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Learning from engineering changes - operationalizing knowledge management at GKN Aerospace

Master's thesis in Quality and Operations Management

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Nina Axelsson and Nils Svensson

Gothenburg, January 2018

Abstract

This master's thesis has investigated how the engineering change and product development processes can be utilized in order to increase learning between both the manufacturing and product development departments as well as between projects. GKN Aerospace Sweden has experienced insufficient learning between manufacturing and product development, which contributes to issues in its robustness and manufacturability of products. This partly takes its form in a large amount of engineering changes. The engineering changes do, however, provide a channel for feedback from manufacturing to product development, that could be utilized to improve inter-project and inter-functional learning. A knowledge management framework has been developed based on a literature review, that highlights important factors to take into account when developing knowledge management initiatives. Based on the framework, interviews and a focus group, a process model has been developed that utilizes the engineering change and product development processes in order to operationalize learning at GKN Aerospace Sweden. The knowledge management framework and the process model can work as enablers for knowledge management and lessons learned at GKN Aerospace Sweden, which through an increased learning can increase its robustness and manufacturability. The process model could in the long term be applied to several similar processes, enabling even further knowledge transfer. As future work, the organization should conduct a quantitative, longitudinal study that measures and investigates the outcome of working more consciously with knowledge management and lessons learned. Furthermore, the organization should investigate how its knowledge management system can be optimized to increase user friendliness and searchability.

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List of Abbreviations

BP .... Best Practice

CAB .... Corrective Action Board

CCB .... Change Control Board

CoE .... Center of Excellence

CN .... Change Notice

CP .... Change Proposal

DP .... Design Practice

EC .... Engineering Change

ECO .... Engineering Change Order

EP .... Engineering Practice

GKN .... GKN (Guest, Keen and Nettlefolds) Aerospace, Sweden

KM .... Knowledge Management

KT .... Knowledge Transfer

LL .... Lesson learned (singular). (Plural: lessons learned - LLs)

NPD .... New Product Development

OMS .... Operations Management System

PD .... Product Development

List of Titles

CEd .... Chief Engineer Deployed

CE .... Configuration Engineer

CM .... Configuration Manager

CME .... Chief Manufacturing Engineer

CVE .... Compliance Verification Engineer

EiC .... Engineer in Charge

EMS .... Engineering Method Specialist

NPI .... New Production Introduction Engineer

PL .... Process Lead

PM .... Program Manager

PME .... Product Manufacturing Engineer

SCM .... Supply Chain Manager

SQE .... Supplier Quality Assurance Engineer

1 Introduction

The ability to effectively create, transfer and use knowledge is crucial for product development (PD) organizations. It is necessary not only within product development projects, but also between projects so as to avoid spending time and resources on repeatedly developing similar solutions from scratch or, worse, repeating mistakes. Knowledge reuse and learning can be difficult to achieve due to a number of factors, one of which is the inherent intangibility of certain forms of knowledge. This thesis investigates how knowledge can be managed and learning increased between organizational functions and projects, as well as potential obstacles and facilitating factors to these processes. The findings were applied to a department representing a product area at GKN Aerospace Sweden, where the engineering change (EC) process was identified as a process where increased learning could lead to fewer mistakes being made in future development projects.

This chapter provides an introduction to the study, including a background to the issue being studied, an introduction to the concept of knowledge and its complexity, as well as the purpose, research questions and delimitations of the study.

1.1 Background

The goal of a PD organization is to develop products that, when sold to the market, can reap a profit for the organization. Since PD oftentimes is knowledge intensive, this requires the capture, transfer and reuse of knowledge (Lindlöf, 2014). Knowledge is created by different individuals and in different areas within an organization. For the knowledge to be reused it needs to be transferred from its place of origin to the intended place of use. Knowledge is an asset, and companies that successfully leverage their knowledge can create a competitive advantage, especially in industries that are knowledge intensive (Wellman, 2007; Argote and Ingram, 2000). The aerospace industry is characterized by its high technology level, its inherent technological complexity, the long break even periods, small markets, and an interdependence between defense and civil markets (Reis, 2011). When technologies are changing quickly and markets become more globalized, companies must take care of their learnings before others do (Wellman, 2007). Effectively managing learning can also breed a sense of optimism in organizations. Knowledge transfer (KT) does not, however, automatically take place (Argote and Miron-Spektor, 2011) and the extent of KT varies greatly among organizations (Szulanski, 1996). Knowledge is often complex, tacit, causally ambiguous and ingrained in the company's operations, which makes it difficult for companies to manage (Uygur, 2013). Many companies have issues managing their knowledge and their lessons learned (LLs). In some cases, systems are set up that have too big a focus on explicit KT and thus loses contact in tacit KT (Wellman, 2007).

GKN Aerospace Sweden has experienced an issue with recurring deviations in its production. In order to reduce the number of deviations in future products, GKN Aerospace Sweden wants to take better care of its LLs. The manufacturing organization possesses a lot of knowledge that is not transferred to the PD organization and the company wants to better utilize how they transfer knowledge between one and the other. GKN is a global engineering business, consisting of GKN Aerospace, GKN Driveline, GKN Powder Metallurgy, GKN Additive and a number of smaller divisions, such as off-highway wheels and drivelines as well as freight services. The company in question in this thesis, GKN Aerospace Sweden (from hereon referred to as *GKN*), is a tier one supplier in the aerospace industry, developing and manufacturing components to aerospace engines in civil airliners, military aircrafts and space propulsion. GKN manufactures components developed in-house, where GKN has the responsibility for the design, as well as components developed by its customers. GKN has to comply with extremely high quality demands and ensure that none of the products they deliver to their customers have any defects. If any defects are detected in the rigorous quality controls, the parts in question have to be reworked until they meet requirements. GKN's products are highly customized and as such they are designed uniquely for each customer. This leads to high demands on the manufacturing department to develop processes that can manufacture the products being constructed by the design department. In some cases, this proves difficult to do.

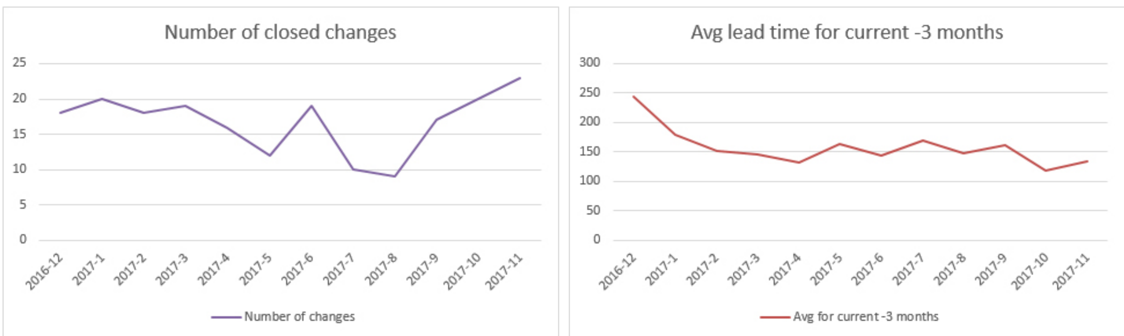

Figure 1.1: Number of closed ECs and average lead times of ECs, Dec. 2016 - Nov. 2017. Based on internal GKN data.

Today, GKN carry out a large amount of ECs (see Figure 1.1). Between December

2016 and November 2017 the company closed 187 (average 15.6 per month) ECs with an average lead time of 170 days. This thesis is interested in how increased knowledge reuse can affect the manufacturability and robustness of products, by increasing the learning from ECs. GKN is experiencing insufficient manufacturability in its products, and wants to improve its abilities to transfer knowledge from production to product development. The company currently attempts to increase its robustness and manufacturability by involving manufacturing personnel in PD, but the vast amount of ECs are indicating that this is insufficient. By increasing the knowledge reuse, the organization is hoping to be able to learn which factors need to be considered in upcoming models to increase the manufacturability of its products. In order to achieve this, GKN wants to improve the way knowledge and LLs are managed and spread out to the organization through the EC processes.

1.2 Knowledge

Knowledge is a complex concept with various dimensions that need to be defined in order to approach knowledge management (KM) issues in an effective way. Knowledge can be both tacit and explicit; it can reside within individuals, groups, documents, processes, policies, physical settings, or digital repositories; and it can refer to an object, cognitive state, or capability (Alavi and Leidner, 2001). KT is a phenomenon that can occur at any point in time between any of the members of an organization, which makes the process a dynamic and continuous phenomenon. These elements of KM show the complexity of the subject, and points to the importance of adapting models to the reality of the specific organization studied.

1.2.1 Tacit and explicit knowledge

When disseminating KM, one must first understand that knowledge is not as straightforward as one can think. As (Polanyi, 1967, p.4) put it when he divided knowledge into explicit and tacit knowledge, "*we know more than we know*". The explicit part of our knowledge is what we can express and put into words. It is knowledge that can be verbalized and stored. However, tacit knowledge is harder to grasp. It is the knowledge we possess, but cannot express. Polanyi (1967) uses the example of faces: we can recognize a person's face amongst millions of faces, but we have trouble articulating exactly how a person looks. The same thing goes for when we recognize a mood in a person's facial expression. We can only vaguely explain why an angry facial expression shows anger. It thus makes it hard or even impossible for us to store tacit knowledge. In a technical setting, tacit knowledge can exist of concrete know-how, crafts, rules of thumb, hands-on experience, and skills (Nonaka, 1994).

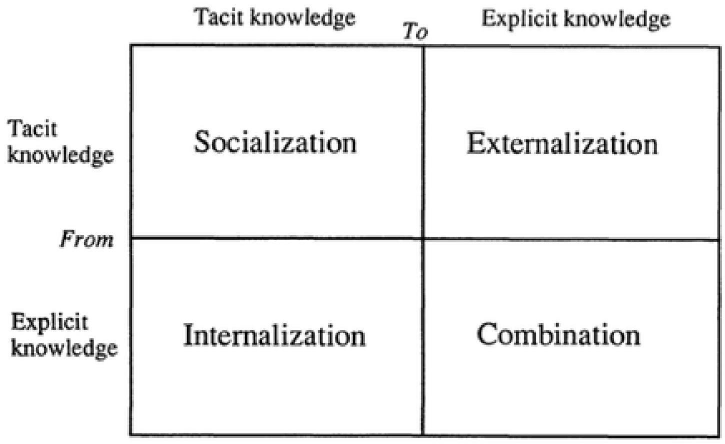

Figure 1.2: The four conversion mode in which knowledge can be transferred or created (Nonaka, 1994, p. 19).

1.2.2 Knowledge creation and the SECI-model

Japanese companies are renowned for their PD and ability to quickly produce innovative new products. Nonaka (1991; 1994) has studied what made Japanese companies so successful in their innovative PD. He studied how the companies work with KM in order to appropriate from the tacit knowledge that resides in the individuals in the organization.

Nonaka (1994) developed the *Dynamic Theory of Knowledge Creation*, commonly referred to as the *SECI-model*, which is a model that explains how knowledge can be created and transferred from different states as well as between individuals and groups. It assumes that knowledge is created by conversion between tacit and explicit knowledge. The conversion between tacit and explicit knowledge is divided into four conversion modes: socialization, combination, internalization and externalization. Figure 1.2 depicts the relationships between the four modes and how they transfer tacit and explicit knowledge. Knowledge creation always starts with the individual and then spreads through groups (Nonaka, 1991). Socialization and combination usually create knowledge more on an individual basis, and externalization and internalization creates knowledge in groups, even though the knowledge of course has to be created in individuals before it can spread.

In *socialization*, the knowledge converts from tacit to tacit, which means that a person learns something by being shown how to do it (learning by observing, imitating, or practicing, e.g. on the job training). In the second mode, *combination*, the conversion goes from explicit to explicit knowledge (Nonaka, 1991). Putting existing information into new contexts or reconfiguring it by sorting, adding and categorizing it are examples of how combination can create new knowledge. Simply put, new knowledge is created by combining previous knowledge. A typical example of combination is a financial controller, who collects information from different parts of the organization and combines it to a financial report (Nonaka, 1991).

Externalization occurs when tacit knowledge is converted into explicit knowledge (Nonaka, 1991). It is when a person manages to explain how something is done, she previously could not explain; when you can put words to something you previously just knew tacitly. An example is when a chef understands exactly how long to cook a dish, if he previously just did it on default for an approximate amount of time. *Internalization* occurs when explicit knowledge converts to tacit knowledge, e.g. when a person learns how to perform an operation by reading an instruction. Knowledge spreads when people begin to add to their own tacit knowledge by picking up information and knowledge that has been externalized by others. Nonaka (1991) points out that a PD organization should have a redundancy in how they work. Functions and activities should overlap in order to stimulate externalization of knowledge. Cross-functional teams is thus an important factor in externalization and internalization of knowledge.

1.3 Purpose

The purpose of this master's thesis is to study how knowledge reuse can be increased in a manufacturing organization in the aerospace industry by taking better care of LLs, with the goal of increasing robustness and manufacturability. The research has focused on how the EC process can be used as a forum for cross-functional knowledge transfer and as a means to improve knowledge reuse.

1.4 Research questions

Managing an organization's knowledge and taking care of the lessons it learns along the way of a development project is an important part of a knowledge intensive organization. It prevents the organization from repeating past mistakes or putting effort into developing similar solutions multiple times. Effective knowledge management could also provide a competitive advantage, while neglecting it risks being surpassed by competitors that manage their knowledge more effectively.

So what is keeping organizations from learning? Why do so many companies seem to struggle and experience issues with their knowledge management? Many researchers have studied knowledge and learning, identifying certain inherent difficulties in managing them. These range from the complexity and intangibility of the knowledge itself to psychological tendencies of the individuals involved (Szulanski, 1996). So what determines the likelihood of a KM effort being successful? What are the aspects that need to be taken into consideration when managing knowledge and lessons learned to increase that likelihood? Many researchers in the fields of knowledge management, knowledge transfer and lessons learned have studied the issue, providing different answers. The first research question aims to investigate what a framework might look like that successfully manages manufacturing knowledge to enable a designer in a downstream development project to efficiently and effectively reuse it.

- RQ 1: *How can a framework that facilitates learning between manufacturing and product development be designed?*

The aerospace industry is characterized by long product life-cycles, complex products and high requirements from both customers and authorities. This means highly customized products whose development can occur decades apart, making it more difficult to ensure that learning takes place between projects. It also means that lessons about a product can be learned in manufacturing years after the original development team has been disbanded and its members have moved on to new projects, possibly to new jobs. This further complicates the task of ensuring that knowledge created in manufacturing is transferred to the design department and taken into account in future development projects. The EC process was identified as a natural forum for feedback from manufacturing to PD on how manufacturable a product turned out to be. The second research question thus investigates how the framework developed in RQ1 can be applied to the PD and EC processes of the aerospace industry to capture and transfer the knowledge created in ECs so as to facilitate its use in subsequent PD projects.

- RQ 2: *How can the developed framework be applied to facilitate learning in engineering change and product development processes in the aerospace industry?*

1.5 Delimitations

Much of the literature on KM focuses on knowledge created in PD and how this can be reused in following PD projects. This study focuses on the manufacturing stages of the product life cycle and how knowledge created in manufacturing can be communicated back to the product development teams in order for them to take this into account in subsequent development projects.

Furthermore, this study is focused on ECs. The EC process has been identified as a natural channel for communication and KT and the study is thus focused on how the preexisting EC process can be developed in order to better facilitate learning from performed changes. Although it is recognized that ECs at GKN can be initiated by personnel from PD, manufacturing and suppliers, as well as by customers, the main focus of this study is on KT and learning between manufacturing and PD.

The study is also delimited to knowledge that resides within the firm, and outside knowledge, such as knowledge from other firms' intellectual property, consultants and experts, will thus not be taken into consideration.

1.6 Report outline

This chapter introduced the reader to the study, providing a background to the study, as well as its purpose, research questions and delimitations. In the next chapter, the strategy and methods used when conducting the study will be described. This is followed by a chapter presenting an extensive literature review on *knowledge management*, *knowledge transfer*, and *lessons learned*. The literature review culminates in an analysis of the literature and the development of a knowledge management framework, effectively answering the first research question. After the literature chapter, a chapter on GKN and their knowledge management work follows. This is followed by a chapter where the GKN knowledge management work is analyzed using the developed knowledge management framework, and a process model is presented, intended to leverage the strengths and fill in the gaps identified during the analysis, which answers the second research question. Finally, the last chapter consists of conclusions drawn from the study, as well as recommendation for GKN and suggestions of further research in the area of knowledge management and learning.

2
Methodology

In the following section, the methodology used for the master's thesis will be presented and explained. The research took a qualitative approach and mainly included a literature review, interviews and a focus group. Theory was generated from a case studied and the research was thus inductive in its nature. The study was predominantly qualitative in character, but included quantitative elements such as ERP system data analysis.

Based on the methods used, a KM framework and a process model were developed. The KM framework was based on the literature review, while the process model in turn was based on the KM framework, interviews and the focus group (see Figure 2.1).

2.1 Research methodology

This master's thesis followed the qualitative approach outlined by Bryman and Bell (2013) and depicted in Figure 2.2. The researchers have through their findings derived new theory and through an iterative approach and continuous data analysis, tightened and answered the research questions.

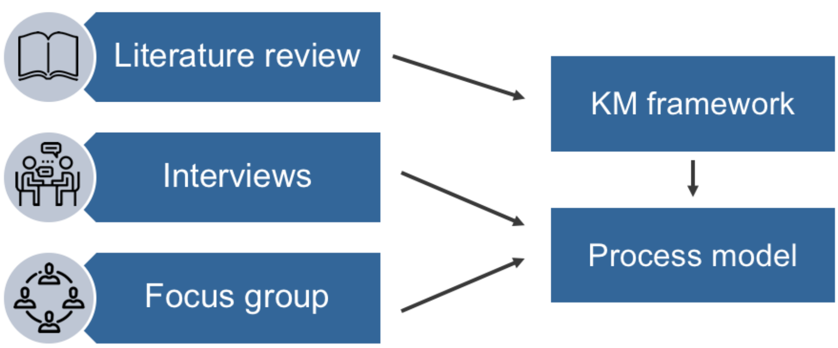

Figure 2.1: The relationship between methods used and the developed KM framework and process model.

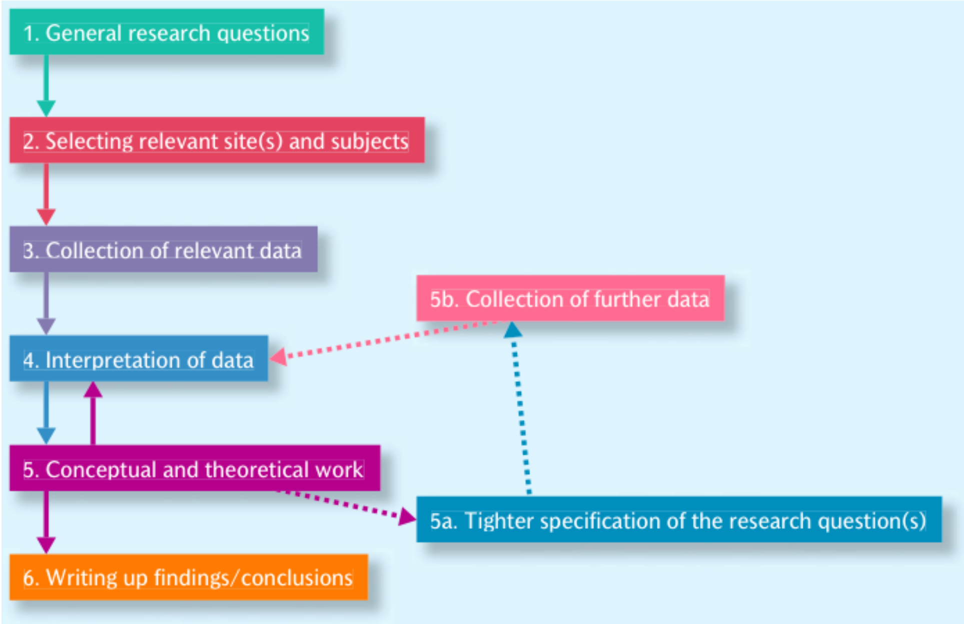

Figure 2.2: Outline of the main steps in qualitative research (Bryman and Bell, 2013, p. 390).

Inductive research is the most common strategy of performing qualitative research and is the approach where observations and findings are the input to the research and theory is the output (Bryman and Bell, 2013). This master's thesis was founded on an extensive literature review, where a framework and implementable process were developed, which could give the impression that the research took a deductive approach. However, since the process and framework was also heavily built upon interviews at the studied organization, the strategy was considered inductive. Bryman and Bell (2013) put forward that deductive elements are commonly used also in inductive research and they further put forward that iterative approaches between data collection and model forming are common, which also was present in this thesis.

The research was based on a case study design, where one single case was deeply analyzed. A case study is concerned with the complexity and particular nature of the case in question (Stake, 1995). A case study can study an organization, a location, a person or a particular event (Bryman and Bell, 2013). The case study for this thesis was performed at the cold structures department at GKN. The thesis partly studied how the organization works with KM in general, but the research also focused more specifically on the engineering change process. The research studied how knowledge was transferred from the EC process to the rest of the organization.

2.2 Literature review

The literature review was used to provide the knowledge base on which the study was conducted, as well as to form the KM framework. It was focused on finding literature relevant for creating an academic knowledge about areas that would enable answering the research questions. The areas were studied in order to acquire a holistic view of the broad and complex subject of KM. The main areas studied in order to form the framework for this thesis were knowledge management, knowledge transfer, lessons learned and engineering change management.

An iterative approach was used in the literature review, where the search for relevant literature was based on previous findings. The researchers based downstream searches on the upstream literature. This way, the researchers could close their knowledge gaps and form an understanding of the relevant areas.

Two databases were used to find literature, where the primary database was the Chalmers library database *Summon*. It was used to find the main part of the literature in physical books, eBooks, dissertations as well as articles published in scientific journals. The secondary database was *Google Scholar*, which was used when relevant literature was not found in Summon. When using keywords in databases, a researcher must think of possible synonyms to keywords as well as different spellings of keywords (Bryman and Bell, 2013). Therefore, keywords such as *knowledge management, knowledge transfer, cross-functional communication, engineering change management, ECM, lessons learned* and *LL* were used to find a wide variety of literature.

2.3 Exploratory and in-depth interviews

An important part of the study's data collection consisted of interviews, which were performed in order to acquire an understanding of the current situation at GKN and how the organization currently works with KM. The interviews along with observations at the organization were important to create an understanding of the problem at hand and the organization's development processes. The interviews were divided into exploratory interviews and in-depth interviews. The exploratory interviews created a base understanding of how the organization operates. They were used to identify weaknesses and strengths in how it works with its KM processes. When such weaknesses and strengths had been identified, in-depth interviews were held in order to in order to create a deeper understanding of the PD and EC processes at GKN, as well as to fill in knowledge gaps about how the developed KM framework could be applied at the company. The results were then used to develop the process model that this thesis resulted in.

The interviews were semi-structured as well as qualitative in their approach and were thus quite flexible in the phrasing of questions, order of questions, follow-up questions, et cetera (Bryman and Bell, 2013). The context in which people work and operate is often important in qualitative research (Bryman and Bell, 2013). One of the biggest reasons for studying the context of processes is often that it is by mapping the context of a process that the organizational behaviors can be understood. The questions were thus altered depending on in which function and context the interviewees worked in order to acquire an understanding of their context and how it affected their individual perceptions of the situation. Interviewing takes time, and to avoid over-extending the ambitions of the project, the authors' set an internal cap of maximum 15 interviews. In total, 14 interviews and a focus group (see Section 2.4) were conducted.

Prior to the interviews, the researchers formulated questions that took the context of the interviewee in mind. Examples of interview templates for the exploratory and in-depth interviews can be found in Appendix A and B, respectively. The purpose of the interviews was to form an understanding of the current situation and how it could be improved, and thus, the context of the interviewee was important to capture. The interviews were conducted by both authors. One of the researchers took a lead role and asked the main part of the questions and the other researcher took a supportive role and was responsible for taking notes and making sure that audio was recorded. The supportive researcher only asked follow-up questions that the lead researcher did not think of. After the interview, the notes from the interview were digitalized and extended. The notes were then sent to the interviewees for respondent validation, as well as to let them strike parts of their answers or add something that the researchers did not capture. Transcription was perceived as too time consuming and was thus not performed.

2.3.1 Mapping of interviewees

The initial step of conducting interviews was to map candidates suitable for interviewing. Along with the company supervisor, initial key personnel and stakeholders to the study were identified and interviewed. Based on the results of the interviews, the authors' knowledge gaps about the processes at GKN were identified and further interviews were scheduled in order to fill the gaps. The process is depicted in Figure 2.3.

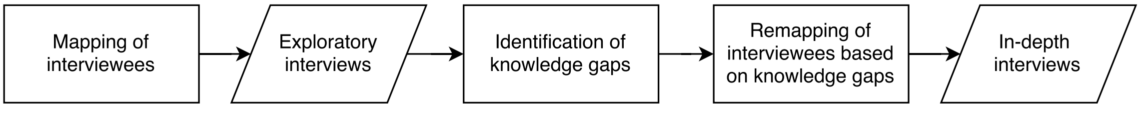

Figure 2.3: Outline of the interview process, parallelograms depicts actual interviews and rectangles depicts preparatory work leading up to interviews.

The positions and persons interviewed are shown in Table 2.1. The positions interviewed were Chief Engineer Deployed, Chief Manufacturing Engineer, Configu-

Table 2.1: Interviewee positions, number of exploratory and in-depth interviews, and focus group attendence.

No.	**Position**	**No. of exploratory interviews**	**No. of in-depth interviews**	**Attendence at focus group**
1	Chief Engineer Deployed	1	0	No
2	Chief Manufacturing Engineer	1	0	No
3	Configuration Engineer	0	1	No
4	Configuration Manager	0	2	Yes
5	Design for Robustness Specialist	0	0	Yes
6	Engineer in Charge	1	1	Yes
7	Engineering Methods Specialist	0	1	No
8	New Production Introduction Engineer	0	1	No
9	Process Lead	0	1	No
10	Product Manufacturing Engineer	1	0	Yes
11	Program Manager	1	0	No
12	Robust Design Engineer	0	0	Yes
13	Supplier Quality Assurance Engineer	1	0	Yes
14	Supply Chain Manager	1	0	No

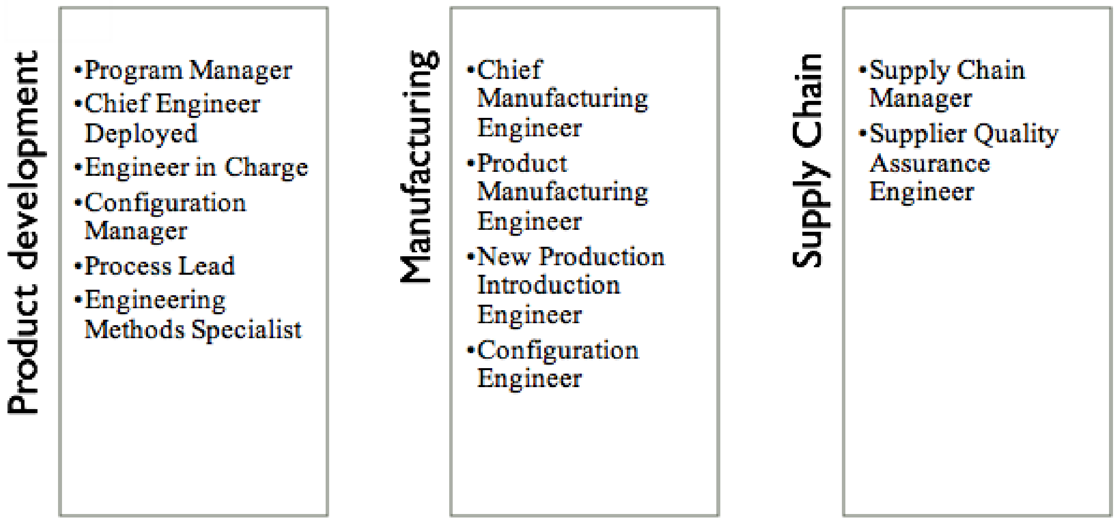

Figure 2.4: The functional division of the interviewees.

ration Engineer, Configuration Manager, Engineer in Charge, Engineering Method Specialist, New Production Introduction Engineer, Process Lead, Product Manufacturing Engineer, Program Manager, Supplier Quality Assurance Engineer, and Supply Chain Manager. The functional division of the interviewees is depicted in Figure 2.4.

2.4 Focus group

As a final step to validate the developed process model, a focus group was held with several of the previously interviewed staff, as well as the company supervisor and a Robust Design Engineer. The focus group was held after the proposed process model had been developed, with the main goal of letting the participants discuss the process model as a whole, identifying necessary prerequisites for and possible obstacles to implementation, and of getting a better detailed understanding of which inputs and outputs are necessary to each process step. It was the dynamics of the discussion and the possibility to acquire new insights that was of primary interest. No changes were made to the process after the focus group, but several helpful insights were gained.

The focus group was held in a cross-functional setting, with representatives of production, product development, product supply and configuration management, making up six persons in total. The focus group was audio recorded and notes were kept.

2.5 Ethics

To ensure that research is performed in an ethical fashion, Bryman and Bell (2013) put forward four ethical principles that should be taken into consideration when conducting research: lack of informed consent, harm to participants, invasion of privacy, and deception. Together with conforming to legal practices, transparency in the four main areas let the respondents know what they participated in. By ensuring that the participants understood the research and its process, what their participation entailed as well as how the results were to be used, the information they provided was usable and just.

In this thesis, where the main data collection was conducted through interviews, it became crucial to ensure that the ethical principles were met during the interviews. To ensure that the participants were informed, the purpose of and background to the research was explained. They were informed on that results would be used in both the current state analysis as well as the forming of the process model. The participants were also asked if they allowed to be audio recorded and after the interview, they were sent the notes to allow them to strike sections or clarify the meaning of their answers. Furthermore, the participants were given the option to stay anonymous or refrain from answering any question for any reason.

3

Literature review and knowledge management framework

This chapter first briefly introduces the concept engineering changes. This is followed by an extensive literature review of the areas of knowledge management, knowledge transfer and lessons learned. The literature is analyzed, identifying patterns, and resulting in a framework for knowledge management and learning.

3.1 Engineering changes

Engineering changes are defined as *"...a modification to a component of a product, after that product has entered production"* (Wright, 1997, p.33) with regards to forms, fits, materials, dimensions, functions, etc. (Huang and Mak, 1999). Engineering Change Management (ECM) is an important factor of the success of NPD projects (Li and Moon, 2012). It can solve critical functionality problems of a product and it also reflects the customers' requirements as well as technology developments. Furthermore, ECM can be a forum for actively managing knowledge that in the end results in avoidance of manufacturing problems (Saeed et al., 1993). It can thus increase the manufacturability of products.

How an organization works with ECM, and more importantly, how it works to avoid late ECs, can significantly affect the time to market as well as the accumulated learning of a PD project (Sullivan, 1986). As depicted in Figure 3.1, Japanese companies have had a much faster clearance of ECs compared to U.S. companies, which partly is related to how they work proactively with product development methods to, at an early stage, identify what the customers need.

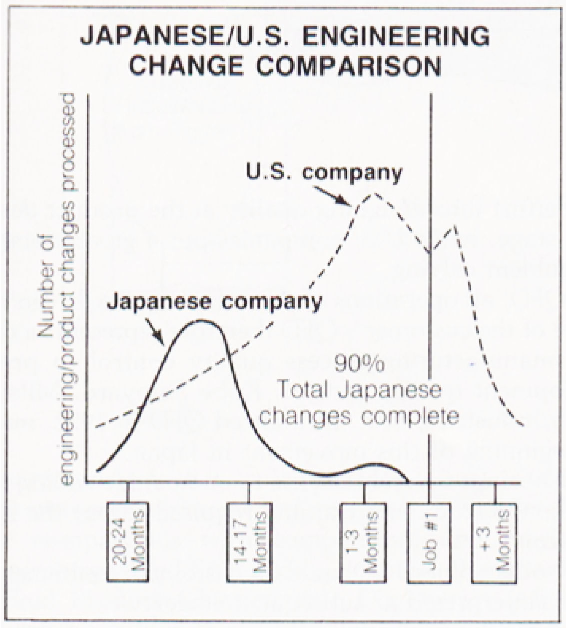

Figure 3.1: Comparison of Japanese and U.S. ECs (Sullivan, 1986, p. 39)

3.2 Knowledge management

The goal of a product development organization is to develop products that, when sold to the market, can reap a profit for the organization. Since product development oftentimes is knowledge intensive, the organization must create knowledge about the product and the market through knowledge capture, transfer and use, in order to create a profit (Lindlöf, 2014). Knowledge management involves managing those activities in a cost-effective way to increase organizational performance and competitive advantage (Becerra-Fernandez and Leidner, 2008).

3.2.1 Probst's practical framework for knowledge management

Along with executives from a range of companies, Probst (1998) has developed a practical model for managing organizational knowledge. The purpose of the model is to take a fuzzy subject and make it practical and usable. The model builds on six aspects with the purpose to make the model work in practice: *compatibility*, meaning that KM initiatives need to fit well with current practices, such as Lean, Total Quality Management, Six Sigma, et cetera, as well as a shared language regarding knowledge; *problem orientation*, meaning that KM must focus on problem solving and test ideas in practice, highlighting that KM initiatives must not stay theoretical; *comprehensibility*, meaning that KM must be built upon terms and ideas that are already used and understood in the organization; *action orientation*, meaning

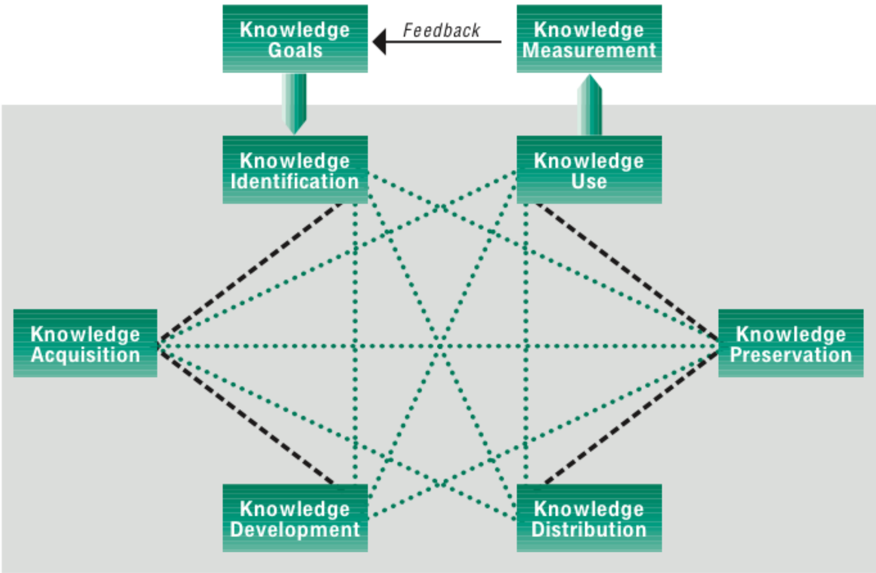

Figure 3.2: Probst's practical model for knowledge management (Probst, 1998, p. 19).

that analyses of an organization's KM should enable managers to evaluate their instruments and inspire to act to improve the KM; and, *appropriate instruments*, emphasizing that the company should be given a number of instruments that are suitable for the organization. However, skillful use of the instruments is more important than the instruments themselves.

The model divides the KM process into eight building blocks (Probst et al., 2000) (depicted in Figure 3.2). The building blocks are: *goal-setting; measurement; identification; acquisition; development; distribution; preservation, and use* of knowledge, which will be explained further below.

Knowledge goals

Companies must set up goals for their KM initiatives in order to point the way for the KM activities (Probst et al., 2000). Defining goals enables companies to steer and direct KM efforts. The goals should be set on three levels; *normative goals*, which are directed at creating good preconditions for KM, such as corporate culture; *strategic goals*, which indicate which core capabilities and knowledge a company must gain to stay competitive; and, *operational goals*, which turns the normative and strategic goal into action, such as the goal that everybody should have access to all documents in the firm or that the employees should possess a certain language skill level.

Knowledge measurement

Theres an old management saying that *"if you can't measure it, you can't manage it"*, which also is true for KM. Knowledge is however difficult to evaluate, but methods must be found to adequately measure the KM progress. The method of measurement must reflect the normative, strategic and operational goals of the company (Probst et al., 2000). The measurements must then also be made visual in order to enable interpretation in relation to the knowledge goals. Goals must thus be measurable and can be both quantitative, such as turnover, return on investments and profit margin; or qualitative such as brand and public image of the company. Purely quantitative measurements are not only unrealistic, but might even be counter-productive. Measuring customer satisfaction, for instance, is qualitative information that can increase the knowledge about customer preferences and give useful data to the design department.

Knowledge identification

Probst et al. (2000) put forward that nobody can know everything — but the employees should know where to find whatever it is that they need. A company must know which knowledge it possesses both internally and externally, and make it available to the people in the organization. Explicit knowledge can be effectively stored in IT systems, but structures must be set in place to allow for tacit knowledge transfer. Several ways of achieving this exist, and creating knowledge maps, expert Yellow Pages and attaching contact information to LL systems are a few of them mentioned by Probst et al. (2000). The latter one makes tacit knowledge transfer possible through allowing downstream projects to find who was responsible for previous projects' learnings (Probst et al., 2000; Bartezzaghi et al., 1997). Information such as current workplace, phone number and email address should be stored to both internal and external people (Disterer, 2002).

Furthermore, coding of knowledge can make LLs and knowledge easier to both store and retrieve (Bartezzaghi et al., 1997; Goffin et al., 2010). LLs could then be coded by factors such as degree of innovation, the project's size, type of relationship to suppliers, and major technologies involved. One flexible way of categorizing knowledge is in platforms and best practices (BPs). The classification should be performed cross-functionally and be as flexible as possible (Bartezzaghi et al., 1997).

Post Project Reviews (PPRs) are effective in transferring knowledge (Bartezzaghi et al., 1997; Goffin et al., 2010). The PPRs should focus on finding cause-and-effect relationships between events in the projects and their outcomes in order to find root causes to problems (Bartezzaghi et al., 1997). However, PPRs lack mechanisms for tacit knowledge transfer. Goffin et al. (2010) mean that socialization is an important mechanism that can be facilitated by cross-functional development and utilizing experienced people as vehicles for knowledge creation.

Knowledge use

The entire purpose of KM is to effectively and efficiently deploy the knowledge captured and gathered. Knowledge is of no value if it is not used and applied. The potential user must thus be taken into consideration when developing KM activities, and it must be made sure that the potential user sees the advantages of adopting the knowledge (Probst et al., 2000). KM information systems and processes must be developed with the user as the top priority and the user needs must be in focus in all stages of the KM process. Often the systems are not practical enough, which leads to unused and forgotten systems.

Knowledge acquisition

It can be difficult for an organization to create all the knowledge it needs in-house, and instead it can acquire it externally (Probst et al., 2000). Knowledge can be acquired from other firms through partnerships and joint ventures; using information from customers and other stakeholders such as suppliers, owners, and public knowledge; from recruiting experts and consultants; as well as knowledge products such as intellectual property, software, licenses, reverse engineering and legal copying of designs.

Knowledge development

Knowledge must be developed on both on an individual as well as a collective level. To develop individual knowledge, creative processes must be allowed, but processes to efficiently take an idea to a product must also be in place (Probst et al., 2000). To create collective knowledge, the staff must be allowed to work in teams and encouraged to externalize their tacit knowledge in order to make it visible and usable for the entire organization.

An organization must understand that knowledge is not only created in the R&D departments, but can be generated from anywhere in the company (Probst et al., 2000). It must thus be open to ideas from all parts of the company. Knowledge is not always developed as a deliberate effort. It can be a by-product of other processes and the daily activities at the organization. Therefore, the company must be aware and open to unintendedly generated ideas. However, an organization should always be aware of its knowledge goals, and try to form the generated knowledge so that it has a good fit with the goals.

Knowledge distribution

When the knowledge is distributed around the company, it must be decided who should know what and to which level of detail. Not everybody should and can know everything. Knowledge distribution should be supported by a suitable infrastructure that allows for the company to efficiently share knowledge (Probst et al., 2000). Knowledge is created on an individual and specialized level, but can be transferred to a systematic level through experienced people and managers (Bartezzaghi et al., 1997). One effective way of distributing knowledge is by using design rules, product platforms and physical models to embody the knowledge and technological experiences from past projects.

Knowledge preservation

Probst et al. (2000) put forward three ways to store knowledge, namely in individuals, in groups, and in computerized databases. When knowledge has been acquired or developed, the company must preserve it. The company must find a suitable storage for the knowledge that makes the information both accessible and easy to save. Of course a company can't store every single report and document written, and a rule of thumb should be to only store documents that can be of value to others (Probst et al., 2000). Connecting back to knowledge identification, organizations must find a balance between which knowledge it should preserve and not. Since knowledge overflow is a common problem, companies must make sure that only that which can create value is saved in databases.

Bartezzaghi et al. (1997) highlight the difficulties in storing knowledge in databases. In a multiple case study that they did, only 10% of the team members actually consulted the reports in the databases when developing new products. The databases usually contain a high amount of unstructured information that rarely allows the engineers to select relevant insights that allow for them to reduce the uncertainty in development (Bartezzaghi et al., 1997). This highlights the importance of combining databases with tacit knowledge transfer through cross-functional communication and socialization.

3.3 Knowledge transfer

NPD usually requires the knowledge of personnel from different areas within the organization. Consequently, cross-functional cooperation has been identified as an important success factor for NPD and management (Pinto and Pinto, 1990) and it is often suggested that all different organizational functions are involved in all phases of development (Wheelwright and Clark, 1992). One aspect of this cooperation is the KT between entities within an organization. In this context, entities include individuals, groups, product lines, departments and divisions. The transfer of knowledge between entities in an organization allows the organization to leverage its knowledge assets, making it a strategically important activity (Zander and Kogut, 1995). Furthermore, successful KT in organizations has been found to increase organizational performance, and can be an important source of competitive advantage (Argote and Ingram, 2000). KT does not, however, automatically take place (Argote and Miron-Spektor, 2011) and the extent of KT varies greatly among organizations (Szulanski, 1996). Adding to the complexity, the most strategically significant knowledge tends to be complex, tacit, causally ambiguous, and ingrained in the operations of the organization (Uygur, 2013). According to Argote and Miron-Spektor (2011), cognitive, social, motivational and emotional factors can be used to predict the success of KT. The success of a transfer can be seen and measured in changes in the recipient's knowledge or performance (Argote and Ingram, 2000).

Knowledge transfer can be defined in different ways. Some make a distinction between knowledge transfer, knowledge translation and knowledge transformation. One example of this is Carlile (2004), who describes knowledge transfer as the movement of knowledge from a sender to a recipient, knowledge translation as the process of ensuring that the transferred knowledge is interpreted as intended, and knowledge transformation as the process where the recipient's pre-existing knowledge is transformed due to the new knowledge acquired, turning the new knowledge into something that is useful to the recipient. Contrarily, Liyanage et al. (2009) describe knowledge transfer as consisting of identifying existing knowledge, acquiring it and then applying it to develop new ideas or improve existing ideas to increase the efficiency and effectiveness of processes or actions. According to them, knowledge transfer is, thus, not only the action of moving the knowledge from one entity to another, but also to convert it into something that is useful to the recipient and applying it. What Carlile (2004) refers to as knowledge transfer, they instead see as a part of knowledge transfer and refer to as knowledge communication. This broader definition of knowledge transfer, encompassing knowledge communication, knowledge translation and knowledge transformation, will be used in this thesis. These three components are introduced below.

3.3.1 Knowledge communication, translation and transformation

Knowledge communication is how personnel from various different organizational functions share information that is vital to the successful implementation of projects (Pinto and Pinto, 1990). The two basic main components of any communication are the source who sends the knowledge and the recipient who acquires the knowledge (Argote and Ingram, 2000). Pinto and Pinto (1990) divide knowledge communication into four categories: internal and external communication, that is, communication within project teams versus communication between the project team and the rest of the organization or external parties, and; formal and informal communication, that is, the approach of the communication. When it comes to approaches, oral communication is considered the main manner in which technical information is acquired and communicated by engineers and scientists in organizations (Harada, 2003).

Knowledge translation is the process of ensuring that communicated knowledge is interpreted and understood as intended (Carlile, 2004). The difference in experience and competence between entities from different areas of an organization leads to them developing their own understanding of the organization (Jelinek and Schoonoven, 1990). Bechky (2003) argues that understanding is situational, cultural and contextual, and that the members of an organization will interpret knowledge within their respective contexts. This means that even if knowledge is communicated, it may not be understood as intended. Knowledge must thus be translated so that it can be understood by other parties in an organization.

Knowledge transformation occurs when the recipient of knowledge realizes how the communicated knowledge fits within their own working context (Bechky, 2003). Even if knowledge is successfully communicated and understood as intended, the recipient needs to understand how that knowledge is useful to them. Liyanage et al. (2009) argue that successful KT can only be achieved if the organization has the ability to absorb knowledge and apply it effectively. According to Carlile (2004), this happens when the existing knowledge of the recipient is transformed due to the new knowledge. The recipient's knowledge is expanded, not only by the addition of new knowledge, but also by the placement of that knowledge in the recipient's context, increasing their understanding of their own work (Bechky, 2003).

3.3.2 Process for knowledge transfer

In this section, the process of KT will be discussed. A six step process introduced by Liyanage et al. (2009) will be used as a base. This process can be seen in Figure 3.3. The process will be expanded based on additional literature on the subject. The six steps of the process are knowledge *awareness*, *acquisition*, *transformation*, *association*, *application* and *externalization*. The knowledge awareness step is the step where the relevant or valuable knowledge is identified. This step is followed by knowledge acquisition, where the recipient captures the identified knowledge. The third and fourth steps of the KT process constitute a conversion of the knowledge into something that the recipient can use to create new knowledge or to improve existing knowledge or capabilities. The first step of the conversion is knowledge transformation. According to Liyanage et al. (2009), this can be done either by adding or deleting knowledge, or by translating the knowledge. What they refer to as *knowledge transformation* is thus the equivalent of what earlier in this chapter was referred to as *knowledge translation*. The step that follows, knowledge association, is when the knowledge is matched with internal needs and capabilities of

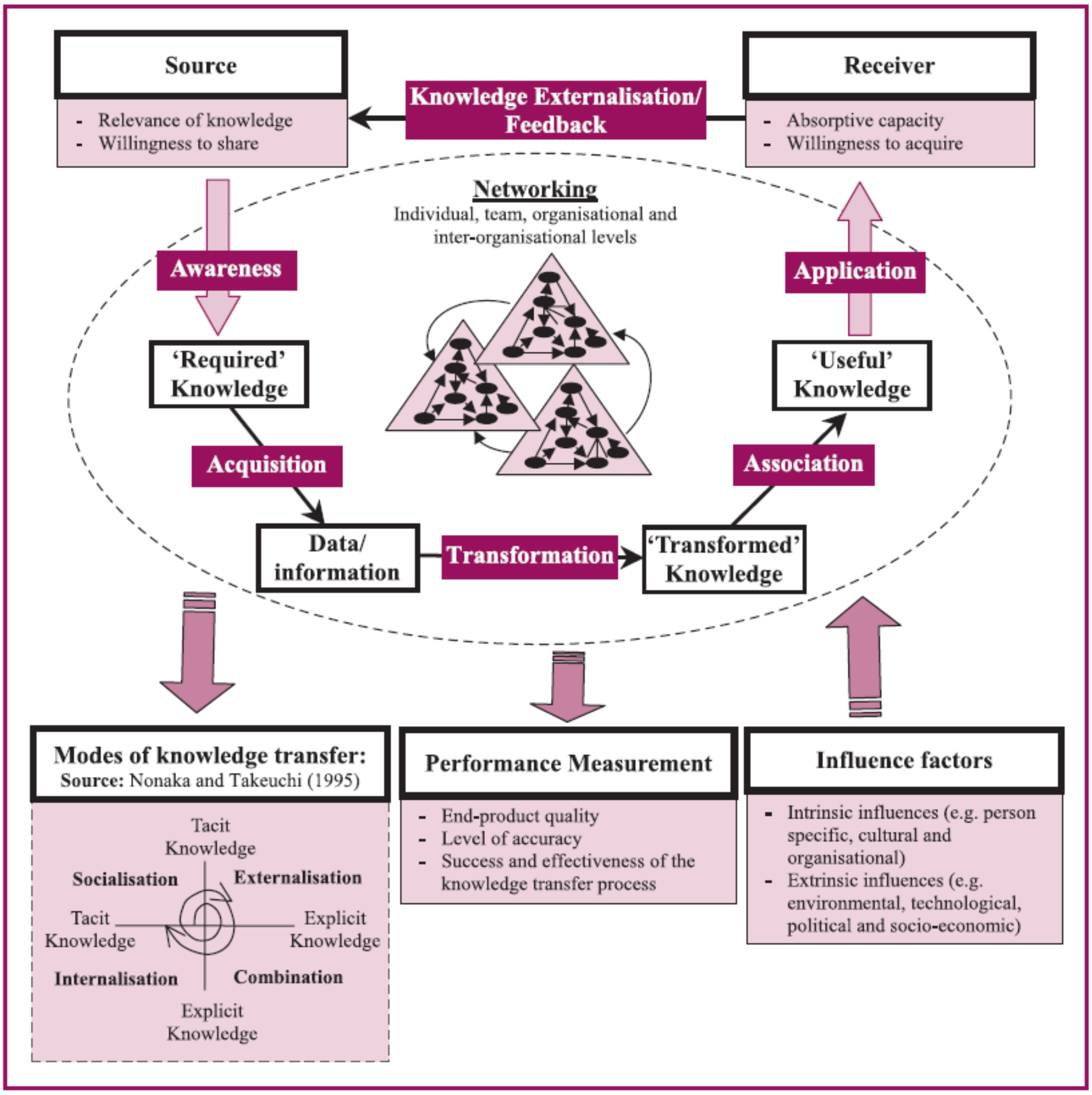

Figure 3.3: Process for knowledge transfer (Liyanage et al., 2009, p. 126).

the organization, and as such is similar to what has previously been referred to as *knowledge transformation*.

The second to last step of the KT process, the knowledge application, has, according to Liyanage et al. (2009), by many researchers been found to be the most important step of a KT process. This is the step where the knowledge is directly applied to a concrete problem. Alavi and Leidner (2001) explain that the reason for this step being so significant is that the knowledge in itself does not create value or improve performance, the application of the knowledge does. Three mechanisms that facilitate knowledge application, identified by Grant (1996), are *rules and directives*, *routines* as well as *group problem solving and decision making*. He describes *rules* as *"standards which regulate interactions between individuals"* (Grant, 1996, p. 114) and states that as such they constitute a low cost way for tacit knowledge to be converted into explicit knowledge. He uses the example of a production facility and a quality engineer. Instead of teaching every production worker everything he or she knows about quality, the quality engineer can put into place certain rules and procedures regarding quality control to ensure quality in the production process. He describes *routines* as having *"the ability to support complex patterns of interactions between individuals in the absence of rules, directives, or even significant verbal communication"* (Grant, 1996, p.115). The third mechanism, the *group problem solving and decision making*, constitutes a contrasting but complementary means of applying knowledge. As opposed to the two previous mechanisms, which were low-cost and low-communication, this one promotes a more personal and communication-intensive approach. Grant (1996) observes that this last mechanism is more commonly used for unusual, complex, and important tasks. According to Liyanage et al. (2009), the process of knowledge application can be improved by rich communication and collaboration.

Finally, the last step of the KT process proposed by Liyanage et al. (2009) is the externalization of knowledge. They describe this as being the process of transferring the experiences or new knowledge created by the recipient to the source of the original knowledge. This can lead to improved collaboration and relations, and adds value to both the source and the recipient (Liyanage et al., 2009).

That concludes the KT process as suggested by Liyanage et al. (2009). Alongside the process, they present four prerequisites for the process to work effectively as well as three additional elements to take into consideration. The four prerequisites of the process are the *location* of the required knowledge, the *willingness to share* knowledge, the *willingness to acquire knowledge* and the *absorptive capacity* of the recipient. The prerequisite of knowing the location of the knowledge refers to the need to know where the required knowledge resides and what the most appropriate source of the knowledge is. It is also necessary for the source of the knowledge to be willing to share it with other members of the organization, as well as for the recipient of the knowledge to be willing to acquire it. The last prerequisite of the KT process is the absorptive capacity of the recipient, meaning the recipient's ability to put the source's knowledge to use.

Lastly, the three additional elements that, according to Liyanage et al. (2009) need to be taken into consideration when performing a KT are *networks*, *performance measurement* as well as *positive and negative factors*. They express networks to be an important facilitator to the close interactions between individuals, teams and organizations needed for effective KT. The element of performance measurement emphasizes the need for evaluating the quality of the knowledge transferred as well as the transfer process. The positive and negative factors are factors that affect the KT process, either positively or negatively. Liyanage et al. (2009) emphasize the importance of identifying these factors and understanding whether and to what extent they affect the process.

3.3.3 Capturing knowledge

Before knowledge can be transferred and reused, it needs to be captured. This means identifying what knowledge has been created that should be learned by the organization. A plan for capturing knowledge from a project should be made during project definition, and project closing seems to be the most important phase of a project for knowledge capture (Disterer, 2002). Collison and Parcell (2004) suggest a ten-step process for sessions aiming to capture knowledge:

1. Call the meeting
2. Invite the right people
3. Appoint a facilitator
4. Revisit the objectives and deliverables of the project
5. Go through the project step-by-step
6. Ask "What went well?"
7. Find out why these aspects went well, and express the learning as advice for the future
8. Ask "What could have gone better?"
9. Ensure that the participants leave the meeting with their feelings acknowledged
10. Record the meeting

The first three steps precede the session. When calling a meeting, Collison and Parcell (2004) recommend a face-to-face meeting, preferably a physical one. They further suggest the meeting be held as soon as possible after the end of the project and that the venue be similar to the working context of the project. This, to stimulate an abundance of accurate memories from the project team members. When choosing who to include in the session, they emphasize the importance of the project leader attending, and suggest that he or she be responsible for scheduling the session. This because the project leader has the most ownership of the project, knows who the key members of the project team were, and may still have a level of influence on team members. If possible, Collison and Parcell (2004) suggest including the project customer in the session, though they caution that it may inhibit some team members. They also advocate inviting members from future project teams that are about to initiate similar projects and that could possibly directly apply some of the learnings. The last thing Collison and Parcell (2004) suggest is done before starting the session is to appoint a facilitator. The facilitator is supposed to be a person that was not directly involved in the project and who does not evaluate the performance of any of the members included in the session. The purpose of the facilitator is to ensure that the focus of the meeting is to determine what a future project team should do under similar circumstances, and that all participants contribute.

Steps four through nine are performed during the session. Collison and Parcell (2004) suggest to start the session by clarifying the original objectives of the project, and then review whether or not they were achieved. Next, they propose going over the project one step at a time, identifying tasks, deliverables and decision points. The purpose of this is to facilitate identifying which parts of the project were delayed or inefficient and which were particularly efficient or completed ahead of schedule. Once this is done, Collison and Parcell (2004) recommend starting on a positive note by identifying the things that went well during the project. They suggest using the technique of asking "*why*" several times until getting to the root cause of each success. The importance of hearing the opinion of the more quiet participants is emphasized, since these opinions are less likely to have been voiced in the group before (Collison and Parcell, 2004). The next step is to translate the identified successes into specific advice for future projects. Collison and Parcell (2004) emphasize that these need to be based on experience, not feelings. The eighth step consists of doing the same thing, but for aspects of the project that did not go as well. The focus should be on identifying mistakes as well as methods to avoid them in the future, not on placing blame (Collison and Parcell, 2004). The last step of the process that takes place during the session involves ensuring that all participants feel that all key issues, positive as well as negative, have been dealt with. One way to do this is to ask each participant to rate the project on a scale from one to ten and then ask what would have made the project a ten for them. According to Collison and Parcell (2004), this can show patterns in rating between different functions and raise issues that did not come up in discussions earlier during the process.

The very last step of the knowledge capture process introduced by Collison and Parcell (2004) is performed after the conclusion of the session. This step involves the recording of the results from the session. It is recommended that the records include guidelines for the future, a background of the project, names and photos of the people involved, as well as key artifacts such as documents and project plans.

Chirumalla (2013) discusses some difficulties in capturing knowledge. One such difficulty is the inadequacy of using text-based approaches for capturing knowledge. According to Chirumalla (2013), these approaches may be appropriate for capturing explicit knowledge, but that they are insufficient when it comes to capturing the tacit knowledge that is normally communicated in informal meetings and spontaneous discussions. He also emphasizes the difficulty of capturing the tacit, skill-oriented knowledge created in downstream phases in a manner that enables its reuse in the design phases of subsequent projects.

3.3.4 Aspects influencing knowledge transfer

As mentioned, KT does not occur automatically, and in a study performed by Galbraith (1990), he found that one in three KT attempts within the organization studied failed. This illustrates the difficulty of KT, leading to the question of what aspects affect the successful outcome of KT, and how. Various influencing aspects have been identified in literature. Szulanski (1996) chose to divide the aspects he had identified into four categories, namely characteristics of the *knowledge transferred*, of the *source*, of the *recipient* and of the *context* where the KT takes place.

Characteristics of knowledge

The aspects relating to characteristics of the knowledge transferred that Szulanski (1996) covers are its causal ambiguity and its provenness. Causal ambiguity refers to a lack of understanding of the connections between actions and their results and affects KT negatively (Uygur, 2013). Uygur (2013) found that this aspect, in turn, is affected by four factors of knowledge: its complexity, tacitness, relevance to the existing knowledge base of the organization, and its locality. The first two were found to be positively related to causal ambiguity, while the latter two were found to have a negative relation to it. Szulanski (1996) adds that another cause for causal ambiguity could be a poor understanding of the context where the knowledge is to be applied. The provenness of knowledge is described as the degree to which the knowledge to be transferred has been proven to be useful in the past, where more well-proven knowledge is more easily transferred (Szulanski, 1996).

Characteristics of the source of knowledge

The characteristics of the source of the knowledge that were identified by Szulanski (1996) were motivation and reliability. Motivation refers to the source's willingness to share their knowledge, which according to Uygur (2013) increases when they can see a direct connection to personal gain from transferring the knowledge, for instance, if they believe that it will forward their career or improve their reputation within the organization. Regarding reliability, a source that is considered to be trustworthy is more likely to have an influence on the recipient's behavior, while knowledge being transferred from a source that is considered to be unreliable is more likely to be questioned and resisted (Szulanski, 1996).

Characteristics of the recipient of knowledge

Szulanski (1996) discusses three aspects relating to the recipient that affect the effectiveness of KT, namely their *motivation*, their *absorptive capacity*, and their *retentive capacity.* A lack of motivation in the recipient to obtain knowledge constitutes an obstacle to KT. One example of reluctance to acquire knowledge is the so-called Not-Invented-Here syndrome, which is a tendency for recipients to reject knowledge from external sources due to a belief that the external knowledge very improbably could reach the quality of internally developed knowledge (Katz and Allen, 1982). In this context, external sources can be other project teams, organizational functions or organizations. A lack of motivation in the recipient of a KT can lead to the recipient being passive, only pretending to accept the knowledge, secretly sabotaging the utilization and application of the knowledge, or openly rejecting it (Szulanski, 1996).

A recipient's absorptive capacity refers to their ability to put external knowledge to use, which according to Dierickx and Cool (1989) largely depends on their amount and level of pre-existing knowledge. Lastly, the retentive capacity of the recipient concerns the recipient's ability to make the utilization of the new knowledge permanent, to institutionalize it (Szulanski, 1996). A lack of retentive capacity can lead to the utilization of the new knowledge being terminated at the first obstacle encountered, and consequently to a reversal to the former state (Zaltman et al., 1973).

Characteristics of the context

The two aspects identified by Szulanski (1996) relating to the context in which knowledge is being transferred were the organizational context and the relationship between the source entity and recipient entity. The organizational context refers to the fact that something that works in the context of one area of the organization may fail in a different area with a contrasting context. Szulanski (1996) mentions formal structure and systems, sources of coordination and expertise, as well as behavior-framing attributes as aspects of the organizational context that affect both the number of KT attempts and their success.

As described in Section 1.2.2, Nonaka's (1994) theory of knowledge creation states that various individual exchanges may be necessary for knowledge transfer, especially if that knowledge is tacit. The effectiveness of these exchanges partly depends on the relationship and ease of communication between the individuals involved, where a poor relationship may inhibit KT (Szulanski, 1996).

3.4 Lessons learned

Making sure that old mistakes are not repeated and that successful operations are set into best practice is important to create a sound knowledge base. Effectively and efficiently managing LLs can create a sustainable competitive advantage (Wellman, 2007). As technologies change rapidly and markets become more global, organizations must quickly adapt to new situations and take care of their learnings before others do. They must also understand that learning is an asset much like intellectual property, capital investments and a skilled workforce. Companies that understand that learning is an asset and utilize it will prosper and others will fall behind. Furthermore, learning is a central element in a healthy organization and will keep the organization moving forward and breed a sense of optimism (Wellman, 2007).

Secchi et al. (1999, p. 57) define and elaborate on lessons learned as *"knowledge or understanding gained by experience. The experience may be positive, as in a successful test or mission, or negative, as in a mishap or failure. Successes are also considered sources of lessons learned. A lesson must be significant in that it has a real or assumed impact on operations; valid in that is factually and technically correct; and applicable in that it identifies a specific design, process, or decision that reduces or eliminates the potential for failures and mishaps, or reinforces a positive result".* In this chapter, LLs will be further explained and *Wellman's framework for managing LLs* will be presented.

3.4.1 Wellman's framework for managing lessons learned

Wellman (2007) has identified four ways of taking care of an organization's LLs, namely: *Culture, Old Pros, Archives* and *Processes.*

Wellman (2007) defines *culture* as *"the set of behaviors and operating principles that nearly everyone knows, but which are not written."* These social norms and behaviors sometimes capture the lessons repeatedly learned by the organization. Since the culture captures LLs by the organization, it can be a useful tool for transferring knowledge. However, managing culture can be difficult. Culture is mysterious, meaning that the reasons for a particular norm or way of doing things can be lost along the way. It is viscous, meaning that it is difficult and time consuming to embed LLs in the culture, and can take years of persistence. It can embed LLs that are no longer true and the organization then runs the risk of applying LLs that will hurt the organization. Culture is also pervasive and can spread through the organization seemingly uncontrollably. To tackle these issues, management must consciously manage the culture, acknowledge its existence and influence, and keep a holistic and persistent vision of the culture and how it should be changed.

Old Pros are the experienced people that have accumulated great deals of knowledge about the products, processes, environment and capabilities of the organization (Wellman, 2007). These people can thus be a valuable source of knowledge, but some difficulties exist in capturing and storing LLs in Old Pros. First, since they are individuals, they are not always available when and where needed. Second, we might not realize that we need to use the knowledge possessed by the Old Pros. Third, the Old Pros often do not consciously know the LLs they have accumulated.

Rather, the knowledge emerges when they come across a specific problem. Finally, Old Pros retire, and then the knowledge that they have not been able to transfer to other individuals, groups or systems will leave the organization.

Management must recognize that Old Pros exist, and that they are a valuable resource (Wellman, 2007). They could also be used in different parts of the organization, increasing both their overall experience as well as their utilization. Also, they can be used for facilitating LL workshops at the end of major activities, and thus identifying, codifying and embedding LLs in the collective memories of the participants.

Archives is a common way of managing LLs (Wellman, 2007). However, they are often poorly maintained and after some time, they fall out of use. Difficulties exists in the human interactions with the systems, and the root cause is often that such systems have a hard time dealing with tacit knowledge. Different people have different views of what is important to document, and from whose point of view. It is thus often a challenge to determine which lessons that should be archived. And even if there is a broad consensus about what should be captured, the wording of the lessons can alter the accuracy of what was actually learned, which also opens up for misinterpretation. Further, the context is often lost, or at least too vaguely explained, making the learning less effective. Finally, what actually was the lesson learned often changes as time passes. After some time, the perception of the reason for an event can change. What seemed important a few months ago might today have been shown to have a low impact. This raises the question of when a LL should be recorded - when is it correct and accurate?

The most challenging, disciplined and sustainable way of capturing LLs is in *processes*. The way we work with KM processes must blend well with the way work is done on a daily basis Davenport and Prusak (1998). The reason for the power of processes as a KM tool is that since it is done on a daily basis, the captured knowledge is available at all times (Wellman, 2007). The processes are continually controlled and governed with owners responsible for integrity, efficiency and currency of each process. Furthermore it is easier to mend processes than culture.

These four factors interact and should be managed simultaneously. Organizations that appreciate the power, complexity and challenge of managing all four factors are those that have the ability to effectively manage their knowledge.

3.5 Knowledge management framework

This chapter has covered literature on knowledge management, knowledge transfer and lessons learned, as well as models for each area. Despite the differing foci of the models, certain patterns and similarities could be discerned from them, leading to the development of a framework for KM and learning. The framework consists of six significant factors that were identified to influence KM, and is depicted in Figure 3.4. As can be seen in the figure, the factors are *culture, goals and measurements, problem and action orientation, compatibility, location of knowledge*, and *networks*.

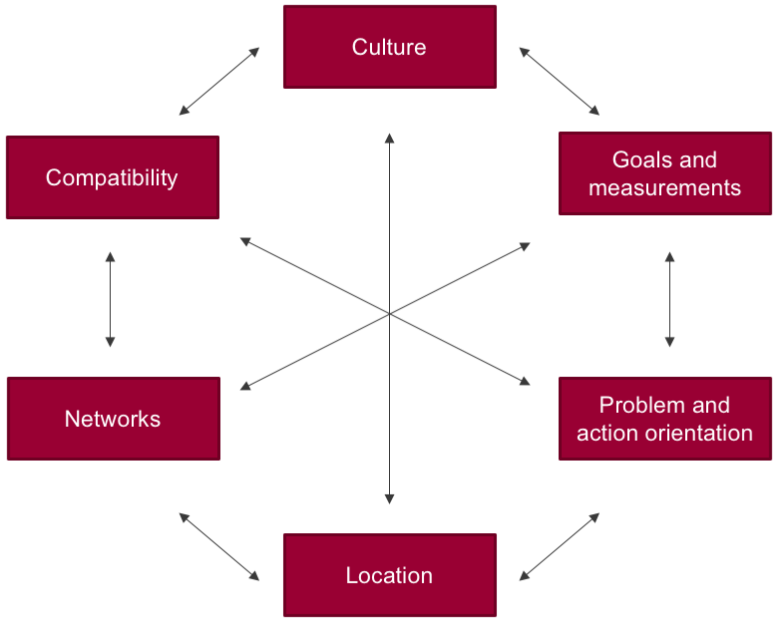

Figure 3.4: Framework for managing knowledge and lessons learned.

In this section, the framework is presented and its factors discussed, answering the first research question:

- RQ 1: *How can a framework that facilitates learning between manufacturing and product development be designed?*

The framework takes into consideration both tacit and explicit knowledge transfer. Its factors are interconnected, meaning that an organization must bare all of them in mind when developing their KM initiatives.

3.5.1 Culture

Much of the literature studied identifies culture as an important factor when developing KM systems and processes. It is the bridge between IT systems and people, and the holistic glue in KM. From the perspective of LLs, Wellman (2007) describes culture as something that permeates the entire organization, and that as such, it has the ability to capture LLs and transfer knowledge. He also emphasizes, however, that culture is difficult to manage. Culture is also discussed in the field of KT, but in the shape of the source's willingness to share knowledge and the recipient's willingness to acquire knowledge (Liyanage et al., 2009), both aspects that are largely influenced by the organizational culture. For an individual to share its knowledge, the person must feel that it has a personal gain of sharing what it has previously learned. A belief that sharing knowledge will take the person a step further in their career or increase the reputation within the firm are two personal gains that Uygur (2013) mentions. Wellman (2007) also argues that financial compensation can be an instrument to increase the willingness to share knowledge. An individual can also be opposed to acquiring knowledge, an example being the NIH syndrome. From a KM perspective, there is a focus on goals, expressing that the knowledge culture must be consciously managed to make sure that knowledge is created in line with the corporate goals (Probst et al., 2000).

The take-away is that, even though it may be difficult, it is crucial that management attempts to manage the company culture so as to encourage knowledge sharing and support KM activities. This means rewarding knowledge sharing behavior and removing obstacles to KT so as to reduce the effort required to share and acquire knowledge. It also means identifying factors that positively impact knowledge sharing and learning, and finding ways to emphasize and develop them.

3.5.2 Goals and measurements

KM literature emphasizes that we cannot manage what we do not measure. Probst et al. (2000) state that goals for the knowledge to be created must be defined and the measurements to control how the organization will get there must be in place. The goals must then be monitored and managed in a way that ensures that the organization fulfills them. The topic of performance measurement is also covered in KT literature. Liyanage et al. (2009) includes it as an element to consider in their KT process, emphasizing the importance of evaluating the quality of the knowledge transferred in order to subsequently be able to evaluate the quality of its transfer process. Tirpak (2005) suggests that knowledge goals can aid in institutionalizing KM by incorporating them in the performance reviews and scorecard goals. There is thus an agreement on the importance of goals and performance measurement in KM. The literature on *how* these goals should be set and measured is much more scarce. Argote and Ingram (2000) suggest that the success of KT can be measured in changes in the recipient's knowledge or performance. They do not, however, expand on *how* to measure that knowledge. Probst et al. (2000) divide knowledge goals into three levels: normative goals, which should be directed to creating good preconditions for KM, such as creating a knowledge culture; strategic goals, which indicate the core capabilities that the firm must acquire to stay competitive in the long term; and, operational goals, which turn the normative and strategic goals into action through goals such as language and technological capabilities that the employees should meet. This type of classification could aid in defining goals.

In can be concluded that setting goals for knowledge creation and sharing, and following them up through measurement, is considered highly important in KM. The advice on how to do this is, however, limited. Probst et al.'s (2000) three levels could be used to facilitate setting goals, but then it would be up to the individual firm to determine how these goals could best be measured in the specific context and situation of the firm. The importance lies in realizing that KM efforts need to be evaluated to determine their effectiveness, just like other initiatives within the organization.

3.5.3 Problem and action orientation

In his model for practical KM, Probst (1998) emphasizes the importance of KM initiatives being applied to solve problems and not staying theoretical. Not only should they be problem oriented, they should also inspire managers to act to further improve the KM. A similar notion is evident in KT literature, where knowledge application has been identified by many researchers as the most important step of the KT process (Liyanage et al., 2009). Liyanage et al. (2009) describe this as being the step where the knowledge transferred is being directly applied to a concrete problem. This shows that in the KT literature, problem orientation is not only considered important, but *most* important. This stems from the observation that knowledge in itself does not create value or improve performance, but that this occurs in the *application* of the knowledge (Alavi and Leidner, 2001). Wellman (2007) brings up the issue of IT and LL systems often becoming idle over time, and that KM initiatives that inspire action could prevent this. He emphasizes processes as being the most disciplined and sustainable way of capturing LLs, since they are controlled and maintained by process owners and involved in the everyday work. This relates to the way in which the issue is handled in the KT literature, where there is a large focus on creating models and processes with detailed steps explaining how to go from acquiring the knowledge in one location of the company and transforming it into something that is useful in a new location (Carlile, 2004; Liyanage et al., 2009).

It is thus emphasized by researchers in all three fields that it is crucial that KM initiatives inspire action and are applied to real problems in order for them to create value for the company. This hints at there being a tendency for KM initiatives to either stay theoretical or not be sustainable enough to last in the long run. The main approach being introduced to prevent this and making KM work more sustainable is through processes, and the KT literature details the shapes such a process could take.

3.5.4 Compatibility

KM literature emphasizes the importance of KM initiatives and processes being compatible with the organization's existing practices and processes, its culture, as well as established and understood terms and ideas. Davenport and Prusak (1998) express that KM processes need to blend well with the way everyday work is done. In the practical framework presented by Probst (1998), he emphasizes the importance of KM tools being suitable for the organization while facilitating efficient KT as well as being easy to use. Literature on KT also discusses compatibility, but regarding the knowledge itself. Uygur (2013) found that the relevance of the transferred knowledge to the existing knowledge base of the organization affects the transfer, where knowledge that is considered to be relevant to both the organization and the recipient is more easily transferred. Szulanski (1996) does, however, caution that the recipient's existing knowledge can also constitute an obstacle to KT, if it requires them to unlearn some of their pre-existing knowledge in order to learn and apply the new knowledge. New knowledge must, thus, not only be relevant to the recipient and organization, but also compatible with their pre-existing knowledge. From the more practical perspective of LL, Wellman (2007) discusses the difficulty of determining which knowledge is relevant and important to document and disperse, stating that the opinions on this tend to vary depending on who within in the organization is asked.

This shows the importance of compatibility of KM processes and initiatives with existing processes, procedures, culture and ideas, as well as the compatibility of the knowledge being shared through those processes with existing knowledge and the needs of the organization and the recipient.

3.5.5 Location

The necessity of employees knowing where relevant knowledge is stored is brought up in both KM and KT literature as a prerequisite to knowledge transfer and reuse (Probst et al., 2000; Liyanage et al., 2009). Alavi and Leidner (2001) bring up IT systems, individuals and groups as possible locations of knowledge. Wellman (2007) further adds the company culture and processes as ways to conserve knowledge. Probst et al. (2000) emphasize that though IT systems can be used to effectively store explicit knowledge, they do not support the storage and transfer of tacit knowledge. Wellman (2007) agrees and suggests that IT systems' inability to manage tacit knowledge is why those systems often fall out of use. Further issues with this approach to recording knowledge are, according to Wellman (2007), the risk of losing the context where the knowledge was created, and the difficulty of determining which knowledge should be archived in LLs, what information should be included in the LLs, as well as how this information should be worded in order to minimize the risk of misinterpretation. Probst et al. (2000) suggest that the difficulty of transferring tacit knowledge through IT systems could be dealt with by enabling the identification and involvement of the people who were involved when the desired knowledge was created. This is closely related to both what Wellman (2007) refers to as *Old pros* and Liyanage et al. (2009) refer to as *networks*. The concept of networks in KM and learning will be discussed further in the following section.

The importance of employees knowing which knowledge exists within the company as well as where to access it is thus considered important from both the KM, KT and

LL perspectives. IT systems are considered effective, but potentially problematic, tools for storing and transferring explicit knowledge. Regarding the transfer of tacit knowledge, all fields studied emphasize the importance of enabling the direct involvement of the people that possess the knowledge desired.

3.5.6 Networks

The previous section concluded that both the KM, KT and LL literature advocate the involvement of people possessing desired knowledge in order to enable the transfer of tacit knowledge. Using the terminology of Nonaka's (1994) Dynamic Theory of Knowledge Creation, this means enabling and facilitating socialization and externalization of knowledge. KT literature focuses on the influence of personal relationships on the effectiveness of the KT that takes place during socialization (e.g. Liyanage et al., 2009; Szulanski, 1996). A KT is concluded to be more likely to be effective if the source and recipient of knowledge have a good relationship and can communicate with ease. From the KM perspective, Goffin et al. (2010) recommend appointing knowledge brokers to projects, who are responsible for collecting learnings from previous projects and relaying them to the new project team. This constitutes one way of ensuring that there are connections between the different projects and their teams even if these networks do not form naturally. In Probst's practical framework for knowledge management, Probst et al. (2000) also emphasize the importance of enabling the identification and localization of individuals within the organization that possess the currently sought after knowledge. One solution to this presented by Probst et al. (2000) is to include contact information in LL documents to individuals that were involved in the project where the learnings were made. In the LL literature, Wellman (2007) similarly advocates the use of *Old Pros*. He does, however, also mention four risks to relying on the utilization of Old Pros, namely that they are not always available when and where needed, that the project team may not realize that they need the knowledge possessed by Old Pros, that Old Pros may not consciously know the LLs they possess, and finally, that the knowledge leaves the organization if they resign or retire.

It can be concluded that individuals and their interactions highly influence the sharing and reuse of knowledge in organizations. The involvement of key personnel possessing desired knowledge is advocated in all fields studied, where including contact information in LL documents was suggested as one approach to facilitate this. KT literature points out the relationships between these key personnel and the recipients of knowledge as an important factor for the effectiveness of the KT between them. Although this practice is highly advocated, relying on individuals within an organization as the sole source of a certain piece of knowledge does present certain risks, as described by Wellman (2007), which need to be taken into consideration.

4

Knowledge management and learning at GKN

This chapter first briefly introduces ECs at GKN, providing a background to the case and explaining why the EC focus was chosen. Then, GKN's current work with KM is introduced, followed by a brief description of its PD process and a more in-depth account of its EC process. This provides a base from which to work when improving KM efforts and learning within the organization. The results in this chapter are based on the exploratory and in-depth interviews explained in Section 2.3.

GKN has experienced an insufficient manufacturability in its products. One indication of manufacturability not being sufficiently taken into account is the amount of ECs that are made due to issues that occur in manufacturing after start of production. Between December of 2016 and November of 2017, the company carried out 187 ECs. Each of these changes took on average 170 days to complete. Each EC constitutes a piece of feedback on which aspects of a design do not match current manufacturing capabilities well. Consequently, each EC creates further knowledge of limitations in manufacturing and their implications for the design department. This knowledge could be used to avoid similar issues occurring in later development projects, but there are currently no mechanisms in place specifically intended to facilitate learning from the knowledge created in the process for ECs.

4.1 Knowledge management and learning at GKN

GKN uses different methods to facilitate cross-functional communication and KT in its product development processes. Much communication occurs through informal meetings where aspects such as limitations in internal as well as supplier production are discussed and taken into account in the design. This is mainly done through the use of cross-functional teams. However, this close, cross-functional collaboration ceases after ramp-up in production. The formal PD process also contains several cross-functional reviews intended to ensure the involvement and consideration of all affected functions. In addition to these meetings, once manufacturing of a product has started, every two weeks there are formal meetings where deviations related to casting goods are discussed by members of both the design and production departments. This is due to the fact that these goods tend to cause quality issues. The central quality division also holds something called Corrective Action Board (CAB) meetings on a monthly basis, where personnel from production, design and the supply chain departments meet to discuss the state of a certain product and its manufacturing. In addition to these cross-functional meetings, the Chief Manufacturing Engineers (CMEs) of the different programs meet twice a week to discuss issues that they face in their respective programs, enabling communication between programs.

A tool for communication when it comes to managing deviations is a type of document, informally called CAB file, that is created by an employee from the quality department. The CAB files contain data on deviations of different kinds and are adapted to and intended for the different functions. The raw data can be found in SAP, but the CAB files constitute a more easily accessible compilation and overview of this data.

In order to learn from previous programs and increase manufacturability, the design team studies programs for similar products that have already started production. They also communicate with members of those development teams and, when possible, members are transferred from the previous program to the new one.

Although these systems and methods for KT are in place, GKN still experiences issues related to manufacturability. There is a big interest in KT and a willingness to improve it. At the same time, there are no formal processes in place to ensure that this happens and that learning takes place. Learning from one development project to another is largely dependent on the people involved in the respective projects. It is up to the members of one project development team to take the initiative to contact members from previous development projects in order to learn from them. Knowledge sharing is thus dependent on personal contacts and networks. Similarly, knowledge currently largely exists in the minds of personnel from different departments.

Members of different departments experience several obstacles to effective KT. The main aspect is experienced to be a lack of time. The company has a large focus on delivery, which leads to this being prioritized over proper root cause analyses and problem solving when issues occur. Problems are solved so as to enable delivery, but they are not always followed up. Consequently, the company does not know if the root cause of the problem has been taken care of or if they simply treated a symptom of the problem. The perceived lack of time also limits documentation and communication of, as well as learning from, the problems and their solutions.

Learning and KT are also inhibited by a lack of knowledge of what information exists and where. This is further complicated by a lack of understanding of what information the own department is lacking and what it needs, as well as what information other departments need. Even when a department knows which information it needs, another obstacle is that it is not automatically provided this information in an easily understood format. Which is understandable considering that the department owning the information may not be aware of the need. There is a general interest in using knowledge from other departments, but an unwillingness to put effort into locating and acquiring the knowledge. This lack of motivation to acquire knowledge from other functions and programs is perceived as a significant obstacle to knowledge transfer and reuse. The knowledge is often also perceived as being difficult to access if it entails using the different IT systems. The members of one function oftentimes do not know how to use the IT systems that are primarily used by other functions, thus limiting the possibility of using data from these functions directly. It is also considered difficult to locate the relevant information in these systems. An exception to this is the CAB files previously mentioned, as they constitute an easily accessible compilation of information specifically aimed at the different functions. There is a widespread knowledge of the existence of these files, but the extent to which they are used is dependent on the individuals involved in the program in question.

Much data on deviations are collected and communicated between functions. However, there is a lack of data on the cases that go well, and subsequently limited learning from successes. When it comes to GKN production facilities on other sites than GKN Sweden, there is also an issue of them oftentimes not having the SPC data necessary for the design team located in Sweden to make fact-based decisions regarding the design and design changes. In these situations, design changes are generally based on speculations. Another obstacle to sharing knowledge across functional borders and between development projects is the lack of a forum to do so. This is especially true after ramp-up in production when the cross-functional teams are disbanded. One last obstacle is the lack of a system specifically for LLs, which relates to the accessibility of knowledge and ease of locating it.

4.1.1 IT systems

The company has several systems for managing data. The main IT system is SAP, where information such as released designs and production data are kept. They have a system called KPS where production data is recorded, but they are in the process of switching to a system called QSYS. GKN also utilizes design platforms as well as manufacturing platforms. Finally, there is a KM system called KMS intended for knowledge recording and sharing for engineers. The system was introduced in April 2017 and is currently meant to be used by the design teams during development. It is eventually intended to be used by engineers in production as well, but this has not yet been implemented. It contains standardized ways of working in the shape of design practices (DPs), engineering practices (EPs) and BPs. The DPs are very detailed instructions on how to design different parts of a product, such as specific measurements for radii. The EPs are also detailed, but more generally applicable to development projects, such as how to perform a FMECA. Lastly, BPs are softer and contains general advice and examples of good practices, such as an example of a well-performed FMECA. The DPs, EPs and BPs are organized according to product architecture and can be found by first choosing the relevant product and then component from increasingly detailed visual representations of the products.

For each DP, EP or BP, it can be seen which work area it pertains to (e.g. design, verification, etc.), which Center of Excellence (CoE) it belongs to, as well as who the knowledge owner is. Each CoE consist of a group of specialists that is responsible for performing a certain type of analysis. The knowledge owner is an Engineering Methods Specialist (EMS) and is responsible for the method in question. The EMSs are responsible for feeding and updating KMS. They do not necessarily write the documents themselves, but they are the ones who add the documents to the system and ensure that it is up to date. A DP, EP or BP consists of a document which, besides a description of the practice, also contains product tags according to the products the practice pertains to, search words, export control requirements, the development phases in which the practice is applicable, as well as the names of the people who wrote, reviewed and approved the practice. It does not, however, necessarily include the names of the personnel involved in formulating the new practice.

KMS is accessible to all, but not all documents in it can be read by everyone due to issues of intellectual property. The exception to this is a part of the system that deals with KM and new knowledge that has yet to be approved with regard to standards and requirements of different kinds. This part of the system is not accessible to all, since the engineers need to work in accordance with current requirements and standards, and not according to every new piece of knowledge acquired or created. It is required that all DPs and EPs relevant to a product or process are followed. The only way to get around this is by approval from the EMS responsible for the practice in question. At an early stage of a development project, a verification plan is made that details which DPs, EPs and BPs will be used and when. There is currently, however, no system in place for ensuring that the practices are actually followed and it is not expressed as a requirement at any stage of the PD process. The system also is not yet well-known among the personnel nor widely used. There is no requirement to follow the BPs. The collection of BPs is currently quite limited, since the system that was previously used did not contain BPs. The DPs, EPs and BPs also are not updated and used to as large an extent as they could be.

4.2 The product development process

GKN has a formal and standardized process for their product development. It is an internally well-known process that is accessible in detail to all members of the organization in the Operations Management System (OMS). A simplified version of the process can be seen in Figure 4.1. It is a gated process where every phase (depicted

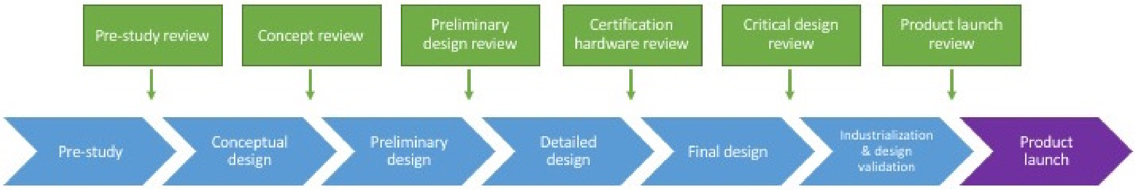

Figure 4.1: The product gated development process at GKN. Authors' own figure, based on the OMS at GKN.

in blue) is followed by a review that constitutes a gate (depicted in green). Certain requirements must be met in each review before the development can continue to the next development phase.

As can be seen in Figure 4.1, the phases of PD are a pre-study, conceptual design, preliminary design, detailed design, final design, and industrialization and design validation. These are followed by a pre-study review, concept review, preliminary design review, certification hardware review, and product launch review, respectively.

It is included in the process that knowledge from previous programs is to be reused, but it is not explicitly expressed as a specific requirement in any of the reviews. LLs, specifically, have been an explicit part of the PD process in the past. This was removed from the process since the experience was that LLs were mostly recorded because it was a requirement, resulting in lower quality LL documents and less reuse of them in new product development.

4.3 The engineering change process

There are two classes of ECs at GKN. The first class concerns changes that affect the function of the product and need to be approved by the customer. Class two changes do not affect the function of the product and thus do not require the involvement of the customer. The process for handling ECs is a formal and standardized process, accessible in OMS. This process is utilized for all change requests that surface after the Critical Design Review of the PD process (see Figure 4.1) until the end of the product life cycle. Before the Critical Design Review, changes are handled more informally through direct cross-functional communication and collaboration, oftentimes in workshop-like activities. The process is managed in SAP.

A change request can originate from internal manufacturing, suppliers, customers or the design department itself. First, a change proposal (CP) is created in SAP. A change originating from the manufacturing department can be initiated by any member of the manufacturing personnel, but the CME has the ultimate responsibility. A common source of change requests is recurring deviations in production. The

Figure 4.2: The EC process at GKN. Authors' own figure, based on the OMS at GKN.

CP contains a description of the problem as well as the suggested change. The CP is first evaluated internally by mainly the CME and the person responsible for the part in question. If the proposed change only affects manufacturing, the decision to go ahead with the change is made by the CME and the program manager, who have the technical and business responsibilities, respectively. When the change request originates in manufacturing, a configuration engineer appoints responsibility for the change. If the change affects the design department, responsibility for the change is handed over to the design configuration manager along with the CP.

For the design department, the EC process starts when a CP is received from either internal manufacturing, suppliers, customers or the design department itself. A simplified version of the process is depicted in Figure 4.2. First, the CP is evaluated to decide whether or not to proceed to perform impact assessments. The problem and proposed solution are described and a rough assessment of the potential impact on aspects such as technical requirements, manufacturing, costs as well as qualifications awarded and authority certifications is made. Once a decision has been made by the Chief Engineer deployed (CEd) to proceed with the change request, proper impact assessments are made in the *Start design change* step. A number of standardized questions need to be answered by members of different organizational functions and the proposed solution is coordinated with concerned customers and/or authorities. Then, a decision is made as to whether or not an Engineering Change Order (ECO) is to be created.

Once an ECO has been created, the process continues on to *Prepare design change* where a design solution is generated and verified with respect to aspects such as product cost, producibility and functionality. Depending on the change in question, this step takes the shape of the PD process. An Engineer in Charge (EiC) is responsible for the generated design solution and for deciding who is to implement the change. The design change is reviewed in the subsequent design review. The next step is then to approve the implementation of the design change. This approval is based on documentation on design change details, substantiation and consequences, and is given by a Change Control Board (CCB). Head of the CCB is the CEd, and the board consists of a configuration manager, the CME, a Compliance Verification Engineer, the program manager or chief engineer, and a representative from quality assurance. Each member of the board is responsible for approving the aspects of the change related to their respective areas, and their official approval is needed for the process to proceed. Once this approval has been achieved, the new design data is documented and released by a configuration manager. The document contains the change, reason for the change, and modifications in requirements. After this step, the responsibility for the ECO is handed over to a configuration engineer from production.

Unless the change was initiated by manufacturing, their part in the EC process is initiated by the reception of the above-mentioned document. This document is then translated into a more detailed change notice (CN). The CN contains information on what is to be changed and why, when it is to be implemented, what is to happen to already produced units, descriptions of the articles that are to be changed with references to their definitions, as well as descriptions of how drawings are changed. This is the information that is shared with internal manufacturing or suppliers, depending on who is responsible for production of the part in question. Based on the CN, a request is sent to definition to change the in-process drawings. The parts homepage, ZPHP, is updated according to the changes described in the CN. Then, the CN is reviewed and approved. Once the modified in-process drawings have been released, so is the CN. In the case of external production, the product planner creates a purchase requisition. The purchaser creates a purchase order and sends it to the supplier along with the defining documents. If the part is produced internally, the process of updating the operation sheet is initiated. A Product Manufacturing Engineer updates factors such as manufacturing structures and operation sheets accordingly, and an updated bill of materials is released. The ECO is then used to follow the implementation until the first product of the new configuration has made it through production and been put in stock. At that point, the ECO is concluded.

5

Case study analysis and process model

The literature review provided a theoretical framework for this thesis, and the interviews at GKN resulted in a description of the company's processes and work in the area of KM. This chapter analyzes the KM work at GKN using the influencing factors brought up in the KM framework and also proposes a process model based on this analysis and the KM framework. The process model shows how such a framework can be applied at GKN and thus answers the second research question.

5.1 Case study analysis

The KM framework is comprised of the six factors that were identified as important in literature on KM, KT and LL. The following section provides an analysis of GKN's KM work from the perspective of each of those factors.

5.1.1 Culture

Culture was identified as an important and highly influential factor on the effectiveness of KM in the literature analysis. Both positive and negative tendencies regarding culture can be seen at GKN. Two significant advantages are the employees' interest in improving the KM work and their realization of its importance to the company's future success. Such attitudes are crucial in enhancing the likelihood of a newly introduced KM process being accepted and successful. Despite this, there is still a tendency to reject knowledge from other individuals. The willingness to receive knowledge is sometimes low, where a desire to create something brand new at times overshadows the necessity of reusing knowledge to increase efficiency in PD and avoid remaking costly mistakes. Furthermore, there is a general reluctance to putting effort into acquiring knowledge. Even the employees that are motivated to use old knowledge for the sake of improvement are expecting that knowledge to be handed to them in an easily understood format, meaning that the source of the knowledge or some version of middle-man would need to do that for them. This is partially connected to the perceived lack of time that is discussed in the following paragraph.

The main tendency regarding culture that can be seen at GKN is the focus on delivery. Delivery is prioritized above all else, including KM work. This focus may improve delivery times in the short term, but it does lead to insufficient time being spent on thoroughly assessing the main causes of the time shortage and preventing similar issues from arising again. This creates a vicious cycle where a continued focus on delivery is necessary since the issues creating the shortage of time are never addressed. This focus on delivery communicates to the employees that making delivery is most important, even though what is officially communicated is the importance of robustness, manufacturability and preventing costs due to poor quality. Even the most motivated employees feel that time cannot be spent on KM and learning due to delivery pressures. This points to a lack of management support concerning these more long-term improvement processes.

There are, thus, a few challenges regarding culture facing GKN in their effort to improve their KM work. Management plays a key role in conveying what is and is not important as well as how different tasks should be prioritized. This includes official communications as well as everyday actions. Currently, the official communications emphasize robustness and manufacturability, while the everyday actions of management prioritize delivery. A clear stance from management could further affect the attitudes of employees regarding receiving external knowledge, and possibly motivate them to put effort into acquiring that knowledge if they feel like they are allowed to allot time to it.

5.1.2 Goals and measurement

GKN is aware that it has an issue with the manufacturability of its products and there is a desire to rectify this. There is also an understanding that in order to do this, more needs to be learned from both manufacturing and old designs, to be used when designing new products. One effort to facilitate this is the recently introduced KMS. Although there exist ideas on what is wanted from current and future KM efforts, there are no clearly defined goals for them. Nor are there defined measurements to track the performance of those efforts. This could be due to KM and learning being a relatively new focus for the company. As literature emphasizes, both goals and measurements to track the performance of an organization's KM are crucial in order to ensure that the efforts are yielding the expected results. Without this, there is no way of knowing whether the efforts were successful or should be improved somehow.

5.1.3 Problem and action orientation

Literature advocates KM efforts being focused on solving specific problems and encouraging taking action, and cautions against allowing KM to become only theoretical. GKN currently tries to leverage knowledge from previous development projects by either communicating with personnel from those projects or including them in the new project team. The current KM efforts are thus completely problem oriented, where knowledge sharing and learning between projects only take place when there is a concrete issue to apply the knowledge to. Furthermore, the focus on ECs and learning from knowledge created in their processes provides a clear problem focus for those specific KM and learning processes, since many ECs (but not all) reflect an issue detected in manufacturing, at suppliers, or by a customer.

The issue seems to be motivating the personnel to take action. As mentioned when discussing the culture at GKN, many employees realize the importance of learning and sharing more knowledge, and are interested in helping the company improve in that area. Even so, they do not feel motivated enough to put effort into making it happen. The focus on ECs could be a starting point to increase their motivation. If the negative consequences of the issues the ECs represent, such as cost and time delays, were to be tracked and communicated, this could serve as an incentive to take proactive action to prevent such issues in the future. And one way to do this is to learn from those issues to avoid making similar mistakes in the future. The structure of the KMS could also aid in making the knowledge application both more problem and action oriented. Expressing the LLs of a project in the shape of DPs, EPs and BPs could provide a clear picture of how these lessons are meant to be used. This could facilitate the application of the lessons to a specific issue, which in turn could encourage taking action by removing obstacles to knowledge reuse. If each LL was to clearly state what the consequences of the original design were which led to the EC, this could also prompt action to avoid those consequences in the future.

5.1.4 Compatibility

Compatibility concerns compatibility of KM initiatives with existing culture, ideas, processes, practices, tools and knowledge. GKN has clearly defined and well-known processes for both PD and ECs. This constitutes an advantage as a process for knowledge sharing and learning would need to be compatible with these processes, and this compatibility is easier to achieve if the existing processes are clearly defined and followed by employees. Furthermore, a habit of following the processes as they are described in the OMS would increase the likelihood of a proposed KM process being followed as long as it is made official in the OMS.

The PD and EC processes each has an owner that is responsible for maintaining and developing the process. Their acceptance of a proposed KM process to complement their respective processes would be crucial to ensure continued use of the proposed process. Here, too, GKN has an advantage in that the process owners in question already see the value in increasing learning in the organization and are motivated to adapt their respective processes to facilitate this effort.

One KM tool that GKN has readily available is the KMS. The KMS is meant to store knowledge created in both PD and production and as such has the potential to constitute an effective tool for transferring knowledge both cross- och intra-functionally. The system is, however, not yet integrated with the processes and everyday work of GKN. It is not well-known among the personnel nor frequently used. GKN thus needs to ensure that the system is user-friendly and integrated into the organization's processes in order to make sure that it is used by the personnel. Otherwise, the company runs the risk brought up in literature of the system being discarded.

Regarding the compatibility of knowledge, literature emphasizes the importance of the knowledge being relevant to the recipient and the organization, as well as compatible with their pre-existing knowledge. It is currently difficult to define what the existing knowledge is of different departments, groups or individuals at GKN, since much knowledge is stored in the minds of its employees. Knowing what the existing knowledge is, is a prerequisite to being able to determine whether new knowledge is compatible or not. This will be discussed further in the next section, covering *location* of knowledge. Regarding determining the relevance of a certain piece of knowledge, KMS supports the use of specific search terms, which could be used to identify the DPs, EPs or BPs that are relevant to the situation at hand. Concerning identifying which knowledge is relevant in the process of capturing LLs and selecting what is to be recorded and passed on to future projects, there are currently no mechanisms in place to facilitate this.

5.1.5 Location

GKN uses a number of IT systems for storing knowledge. Much information is gathered in SAP, but the company also uses platforms for their designs and manufacturing. Which systems are utilized partly depends on the organizational function, but also on personal preference. As mentioned in the previous section, a lot of knowledge is also stored in the minds of the employees. This means that the organizational knowledge is currently quite scattered between the different systems and individuals. This leads to a confusion as to what knowledge is readily available as well as where to find it or how to access it. There are currently no mechanisms in place to facilitate identifying which employee holds which knowledge, making it more difficult to leverage that knowledge.

The recently introduced KMS has the potential to gather knowledge relevant to design and manufacturing engineers in one place. This would prevent personnel from having to search for specific information in several different IT systems. Given the general reluctance to putting effort into acquiring knowledge, gathering all relevant information in one place could increase the chance of that knowledge being acquired and reused. Given the relative novelty of the KMS and the fact that it is still being implemented, it is still unclear how effective and user-friendly the system is. However, the system still being in the implementation phase also means that it could potentially be adapted and optimized for KT and learning. One of these adaptions could be to ensure that there are functions in place to facilitate locating desired information, as well as determining which information is relevant to a specific recipient and situation.

5.1.6 Networks

GKN is aware that a very large amount of company knowledge only resides within the minds of its employees. The company thus has certain mechanisms in place to attempt to access and leverage that knowledge. In the PD process, cross-functional teams are used to capture the knowledge of the different functions when designing the product. Every review in the PD process is also performed by a cross-functional group. It constitutes one effort to increase the manufacturability of each product. The issues encountered in manufacturing causing rework loops as well as the number of ECs initiated there does, however, indicate that these teams currently do not fully succeed in this respect. The close, cross-functional collaboration of the PD teams also ceases after production ramp-up.

The CCB of the EC process is a board made up of individuals from different functions, in order to ensure that the consequences for all organizational functions are considered before implementing the proposed design change. In addition to each function having a representative on the CCB, personnel from relevant functions are also included in producing material for decision making when investigating a proposed change.

Another way in which GKN uses networks to manage knowledge is when trying to learn between projects. When possible, personnel that have been involved in similar projects in the past are included in the project team for the new project. If this is not possible, it is customary to still somehow involve personnel from old, similar projects in a new PD project. It is not, however, a requirement to do so, and there are no mechanisms in place to facilitate locating relevant personnel to include. This makes the practice more dependent on the PD team already possessing the knowledge of who were included in old projects, as well as on their personal relationships and connections with them.

5.2 Process model

The above analysis of KM at GKN using the KM framework revealed both strengths and potential areas of improvement. Based on this analysis, the literature review and a focus group, the framework was applied to the EC and PD processes at GKN, taking the form of a process model for learning meant to enhance the strengths and bridge the gaps identified in the analysis. The purpose of the process model is to increase learning in the EC process, so as to increase reuse of manufacturing knowledge in subsequent PD processes. The developed process model answers the second research question:

- RQ 2: *How can the developed framework be applied to facilitate learning in engineering change and product development processes in the aerospace industry?*

The process model has been developed to facilitate both explicit and tacit learning. It thus uses both the KMS as well as cross-functional collaboration and is integrated with current processes to make it easy to implement and manage. The process model is considered to enable a greater learning within the organization, and similar processes could be used in other fields than ECs. It is important to note that the process model should be embedded in existing processes to leverage its positive sides and to minimize the risk of it falling into disuse.

As depicted in Figure 5.1, the process model is applied to two consecutive product development programs. The green part of the process model belongs to a program where ECs have been made, that the organization can learn from. Those learnings can later be used in the downstream product development program, depicted in blue, in order to reduce the risk of repeating the same or similar mistakes. As emphasized in the compatibility factor of the framework, KM initiatives are most effective when compatible with readily existent processes and ideas, which is one of the reasons for why the processes already in place are used when developing the process model. The PD and EC processes at GKN are combined to facilitate improved learning and achieve an increased knowledge base.

An important first step that would affect all steps of the process model is the definition of knowledge goals and measurements to track those goals. This would serve as a way to communicate the importance of KM and learning as well as what is expected in those areas, affecting the culture of the organization. It could also increase the action and problem orientation of the KM work by increasing the likelihood of the process steps being followed, clarifying why those steps are necessary and what the expected results of them are. Furthermore, GKN has ownership attached to all of its processes, and so should be the case also for this process model. One person should be appointed ownership of the process in order to maintain it as well as the system (Tirpak, 2005). This is another way of encouraging action orientation and preventing that the process and system fall in disuse. Having a formal LL process

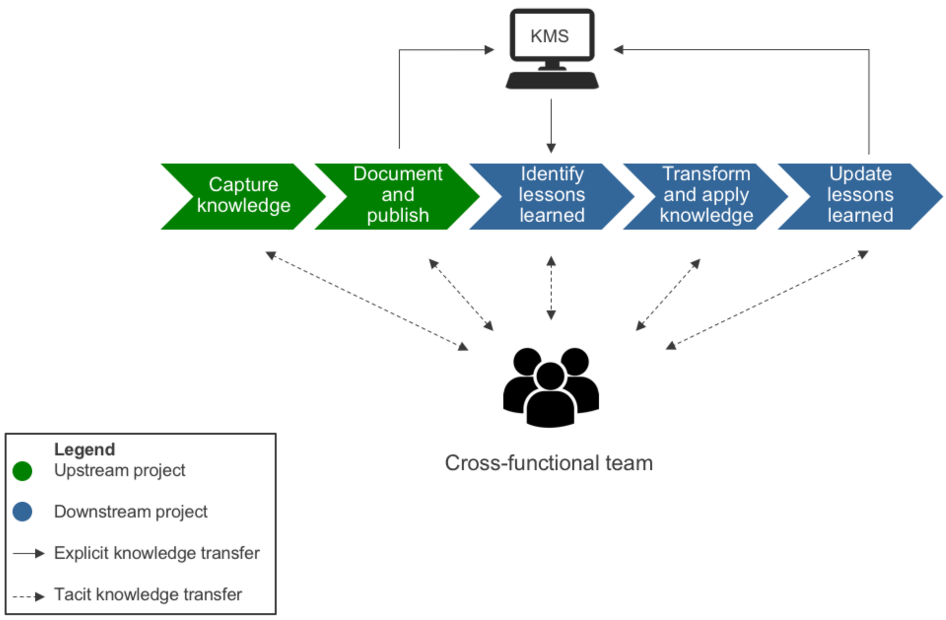

Figure 5.1: The process model, constituting a glue between the EC and PD processes.

with a process owner could also aid in affecting the culture to be more KM focused, showing that KM work is to be prioritized. Through the use of both cross-functional collaboration and the readily existent KMS, the LL process is intended to facilitate both tacit and explicit KT.

The proposed process model has five steps, including *capturing knowledge* and *documenting and publishing knowledge* in the upstream process, and *identifying lessons learned, transforming and applying knowledge,* as well as *updating lessons learned* in the downstream process.

5.2.1 Capture knowledge

In the proposed process, the company should utilize Post Project Reviews (PPRs), meaning that LLs are captured in reviews after a completed EC. After each EC, the company should cross-functionally go through what it has learned from executing the EC in line with what Collison and Parcell (2004) suggest (see Section 3.3.3). However, by only capturing knowledge during the end of the project a lot of knowledge can be lost (Disterer, 2002; Tan et al., 2006). The company should thus continuously capture knowledge and write down LLs during the EC. To be noted though, is that an EC project is usually far shorter than an entire product development project, and PPRs could thus be sufficient to capture the needed knowledge.

Furthermore, knowledge should be captured cross-functionally (Goffin et al., 2010) in order to facilitate tacit learning. Solutions that work in one area might fail in another (Szulanski, 1996). When the knowledge is captured, the team must thus take the context of the problem into consideration and consider how the context has affected the cause-and-effect relationships.

5.2.2 Document and publish lessons learned

When knowledge has been captured it must be documented and published in the organization's KM or LL system. GKN can use its KMS to store and publish LLs. When documenting, the authors of the report must then determine how to express what they have learned as DPs, EPs and/or BPs. Storing the knowledge in design rules such as as the practices is also an efficient way of designing a system for reuse (Bartezzaghi et al., 1997). This way, people from all over the organization can gain knowledge for many of its products from all of the documented LLs. Using one IT system to gather all LL data will clarify the location of this type of knowledge in the company.

Again, the context where the knowledge was created must be recorded (Szulanski, 1996). The documented LLs should contain: *what the problem was, the background to the problem, how the problem affected the product and production processes, results of the change* and, *the cause-and-effect relationships*. Furthermore, to facilitate tacit KT, contact information to the involved staff should be attached to the document (Probst et al., 2000). This further clarifies where certain knowledge is located in the minds of employees. That way, the downstream product development team can utilize the networks and experienced people from the upstream team in order to gain more knowledge on how to avoid repeating mistakes.

Finally, to further facilitate locating relevant knowledge in the KMS, the team must develop and use suitable keywords that make the LLs easier to find for the person who wants to reuse the knowledge. The keywords should reflect the content, context, problem faced and solution to the problem of the LL.

5.2.3 Identify lessons learned

In the downstream process, the engineering team must, based on their expertise and experience, identify which LLs are relevant to the current development project. This is crucial to ensure the compatibility of the LL knowledge with the existing knowledge of the project team as well as the situation they are facing. Using only one IT system to gather all such knowledge constitutes a first step in facilitating the localization of relevant LLs. The inclusion of context in the LLs will aid in determining the compatibility of the LL with the current development project. Effectively locating relevant LLs becomes increasingly important and difficult as the content of the KMS is expanded, leading to an increased amount of LLs to sift through.

This again highlights the importance of developing suitable keywords that facilitate locating relevant LLs. By including contact information to relevant personnel, networks can also be used in determining how relevant the information in a specific LL is to the current situation.

5.2.4 Transform and apply knowledge

Value in KM is created when the knowledge is applied, and it is thus of high importance that the process is designed to prompt action to reuse the knowledge on specific problems. In order to apply the knowledge in LLs, the new project team needs to transform that knowledge so that it fits with the current development project. Taking the context of each LL into consideration, the team must keep in mind what works and what does not work in the new context. To achieve this, the use of networks becomes paramount. It is crucial that members of the manufacturing department are included to see if anything has changed since the LL was documented, and if so, how the product should be developed in order to manage those changes. The transformation of knowledge should thus be conducted cross-functionally in order to facilitate tacit learning from different functions. Another way in which networks could, and sometimes should, be used is by involving people from the upstream project when determining if and how a certain piece of knowledge could be applied in the new context. The cross-functionality and involvement of experienced people from the upstream project could enhance the learning and the team can identify restrictions that were not explicitly expressed in the LL.

5.2.5 Update lessons learned

After a LL from an EC has been utilized and applied in a downstream project, the LL documents (DPs, EPs and BPs) should be updated with the learnings made when applying them in that project. Updating the LLs has three purposes. First, it constitutes a way of keeping the LL documents and system alive, increasing the action orientation and reducing the risk of the KM staying theoretical. This is crucial to keep on gaining long term knowledge. Second, updating the LLs will improve them for a third downstream project by showing how the knowledge was already applied in a different context, effectively increasing the problem orientation of the LLs and facilitating further applications. When the LL is updated, a third, downstream project will be able to improve the product even more and get a better understanding of the problem. Lastly, the update of the LL creates a feedback loop to the upstream project. This not only improves the learning for the upstream team, but also notifies them that the effort they put into writing down the LL was useful to others, which increases their motivation to write more and better LLs in the future. This further encourages the use of the proposed LL process and system, reducing the risk of them becoming theoretical. It can also give them a sense of personal gain from writing down LLs, when they know that others see their work (Uygur, 2013). This could improve the knowledge culture by increasing the willingness to share knowledge.

5.3 Focus group results

During the development of the process model, a focus group was held to acquire further feedback on the model's implementability. The main conclusions from the focus group will be presented in the following section.

During the focus group, the general understanding was that the proposed process has the potential to increase learning at GKN. It is viewed as implementable assuming the precondition that it has management support and that the organization decides that this is the way it wants to work.

The *searchability* of the system is of high importance for enabling KT. The focus group attendees highlighted that effective and representative *key words* must be developed so that the entire organization can find relevant LLs. The KMS must also be developed so that the *usability* is in focus, and users must be able to easily navigate the system. Furthermore, the *context* of he ECs must be thoroughly explained. A reader of a published LL must be able to understand what laid the ground for the problem the first time, and what the preconditions were to solve the problem in that setting. The attendees also highlighted that *results* from the EC must be pointed out. Information such as production process data, drawings and general results from before and after the EC should be made available. However, it is important that the documents contain the right *amount* of information. The documents should neither be too heavy, making them difficult to navigate, nor to light, making them difficult to understand. An *owner* to the knowledge must thus be appointed that can *assure the quality* of the published LLs. Lastly, it was suggested that it should be investigated whether KMS is the best system to facilitate the LLs, or whether systems that can enable inter-project learnings in a better way might exist. However, if the KMS is chosen as the system to be used, it should be made clear to the entire organization that this is the system that GKN should use and thus align its efforts around the system.

The process model is considered implementable, provided that the organization decides that this is the way it wants to work. However, the focus group attendees highlighted that both searchability, context focus and management effort are very important for increasing the likelihood of successful implementation.

5.4 Discussion

The following section discusses first the process model and its strengths and weaknesses. Secondly, it discusses the methodology's firmness and brings up and elaborates on areas of weakness.

5.4.1 Process model discussion

This thesis handles KM to increase reuse of LLs in the EC process. However, the LL process is developed to facilitate use in other processes as well. It has a general form and can with minor changes be used in several fields, such as entirely in PD, for deviation reports, changes to production processes, as well as in purchasing and the supply chain.

One of the main challenges with developing the process model was to find a suitable abstraction level. The process was developed on a general form and does not go into exact details of how each process step should take form. Recommendations and suggestions for options that GKN can use are given, but it is up to the company to decide exactly how each step should be managed. When testing the process in a pilot study and when implementing it full scale, GKN will have the ability to assess the details of each process step. Deciding on exact details is an iterative process that GKN has to accomplish as a means to find a suitable match with the organization.

5.4.2 Methodology discussion

Due to the development programs' life cycles, a suitable program for testing the process was not available. A proper testing of the process was thus replaced by a focus group where the process' implementability, barriers and preconditions to implementation as well as necessary inputs and outputs to each process step, were discussed. The findings from the focus group were insightful, however a structured pilot project would have given further insights and could have proven or disproven the likely success of such a process in a more convincing way.

Furthermore, the interviews focused on mid-level managers. To fine tune the process even more, people working closer to the processes could have been interviewed. The same goes for top management, where interviewing higher management could have created a greater sense of urgency for dealing with KM. However, the focus of the project was to develop an implementable and sound process, and due to time restrictions, mid-level managers were considered the most time efficient interviewees to achieve the goals.

The sample of interviewees is also one factor that needs to be discussed. The main part of the interviewed staff worked in the same development program, which of course could lead to bias. Subcultures may exist in the different programs which could affect the results of the interviews, especially regarding the cultural factor of KM. Finally, 14 people in total were included in the interviews and the focus group. There is thus a risk that the results are not representative for the entire firm.

6

Conclusions, recommendations and further research

The purpose of this master's thesis was to study how knowledge reuse can be increased by taking better care of LLs. To answer the purpose, a theoretical KM framework, comprised of six factors that influence an organization's ability to effectively capture and reuse knowledge, was developed. Also, a process model was developed that can facilitate learning between the EC and PD processes. The following chapter presents the conclusions from this master's thesis and put forward recommendations for GKN. Finally, areas of further research are proposed.

The KM framework consists of six significant influencing factors on KM and works as a base for how to tackle fundamental issues in KM and LL. The factors, that should be managed simultaneously, are: *culture, goals and measurements, problem and action orientation, location of knowledge, networks*, and *compatibility.* Based on the framework, interviews and a focus group validation, a process model has been developed with the goal of operationalizing learning at GKN and increasing its inter-project and inter-functional learning. It has taken a practical form that utilizes the company's current PD and EC processes, which increases the likelihood of successful implementation. Since the process model has taken a general form, it can be applied to other processes than ECs. GKN thus has the opportunity to investigate in which other fields the process model might be implementable.

The interviewees and focus group attendees showed a high degree of positivity regarding the process model and considered it implementable under certain preconditions. First off, the process needs management support and the organization must decide that this is the way it wants to work with LLs and KM. Top-management must thus be committed and provide resources for implementation and continuous development of the process. Secondly, KMS's user friendliness and searchability must be prioritized. The focus group attendees highlighted that the system must be very easy to work with and it must be easy to find relevant LLs. Thirdly, it must be decided that GKN works with one system for all of its KM. Currently, it uses several systems, and it should be centralized to one system in order to facilitate an easy way to find knowledge. Lastly, GKN must go "all-in" if it decides to work with the process. The organization must thus create commitment to work this way if it decides that this is the way to go.

GKN are recommended to initiate a pilot study of the process for one of their development programs. Through the pilot study, GKN can go further into detail on the exact content of each process step. Once the organization feels ready to implement it full scale, it can go even further into detail and thus fine tune the process so that it matches how the organization currently works with the surrounding processes.

As a means of managing knowledge, GKN should introduce knowledge goals and measurements so that they can follow the evolution of knowledge and effectiveness of their KM initiatives. It is a factor that is closely related to the knowledge culture. Many of the interviewees mentioned that top management encourages robustness and manufacturability initiatives, but at the same time has a very high focus on delivery. This creates a feeling amongst the employees of not having enough time for conducting activities that can increase robustness and manufacturability. Top management must "walk the talk" and create preconditions that allow employees to focus more on actively working with KM initiatives in order to increase robustness and manufacturability long-term.

Furthermore, when developing both the KMS and the LL process further, GKN should incorporate statistical functions in the system. The system should visualize which products, parts and types of production processes experience the most problems. This would allow them to initiate manufacturability and robustness initiatives where they are truly needed. As suggested in the focus group, GKN could also research which key words that can facilitate a system that efficiently lets the employees find valuable LLs. Furthermore, the KMS can also be developed further in order increase the user friendliness of the system. *How* the KMS should be developed is thus a suitable area for further research.

Through this master's thesis, new possible research areas have been identified. First and foremost, very little literature covers quantitative research on the effects of working effectively with KM and LL. Longitudinal studies could thus be performed to assess the effects of implementing the proposed process model. Such a study should find suitable measurements and use them to measure the company's performance prior to and after introduction of the LL process and a more conscious work with LLs and KM.

As has been mentioned, the developed process model is quite general, and it could therefore be of interest to research its applicability to other companies within the aerospace industry, as well as from other industries. The application to the engineering change process, specifically, requires those companies to make significant use of such a process, suggesting industries with longer development projects and product life cycles. However, due to the generality of the process model, it should be adaptable to other similar processes as well, and thus applicable to a broader range of industries. Research could study similarities and differences between the applications and find patterns to further improve the model.

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A

Appendix: Interview template of an exploratory interview

This appendix includes an example of an interview template from one of the exploratory interviews (see Table A.1). This particular template is from an interview with an employee from the product development department. Each template was adapted to the interviewee and their position, why other templates from the exploratory interviews may have differed slightly from this one.

Table A.1: Example of an interview template from an exploratory interview.

No.	Question	Facts	Impressions
1	What does your position/role entail?		
2	How does your department work with transferring knowledge between functions?		
3	How do you find out how manufacturable and robust a product turned out after development?		
3.1	How do you make use of that knowledge?		
4	How does your department currently use deviation data?		
5	What currently inhibits your department from sharing/acquiring knowledge?		
6	What information do you need to increase the robustness of products?		
6.1	How would you like that information to be presented?		
7	How can the work with deviation data and other data be improved in order to enable your department to aid in improving the robustness and manufacturability of products?		

B

Appendix: Interview template of an in-depth interview

This appendix includes an example of an interview template from one of the in-depth interviews (see Table A.1). This particular template is from an interview with an employee from the product development department. Each template was adapted to the interviewee and their position, why other templates from the exploratory interviews may have differed slightly from this one.

Table B.1: Example of an interview template from an in-depth interview.

No.	Question	Facts	Impressions
1	What does your position/role entail?		
2	How is the decision made to change a design?		
2.1	Who prepares the basis for decision making?		
2.2	What is the decision based on?		
2.3	Who make(s) the decision?		
2.4	Who else are involved?		
3	What does the process of engineering changes look like?		
3.1	The official process?		
3.2	The actual process?		
3.3	Is the official process followed by everyone or are there several different ways of working?		
4	What does the collaboration between PD and production look like?		
5	[Show the official process] This is what the process looks like in the OMS, is it correct?		
6	What do you do to reuse the knowledge and ensure that similar mistakes are not repeated in the future?		
7	What happens to the engineering change proposals that do not become engineering change orders?		
8	Which information from production do you think PD should use to a greater extent in order to avoid engineering changes?		
9	Is there a database for engineering changes?		
10	What currently inhibits your department from sharing/acquiring information?		