating on the epistemology of knowledge, it is more interesting for this thesis to considerably narrow the scope to explore knowledge in a management context.

3.2.1 Tacit and Explicit Knowledge

Davenport and Prusak (1998) explain pragmatically that existing knowledge that reside in a human being provide a framework for interpreting new experiences and information based on a mix of earlier experiences and information.

The current paradigm suggests that there are two dimensions of knowledge: *tacit knowledge* and *explicit knowledge.* Tacit and explicit knowledge can be seen as either opposites or complementary to each other.

Tacit knowledge can be described in several ways by explaining some of its characteristics:

- Tacit knowledge is complex and abstract (Reber, 1989; Davenport and Prusak, 1998)
- Tacit knowledge is difficult to formalize, document and communicate (Davenport and Prusak, 1998; Zack, 1999; Lam, 2000; Shariq and Vendelø, 2006; Goffin and Koners, 2011; Gascoigne and Thornton, 2013)
- Tacit knowledge is gained by experience and observation (Zack, 1999; Lam, 2000; Wong and Radcliffe, 2000; Gertler, 2003; Gascoigne and Thornton, 2013)

All these perspectives on tacit knowledge derive from the philosophical thinking of Polanyi (1966), emphasizing this particular quote as central: “We can know more than we can tell” (Polanyi, 1966, p. 4). Lam (2000) tries to simplify it by illustrating tacit knowledge as "learning-by-doing".

Explicit knowledge is different from tacit knowledge, which can be recognized by some of its characteristics:

- Explicit knowledge is easy to formulate, document and communicate (Davenport and Prusak, 1998; Wong and Radcliffe, 2000; Goffin and Koners, 2011; Ribeiro, 2013)

- Explicit knowledge is possible to articulate clear and precise (Davenport and Prusak, 1998; Zack, 1999; Wong and Radcliffe, 2000)

Nonaka (1994) summarize explicit knowledge as transmittable with a formal and systematic language. Hence, explicit knowledge contrasts “We can know more than we can tell” (Polanyi, 1966, p. 4), by being what is tellable.

Giving precise definitions of tacit and explicit knowledge are not simple. However, for this thesis, the presented characteristics should provide a sufficient picture of the concept of tacit knowledge.

Grandinetti (2014) clarifies that tacit knowledge may refer to knowledge that is either difficult or impossible to articulate. In a context of making tacit knowledge explicit, tacit knowledge refers to the knowledge that is difficult to articulate. Explicit knowledge relies on knowledge that has been tacitly understood and applied, but making tacit knowledge explicit comes at a cost of losing of information in the process (Goffin and Koners, 2011; Gascoigne and Thornton, 2013).

Wong and Radcliffe (2000) capture the relationship between tacit and explicit knowledge in a "knowledge spectrum", see figure 3.1, where different pieces of knowledge can have different levels of tacitness or explicitness.

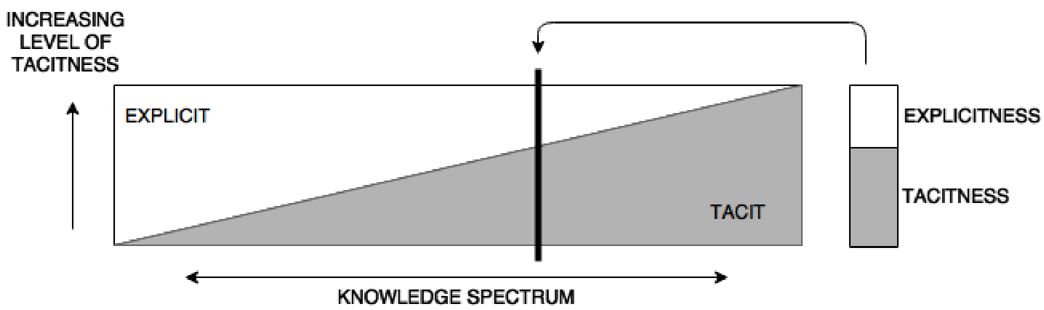

Figure 3.1: Spectrum of explicitness and tacitness of knowledge (Wong and Radcliffe, 2000)

3.2.2 The Hierarchy of Knowledge

The concept of knowledge differs from those of data or information. There is a commonly shared view among authors that there is a need for distinguishing between data, information and knowledge. Both Davenport and Prusak (1998) and Tuomi (1999) describe the relation between data, information and knowledge as:

- *Data* is a set of discrete and uninterpreted facts about events
- *Information* is structured data that has been given meaning and put into a context
- *Knowledge* is a higher level of understanding that mixes experiences, values, information and insights that is derived from minds at work

Ackoff (1989) explains the relationship between the categories as not interchangeable. However, each category are dependent of the other neighbouring categories in the hierarchy. The hierarchy is displayed graphically in figure 3.2. The exact view of how the relations between data, information and knowledge should be defined varies among authors. Tuomi (1999) though explains that despite these variations, the overall description that knowledge is more than information and data is commonly accepted.

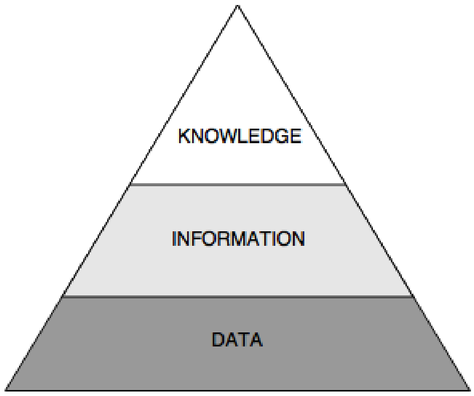

Figure 3.2: The knowledge hierarchy (Tuomi, 1999)

Some authors also include two other categories. For example, Ackoff (1989) adds understanding and wisdom while Tuomi (1999) divides it into intelligence and wisdom. In this context, intelligence can be seen as choices based on received knowledge and wisdom can be seen as intelligent behaviour that are guided with values and commitment. Davenport and Prusak (1998) state that companies have problems with distinguishing data, information and knowledge from each other. Therefore, Davenport and Prusak (1998) choose to include intelligence and wisdom in their description of knowledge, instead of detailing the model further. Consequently, the approach of Davenport and Prusak (1998) is recognized as a suitable level for this thesis project. Hence, concepts like intelligence and wisdom will be considered as an integral part of knowledge.

Tuomi (1999) provides a description of the hierarchy of knowledge but also suggests an alternative view, the reversed hierarchy of knowledge. The relation between data, information and knowledge according to the reversed hierarchy of knowledge can be seen as opposite to the knowledge hierarchy. Data and information would not exist without knowledge to create them. In order to create data, there must be information and knowledge (Tuomi, 1999). Contrary to the knowledge hierarchy, information is not created by organizing and structure data. Instead, information can define data by giving meaning to it (Tuomi, 1999).

Data

Since data is both discrete and objective, bearing no interpretations of facts, it is rather uninteresting on its own because it is neither important nor irrelevant. However Davenport and Prusak (1998) stress that data's importance lies in its necessity as the foundation for creating information.

Information

Davenport and Prusak (1998) suggest thinking of information as "data that makes a difference". Similarly, Drucker (1988) describes information as "data endowed with purpose and relevance". Both assertions support the concept of information as data treated in various ways, which Davenport and Prusak (1998) formulate as: contextualized, categorized, calculated, corrected and condensed.

Knowledge

Knowledge has no simple definition as data, it can be both fluid and solid, and often it is intuitive, which makes it more difficult to formalize (Davenport and Prusak, 1998). Nonaka (1994) explains that knowledge, unlike information, is heavily dependent of the commitment and beliefs of the individual attempting to understand the specific knowledge. Further, Drucker (1988) argues that knowledge is required for conversions between data and information. This perspective supports that knowledge is based on human understanding. Nonaka (1994) concurs, claiming that knowledge within an organization can only be created by individuals. Such creation of knowledge by individuals can be created by several approaches Davenport and Prusak (1998): comparison, consequences, connections and conversations.

3.3 Knowledge Management

In order to reuse knowledge effectively, organizations need to understand the concepts of organizational learning, the creation and sharing of knowledge as well as what knowledge that is desirable for reuse.

3.3.1 Organizational Learning

In order to understand the knowledge creation process, Nonaka et al. (2000) presents the SECI model. By placing tacit and explicit knowledge in a process context it is possible to convert existing knowledge into new knowledge. Nonaka (1994) presents four modes of knowledge conversion. These four modes is also described graphically in figure 3.3. In order to describe how individual learning in the SECI model can be extended to organizational learning, Nonaka (1991) also explains the spiral of knowledge.

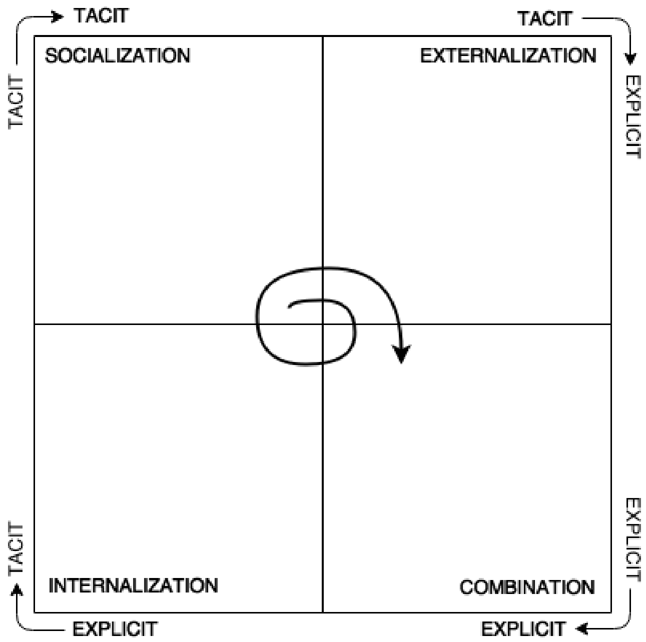

Figure 3.3: The SECI model for knowledge creation (Nonaka, 1994)

The knowledge spiral adds a third dimension to the SECI model. This third dimension displays how the level of knowledge can extend from an individual to inter-organizational level (Nonaka, 1991). Nonaka (1991) further explains how knowledge needs to start on an individual level and that it is a central part for knowledge-creating companies to share that knowledge to an organizational level. The knowledge spiral is described graphically in figure 3.4.

Socialization (Tacit → Tacit)

Socialization is the process of receiving tacit knowledge through interaction and shared experience between persons. Nonaka et al. (2000) describes the process as largely dependent on experience. The process can be seen as typical apprenticeship where the apprentice can learn from experience like observations and practice compared to more formal ways as receiving knowledge through reading literature and books. It does not require any verbal interaction. In order for people to share thoughts and get into each others minds without language, the observations are highly important (Nonaka, 1994).

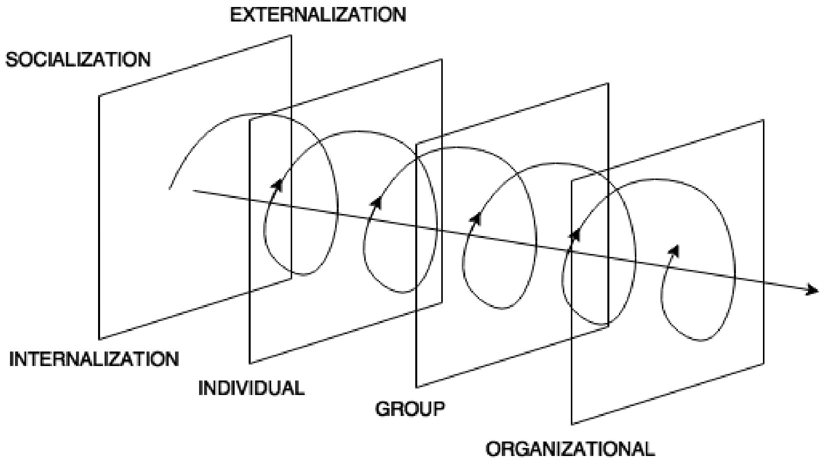

Figure 3.4: Spiral of knowledge creation for organizational learning (Nonaka et al., 2000)

Externalization (Tacit → Explicit)

The term externalization is the way of receiving explicit knowledge from tacit knowledge. It is described by Nonaka et al. (2000) that tacit knowledge that is turned into explicit knowledge makes the knowledge crystallized. Crystallized knowledge means that it is ready to be shared and used by others to become a pediment of new knowledge. One example of externalization is concept creation in new product development and Nonaka et al. (2000) also explains that externalization can be used for improvements in manufacturing processes, i.e with quality control circles, workers can articulate the tacit knowledge through years of observations. In order for externalization to be successful, usage of metaphors, analogy and models are required.

Combination (Explicit → Explicit)

Combination is a process which generates explicit knowledge by combining and exchanging explicit knowledge that is held by different persons. This is primarily done by adding, sorting and categorizing explicit knowledge. A typical example of combination is the modern computers. Another common process for receiving knowledge through combination is interaction through meetings and telephone conversations (Nonaka et al., 2000).

Internalization (Explicit → Tacit)

Internalization is the way of converting explicit knowledge into tacit knowledge. It can be seen as closely related to "learning by doing". The process of internalization can be described as explicit knowledge that is shared in an organization and then converted to tacit knowledge by the individuals. In order to receive tacit knowledge through internalization, the explicit knowledge e.g. knowledge about production processes or product concepts must be put into action (Nonaka et al., 2000). Nonaka et al. (2000) explains that individuals, by reading and reflecting, can use the organizations explicit knowledge to extend and broaden their tacit knowledge further.

3.3.2 Knowledge Transfer and Sharing

It is commonly known that there can be issues when trying to transfer and share knowledge among individuals or in organizations. Davenport and Prusak (1998) state that the problem with knowledge transfer is easy to solve. An organization only need to hire intelligent individuals and let them communicate to share and transfer knowledge among each other. It seems simple but Davenport and Prusak (1998) are aware of the fact, this is not reality. In reality, the companies hire the intelligent individuals but they are given restricted or no time for interaction. They are instead burdened with tasks or placed isolated which complicates and sometimes even disable interaction (Davenport and Prusak, 1998).

As Webber (1993, p. 28) states, "In the new economy, conversations are the most important form of work. Conversations are the way knowledge workers discover what they know, share it with their colleagues, and in the process create new knowledge for the organization". Therefore, there are strategies for facilitating transfer and sharing of knowledge.

3.3.3 Codification and Personalization Strategies

Hansen et al. (1999) introduce two valid strategic approaches to knowledge management, both are applicable on organizations, but heavily dependent of the competitive strategy that drives the organization. The *codification strategy* provides "high quality, reliable, and fast information-systems implementation by reusing codified knowledge", which require a system for people to codify and store knowledge in an accessible way, while the *personalization strategy* provides "creative, analytically rigorous advice on high-level strategic problems by channelling individual expertise", which require a network of individuals for exchanging tacit knowledge (Hansen et al., 1999).

McMahon et al. (2007) try to apply the personalization and codification strategies in an engineering context and conclude that neither strategy can, on its own, satisfy the knowledge management needs of any organization. The advantages of each approach are circumstantial, for example; smaller teams are more benefited of the personalization of knowledge, while larger groups require codification in order to grasp the vast amount of knowledge.

Both Hansen et al. (1999) and McMahon et al. (2007) highlight that neither strategy can fully work on its own. However, Hansen et al. (1999) argue that in an organization, there has to be one primary strategy supported by the other strategy where needed, while the McMahon et al. (2007) conclude that both strategies has its merits within an organization, and should be adapted to each situation. Nonaka

(1991) captures this reasoning, stating that even though new knowledge starts at the individual level, it can be valuable for the entire organization if knowledge is transformed appropriately.

3.3.4 Knowledge Reuse

Oshri (2006) describes knowledge reuse as a process that allows knowledge workers to capture, validate, store and retrieve knowledge. Hence, knowledge reuse as concept differs from sharing och transferring knowledge. In addition to knowledge sharing and transfer, that are activities that focus on spreading knowledge in general and communicating knowledge to a specific recipient respectively, knowledge reuse also include that the transferred knowledge should be able to be made use of and reapplied in different contexts (Oshri, 2006).

By reusing knowledge within organizations, internal capabilities, such as pre-existing knowledge and resources, may be exploited (Oshri, 2006). In this context, knowledge reuse can be seen as a process that aims to help organizations improve the overall effectiveness of certain activities (Dixon, 2000). Schwartz (2006) believes that, for knowledge to be reusable, the knowledge must have the ability to be:

- Acquired
- Organized, categorized or stored
- Distributed

Oshri (2006) describes both advantages and disadvantages with reusing knowledge. One of the main advantages that organizations can achieve by reusing knowledge is to avoid duplicate work. Oshri (2006) describes that reusing knowledge intends to improve not only products or components, but also processes. Duplicate work in product development is common for both products and processes. Preventing organizations from repeating mistakes, commonly known as "avoid reinventing the wheel", is of high priority due to that saving time usually is closely related to saving money (Bellgran and Säfsten, 2010). If organizations can reuse their knowledge in an effective way, they can gain great competitive advantages in terms of “shorter time to market”, lower risks in new projects, lower cost for Research and Development (R&D) and better understanding of customer requirements (Oshri, 2006).

Even if the advantages are many, there can still be disadvantages by reusing knowledge. Oshri (2006) states that by reusing knowledge, organizations can lose their will for continuous improvement and exploration of new development. This would be the result of the comfort that knowledge reuse entails. Another disadvantage that is mentioned by Oshri (2006) is that there might be negative effect on the knowledge reuse if there is lack of information or if the information available turns out to be false.

3.3.5 Actionable Knowledge

The theoretical framework has built up an understanding in order to comprehend that it is actionable knowledge that is desirable for effective knowledge reuse. The discussion of advantages and disadvantages by Oshri (2006) states that reusing knowledge can lead to competitive advantage and Wheelwright and Clark (2012) explain that the information that is reused, need to be rich and intense. There are no simple definition of actionable knowledge but it rather works as an expression for defining rich and intense knowledge that is suitable for sharing and thereby also appropriate for reuse.

Cross and Sproull (2004, p. 446) define actionable knowledge as "knowledge that leads to immediate progress on a current assignment or project".

According to a specialist at the case company, actionable knowledge can simply be explained as knowledge that are relevant and easy-to-use. Relevant means that the knowledge should be of interest for other intended users. To make knowledge easy-to-use, there is a lot of aspects to take into account. Miller (1956) presents evidence that there are difficulties for the human mind to remember information. Therefore it is important to prioritize what information should be shared. In the making of a specific knowledge to become actionable, it is desired that the specific knowledge also becomes easy to understand in order to enable the knowledge user to assimilate as much knowledge as possible. In order to make the knowledge relevant, the knowledge needs to be categorized in a way that makes the intended user understand where to look.

The content of actionable knowledge can differ. Cross and Sproull (2004) describes that actionable knowledge must not always generate solutions directly or descriptions of how to solve the problem. They mention that actionable knowledge also can contain referrals to e.g. people with relevant expertise or point at relevant information in a database.

Argyris (2003) argues that there should be a paradigm change in what is emphasised as important to focus on, in knowledge management:

- From understanding and explaining current knowledge → To include knowledge that can result in producing actions

- From propositions that are descriptive of the current situation → To include propositions that are normative and prescriptive of how to act in the future

- From knowledge that are too generalized → To include knowledge that are applicable in individual cases

- From seeking knowledge that is as complete as possible → To include seeking knowledge that is designedly incomplete, supported by theory and methods to fill in the gaps

3.4 Methods for Knowledge Reuse

There are several methods for reusing knowledge. This section will further provide descriptions of the methods used at the case company.

3.4.1 Engineering Checksheet Method

The ECS is a method for capture actionable engineering knowledge at the case company. It is designed to match the definition of actionable knowledge, explained by Cross and Sproull (2004) as knowledge that lead to immediate progress. It's also a method for capture knowledge that fit the prescription of relevant and easy-to-use.

The ECS is based on categorizing knowledge into Know-What, Know-Why and Know-How as described by Fu et al. (2006). Fu et al. (2006) describes a fourth category to this context as Know-Who. The ECS does not include that category but rather uses Know-How to also include Know-Who. Fu et al. (2006) describes the relation between the categorize as:

- *Know-What* is knowledge of facts
- *Know-Who* is the knowledge of who knows the facts in Know-What
- *Know-Why* is knowledge of laws of nature and principles
- *Know-How* is skills and the the capability of how to do something

The ECS is presented graphically in figure 3.5. The figure shows an empty ECS with descriptions of what should be presented in the categories respectively. Knowledge in the ECS is based on issues or problems and aims to provide the reader with a short description in the three categories Know-What, Know-Why and Know-how in order to assist when facing a similar problem. The Know-What category describes the what the knowledge is about. Know-Why further describes the specific problem with the purpose of explaining why it is a problem. Finally, the Know-How category explains how the problem can be solved or what to think about when searching for a solution. In order to use the ECS method, a description of how to use it can be seen in section 2.3.4

Know-What?	Know-Why?	Know-How?
What area the problems occur, or could occur.	Why the described problems occur and the background to the problems.	How the interviewee was thinking when solving the issues, or what could be thought about when solving similar issues.

Figure 3.5: Example of a simplified ECS with instructions

3.4.2 Documentation of Lessons Learned

Documentation of lessons learned is a method for codifying knowledge (Williams). The concept of lessons learned can simply be described as documenting key project experiences that can be considered relevant and important for future projects (Goffin et al., 2010). The method of lessons learned aims to store knowledge, often in the format of stories or metaphors (Goffin et al., 2010). In this sense, lessons learned is information describing what has happened in the past. An advantage of documentation of lessons learned is that documentation can direct future project managers to relevant lessons learned and also point out which individuals can be consulted based on their experiences (Williams). A problem with this method is difficulties with how to properly spread the lessons learned within an organization (Williams).

The case company uses an adaptation of lessons learned. The process for reusing knowledge with this method is that the project members, after project finish, are asked to contribute with their own key experiences. This information is then stored in a digital database or repository.

4
Results

This chapter will provide the results of the thesis. The thesis result will only consist of what has been done and descriptions of what the collected information consists of. It will not provide any actual information of the case company components.

4.1 Technical Preparation Engineer

The first cycle interviews resulted in a detailed description of the Technical Preparation Engineer (TPE) role. The result is based on the interviewed practitioners' experience of their own work.

4.1.1 The Role of Technical Preparation Engineers

The role as TPE at the case company can generally be described as the intermediary between a product designer and a manufacturing engineer. An integral part of a TPE's responsibilities is to support product designers in the development process for generating manufacturable product design concepts for implementation in the production process.

More specifically, TPEs work towards implementing new technology solutions in a pilot plant. Rather than producing vehicles to customers, the pilot plant serves as a plant where new projects can be deployed for testing before getting implemented in the actual manufacturing plants. The pilot plant is regarded as a visionary plant, aiming to become what is desirable in an actual plant in the future. Hence, the pilot plant functions as a model for the case company's other plants.

Important deliverables for TPEs are to decide on requirements for components regarding ability to be assembled, i.e. DFMA, by creating a picture of what has to be changed for the new technology to be implemented. It is desirable for the TPEs to deliver their requirement recommendations early in the development projects.

Challenges for a TPE include choosing which requirements to cater when the requirements contradict each other, e.g. safety, ergonomics, cost and assembly requirements. Despite difficult prioritization of the trade-offs, another challenge is to negotiate solutions that are agreeable for both design and production.

In order to discuss and solve problems in a project, TPEs has meetings with the project group continuously. These meetings are cross-functional and include both designers and process engineers as well as project managers and accountants. There can also be physical mock-up meetings, where the project team is gathered around a work station in production. The TPEs role in these meetings is to explain main requirements.

4.1.2 Knowledge Reuse for Technical Preparation Engineers

The TPEs struggle with knowledge reuse in their work. There are no method for reusing knowledge that are actually used by the TPEs. The current situation relies formally on documentation of lessons learned after finished projects and informally on discussions during lunches or coffee breaks. The TPEs' knowledge reuse are to large extent dependent on tacit knowledge. TPEs have much knowledge in their minds but that knowledge are not stored anyway and its hard for other TPEs to access that knowledge.

4.2 Codified Knowledge from the Technical Preparation Engineers

The interviews resulted in a lot of information from these primary sources. The information was detailed accounts of the interviewees' problem descriptions. The interviews aimed to gather information concerning the typical problem areas of the TPEs. These typical problem areas often affect the development processes of either product design or production engineering. The information primarily consisted of requirements and trade-offs for these typical problem areas:

- Safety
- Ergonomics
- Cost
- Assembly issues

The interviews resulted in detailed descriptions of issues and problems that the interviewees chose from their own experience. The information gathered were rich in content and consisted of a lot of information. These three examples of information pieces about specific problem are directly gathered from interviews and translated from Swedish to English:

Information Piece 1

There are quality issues with cables and routing of media. There can occur skewing against other components. Pipes and tubes are dynamic, dependent on operators and not as well defined in their nature. This puts higher requirements on the design. The assembly operators need to know how parts should be assembled in the [base component]. The product development department cannot release cables with lengths so that there are cables that fit all products due to tolerance issues. [Base components] can vary in length and it is unlikely that two of the same [product] are exactly the same. Therefore, variables and packing, i.e. where components should be assembled, differs and cables can not be 100 % optimized for all [products] and exact measurement of lengths cannot be achieved, there is [an interval length] leaps between different cable lengths. The choice of length is made early in projects, where stakeholders submit their requirements. Since there is a wish for less variants of cables, some cables can be too long. This extra length is called overlength. What is then done with this overlength? This is first checked virtually. Overlengths are not always apparent. It is desirable for overlengths to be placed at same places, so that it isn't in the way of other components. Concerning cables, TPE:s are trying to steer so that operators are encouraged to assemble in a specific way by using markings or colourings on where to attach the cables. This should lead to that overlengths occur where expected. The designer decide cable lengths based on [a database]. The TPE think of the assembly process.

Information Piece 2

There was a problem with [assembling] [components] due to that there is not enough clearance around [another component]. Despite new [tools], new measurements and [simulations], it was not possible to do the [assembling]. At first, TPE:s at [another factory at the case company] do not think that this issue is a problem. However, after inquiring the operators, they also recognized this problem. Therefore, it was reported as a [major issue]. Then, a calculation of tolerance chains were performed, with many figures measured, and the variation of tolerances when [assembling] [components] was discovered. In general, calculations of tolerances are conducted in various extent. Calculations are primarily done for components that are visible for customers. It is decided by the designers whether to perform these calculations or not, but the TPEs can come with suggestions. The experience from these events is that chains of tolerances can affect the assembly, and when the same assembly sometimes work and sometimes do not work, without any apparent reason, it can be good to check and calculate the chains of tolerances.

Information Piece 3

The more factories there are, the more a change costs. A small change in a factory affects other factories. Heavy components from suppliers need to be lifted in a way so that it becomes easy to assemble. If heavy components arrive on pallets, it need to be lifted into a fixture from hooks from the ceiling, and it is sensitive of bumping into other things. It should be requested that there are lifting points that the heavy components can be hooked on into the lifting fixture. Such solutions are necessary at both the case company and at the supplier. For example, there are [a number of] different variants of [heavy components], and the lifting tool should be able to lift all of them. To know how the lifting tool should be, you need to know how you want to assemble the [product], how you want to do the lifting. It is a long process that includes logistics and material handling. Also, the supplier can also vary. There are also different guidelines regulating when it is necessary to have lifting tools. It is different here and at [another factory at the case company]. If you also need to change the lifting tool frequently to lift different [heavy components], you lose time.

4.3 Completed Engineering Checksheets

The analysis of the codified TPE knowledge generated in 18 checks, inserted in the ECS. The checks corresponded to different areas of the Case Company's products' components. The result from the codified TPE knowledge that is described in section 4.2 was analysed using the ECS method and corresponds to the specific checks in figures 4.1, 4.2 and 4.3. These specific checks are 3 examples out of the 18 checks delivered to case company.

Know-What?	Know-Why?	Know-How?
Routing of media cables - Cable length.	The [base component] can vary in length. This variation will cause problems with the cables due to the predefined standard lengths of cables which results in a mismatch between the actual and the desired cable length. This is important to consider when cables are too long, which normally occurs. The operators will take own initatives in how to solve the problem. Often, this is done by clamping the cables in an undesired way.	It is desired to have the "cable overlength" placed in one designated area, and if not possible, as few areas as possible. The cables "placement points" should be well defined so that the "cable overlengths" are forced into the designated area(s). In this way, the assembly becomes noninterpretable for the operators.

Figure 4.1: Actionable knowledge in ECS format, based on Information Piece 1

Know-What?	Know-Why?	Know-How?
Simulation of tolerances for [component].	Simulation tends to show a working design solution where tolerances might not be accounted for, which is problematic since sometime there is not enough clearence for [assembling] [components]. Examples of such problems occuring can be: [assembling] angle; or attachment problems.	To ensure that a [assembling] is possible, one may request detailed tolerance calculations in order to properly assessing the [assembly] of [components].

Figure 4.2: Actionable knowledge in ECS format, based on Information Piece 2

4.4 Validation of Engineering Checksheets

There were 3 validation interviews with 3 TPEs, 1 interview with a diagnosis engineer and one group discussion on a meeting with a mid-level management group.

Know-What?	Know-Why?	Know-How?
Tool for lifting heavy components	Heavy components needs lifting tools in order to be assembled ergonomically and without damaging the component. Suppliers tend to vary their "lifting points" which requires a large amount of different lifting tools for the production.	Suppliers should be consulted in unifying standards for "lifting points", so that same lifting tools can be used for different heavy components at each workstation.

Figure 4.3: Actionable knowledge in ECS format, based on Information Piece 3

The interviews with the TPEs focused on the value of the knowledge content of the ECS and the categorization of Know-What, Know-Why and Know-How. The interview with the diagnosis engineer was performed to get an outside perspective on the ECS as a tool. The mid-level management group, which include the TPEs' managers to both evaluate the ECS as a tool and also inquiring the interest of possible future implementation.

The validation interviews resulted in a overall positive response about the possibility to implement the ECS method. The validation interviews further resulted in the interviewees' descriptions and thoughts about the ECS.

A filled ECS with knowledge can be presumed to be very useful for TPEs, especially for engineers new to the specific component or inexperienced engineers for the role. For these TPEs, the ECS is preferably consulted in early stages, since the ECS can function as a catalyst that can help TPEs to orient how to approach an issue or what to consider when solving a problem. Also, an additional benefit is that early stages of projects have better possibilities to mitigate cost impacts from expensive changes compared to late changes.

The ECS must not always show a solution, it can be very helpful for the TPEs' work even if the ECS shed light on previous problematic issues. In this sense, ECS can facilitate an initial approach to issues, rather than proposing a definite description of a final solution. Also, the ECS need to be closely intertwined with the central concept of actionability in order for the ECS to be relevant for the knowledge user. This relevance also require an appropriate level of generalization, so that the ECS are easily applicable for the knowledge user. Earlier knowledge management practice, such as documentation of lessons learned, include more information about projects. An advantage of the ECS method is that it focuses on the intended knowledge user, which makes ECS simpler to actually consult.

However, even though there is an appreciation towards the intent, there exist some scepticism towards implementing the ECS method. This criticism, directed from the mid-level management group, is primarily resistance against the possible increase of workload for the TPEs. This issue will most likely affect the success of the ECS method.

5

Discussion

This chapter will discuss the methods used for reaching the goals of the thesis as well as discussion of how the results impact the theory. The impact of knowledge reuse on sustainable development is briefly commented on in the end of the chapter.

5.1 Reflection on Applied Research Methods

In order to generate a good result for the thesis, there was a need for selecting appropriate methods to address the research topic in the best possible way. Blessing and Chakrabarti (2009) provide a range of selectable options within the DRM framework.

If interviews with renowned experts were possible, the understanding of the research area could have been both deeper and wider. However, the accessibility to appropriate information meant that a literature study was more preferred than interviewing primary sources when creating a theoretical framework. The large amount of available research concerning knowledge management and product and process development was an obvious source of information. In this sense, the literature study was a great choice for enable the creation of a theoretical framework, which is the recommended method by Blessing and Chakrabarti (2009). In turn, the theoretical framework provided a good foundation for creating the final ECS. It resulted in an understanding of what knowledge that is the most appropriate to reuse. By adapting the theory of actionable knowledge to the interview results, a good ECS could be generated.

It was important to know the TPEs' work tasks for analysing the TPEs' knowledge. The structured topics gave the possibility to easier analyse and compare the answers. The follow-up questions were open-ended, allowing exploration of the interviewees' engineering work tasks. The small amount of TPEs available made it suitable to choose a qualitative research in order to generate as much information as possible from each practitioner of the TPE role.

For obtaining detailed information concerning the TPEs' work, it was advantageous to perform interviews, since it provided open answers and allowed for getting more technically detailed information. In this sense, surveys or questionnaires do not provide a desired result since such methods cannot guarantee the level of detail (Blessing and Chakrabarti, 2009).

In general, the qualitative approach is suitable due to the thesis goals of investigating the case company's current situation concerning knowledge reuse and for gathering detailed information when testing with the ECS method. There was a positive interface between the literature study and the interviews because the analysis was dependent of the scientific research provided by the literature and the empirical information collected from the interviews.

5.2 Reflection on Results

Knowledge can be seen as both explicit and tacit, as illustrated in figure 3.1, but in its codified form it appears as explicit (McMahon et al., 2007; Wong and Radcliffe, 2000). This phenomena requires the tacit knowledge to become explicit through an externalization process (Nonaka et al., 2000). Regardless of how much knowledge is externalized of any specific knowledge piece, it is considered as a success, even if it is a small piece of explicit knowledge that is codified.

From the start of the thesis, it was expressed by the case company that it was desired from other roles in the organization to reuse knowledge. The possibility to reuse knowledge effectively was investigated for the TPE role. The predefined ECS method has already been proven effective and appreciated for another role, the design engineer, even if it is still used on a voluntary basis. The analysis generated in detailed checks of specific knowledge, based in the interviews with the TPEs. Commonly for all these checks in the ECS are that the issues can be encompassed by these concepts:

- Platform-based products
- Design for manufacturing and assembly
- Cross-functional integration

The TPEs work in cross-functional teams where one of their main tasks is to apply DFMA on platform based products. These areas are commonly known in management of product and production development. The theory of platform based products emphasises the importance of knowledge reuse due to the already existing reuse of product design. Platform based products enable companies to focus their resources to product families (Ulrich and Eppinger, 2011). This focus leads the TPEs to work with similar products and processes over time. By reusing knowledge in an effective way, this would be beneficial compared to working with product and process designs that are rapidly changing. From the TPE role description, it is clear that as the intermediary between product and production, that the TPEs work with DFMA. It is also apparent that TPEs need to have good communication with both designers and process engineers in cross-functional integrated teams. There are more areas of interest for TPEs, however these three areas are primarily important. Since knowledge reuse is important for realizing platform based products and DFMA, it is also important for TPEs. This notion is strengthened by the interview results.

The TPEs use a lot of face-to-face communication, which relates to the theory of personalization. As Webber (1993) states, conversations are the most important form of work. Knowledge is dispersed among informal social groups at the case company. Although it is positive that the knowledge is shared, it is not a systematic process. Therefore, there is a risk of losing knowledge due to lack of codification, which also makes the knowledge difficult to trace. Currently, there is an overbalance towards personalization at the case company. The current codification situation relies on producing documentation of lessons learned, which focuses on storing knowledge for reuse. However, documentation of lessons learned usually is descriptive of what have been learned, rather than prescriptive of actions should be made in the future. Therefore, it is desired to improve and extend the codification processes of knowledge reuse, so that important knowledge can be stored in a way that encourages knowledge reuse at the case company. McMahon et al. (2007) describe the importance of using both personalization and codification strategies in order to receive a good result. The face-to-face communication is still important in the work for TPEs, but as shown in the result chapter, sections 4.2 and 4.3, the knowledge explained in the specific pieces are a lot harder to grasp than the actionable knowledge in the ECS, described in figures 4.1, 4.2 and 4.3.

The theory proposes that knowledge needs to be actionable in order to be reused effectively. The actionable knowledge was defined by Cross and Sproull (2004) as knowledge that leads to immediate progress. The predefined criteria of actionable knowledge as both relevant and easy-to-use for the intended user are the two ingredients for achieving the immediate progress as suggested by Cross and Sproull (2004). Markus (2001) states that it is important to clearly define both who the knowledge comes from and to whom the knowledge is intended for. In this thesis, both the source of knowledge and the intended user are TPEs. The investigation has shown that this actionable knowledge, which has been formulated by the ECS method, have some common characteristics:

- It is general enough to be of use for the intended user
- It is concrete enough to be easily applied
- It is codified explicit knowledge
- It is focused on producing and supporting future action

The importance of supporting future action should be emphasized. The prescriptive knowledge that recommends future action, rather than describing past events, is especially important for the intended user in a knowledge reuse process (Argyris, 2003).

On a short term basis, other simpler methods may be sufficient to remember knowledge, e.g. post it notes on the desk. However, the ECS method aims to provide benefits on a long term basis and help the organization to increase their knowledge reuse in an organizational learning context.

The validation interviews' positive response to the ECS method strengthen the predefined assumption that it is possible to apply the ECS method for TPEs. The criticism from the interviewees against the ECS method is a greater workload for TPEs. On a short term, the fear of increased workload for individual TPEs is probably justified. However, on a longer perspective, the ECS method has potential to decrease the overall workload for the users of ECS. The more engineers participate in knowledge reuse activities, the more time can potentially be saved. The ECS method is a concept that facilitates knowledge reuse. Implementing the ECS method for TPEs has the potential to generate positive outcomes. These positive outcomes of implementation are:

- Not reinvent the wheel
- More effective processes
- Simplify work for new TPEs
- Save information within the organization
- Information is presented in a prescriptive manner
- Flexible system, where more checks can be added

Even though the validation interviews strengthen evidence that the ECS method is a good approach for reusing knowledge, it is not enough to determine if the ECS method is suitable on a long term basis. Theory support actionable knowledge as suitable for reusing knowledge, which this thesis also do. However, there is a lack of empirical data on the long term use of actionable knowledge. To properly assess the value of actionable knowledge and the ECS method, an actual long-term implementation and evaluation is necessary, which is explained by Blessing and Chakrabarti (2009) as the DS-II stage in the DRM framework.

Concerning the categorization of the ECS into Know-What, Know-Why and Know-How: Can it be improved? In the framework of Fu et al. (2006), there is a fourth category Know-Who. It can be worthwhile to consider adding Know-Who to the ECS. By adding Know-Who to the ECS, there is a possibility to complement and clarify the other categories in the ECS. When the interviewees were first shown the completed ECS, most of the TPEs knew from which of their colleagues almost all of the knowledge originated from. This recognition of specific knowledge is evidence for that face-to-face communication is usual at the case company among TPEs. A benefit is that the TPE are advised to discuss certain matters with other roles. A risk is that a Know-Who category will recommend you to consult the same people on all checks, which renders the category redundant.

5.3 Sustainable Development

In general, reusing knowledge avoids doing the same mistakes again. By reusing knowledge early in projects one can avoid late changes. This is a great benefit financially due to that changes in project is more costly, later in the process. Socially, the TPEs' work of searching for knowledge in projects can be facilitated. This might ease the stress that occur in tight schedules which over long time will generate in more satisfied people at work. Also, reusing knowledge help engineers to apply earlier developed technologies that are environmentally sustainable.

6
Conclusion

The research of this thesis has investigated if it is possible to capture knowledge from TPEs and apply it with the ECS method. The ECS method has earlier supported designers' work in projects. The expansion of the ECS method meant to explore if it is also possible to support TPEs' work in processes.

The case company sees advantages of knowledge reuse. Applying the ECS method for TPEs helps the case company to reuse knowledge. The results of this thesis show that it is possible to extend the use of the ECS method to the TPEs. Thereby, it can be concluded that the ECS method can capture knowledge in projects as well as in processes. The results confirm that the ECS method is a good framework for reusing knowledge and that it is actionable knowledge that can improve the reuse of knowledge.

The formulated theoretical framework aimed to formulate a clear view of what knowledge that is appropriate to reuse. By combining the concept of knowledge in knowledge management with the context of product and production development, it was possible to generate the desired results of this thesis. Therefore, this framework can be seen as relevant for future research relating to knowledge management in product and production development.

The thesis' purpose was not to implement the ECS method, but rather investigate the appropriateness of the ECS method to capture actionable knowledge for TPEs. The appropriateness of the ECS method is the foundation for future implementation. Future work in this area would be to continue where this thesis ends and focus on the implementation of the ECS method for the TPEs. Challenges that need to be addressed when continuing with future work are:

- To find an appropriate system for handling the ECS method
- To investigate if the use of the ECS method can be extended further

Concluding remarks, to reuse knowledge effectively, codified knowledge needs to be actionable for the intended future user.

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