Høgskolen i Sørøst-Norge
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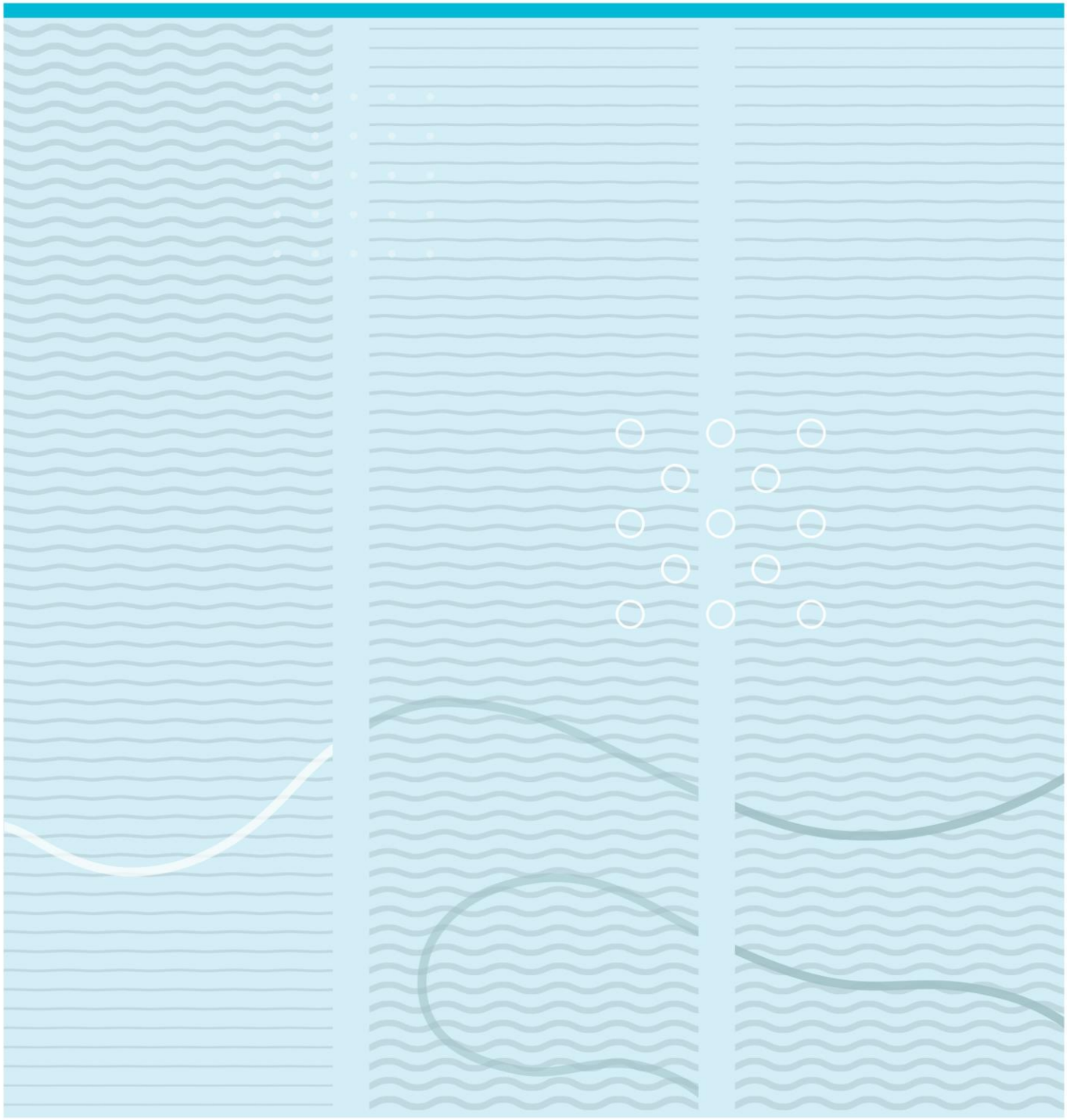
Anja Linnerud Hansen
Carina Røren Husmoen

Lean and Knowledge Management in Product Development

How do organizations use Lean Product Development and Knowledge Management when engineering Complex Products and Systems in projects? - how do the two concepts influence each other?



Høgskolen i Sørøst-Norge
Handelshøyskolen og fakultet for samfunnsvitenskap
Institutt for strategi og økonomi
Postboks 164 Sentrum
3502 Hønefoss

http://www.usn.no

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Preface

This thesis marks the termination of the master's program in Business Administration and Management, with specialization in Industrial Business Management, at the University College of Southeast Norway. We conducted a literature review during the spring of 2015, based on our interest regarding Lean and Knowledge Management. As Knowledge Management and especially Lean is more commonly utilized in manufacturing, we wanted to explore these two frameworks in a product development context. As a result, we chose to study how organizations use these frameworks in practice, both separately and in combination during engineering of Complex Products and Systems. In terms of Lean, we chose to examine how organizations use this framework in order to enhance efficiency, standardize processes, products, etc., and reduce waste. Regarding Knowledge Management, our focus areas were knowledge creation, transfer, storage, and application. We also examined how these two frameworks influenced each other. Thus, this thesis has given us insight into how organizations which develops and produces Complex Products and Systems use these frameworks in practice during the engineering phase in projects. Further, our work with this thesis has also been educational in terms of both collection and processing of data.

We would like to thank all informants who participated and thus made this study possible. Special thanks to our supervisor Roland Hellberg for his support and guidance throughout this whole process. We would additionally like to give our sincere thanks to Eivind Arne Fauskanger and Rolf Qvenild for helping us with acquiring case study organizations through their contact networks.

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Anja Linnerud Hansen

Carina Røren Husmoen

Abstract

Today, organizations are concerned with how they can produce high quality products at the lowest cost possible, in order to stay competitive in a highly competitive market. Lean and Knowledge Management have proven to be important concepts in order to achieve competitive advantage. Complex Products and Systems are regarded as high cost technology and software intensive products or systems, which are manufactured in small batches or one-off projects with long development lead time. Hence, making the projects run smoothly and efficient, in addition to provide competitive products and systems at a low cost, is important.

There is a lack of research on how Lean Product Development can be exploited in organizations that develop Complex Products and Systems. However, the literature that do exist regarding Lean Product Development, suggests that this concept is important in order to develop high quality products efficiently, which also is vital when developing Complex Products and Systems. Knowledge Management is considered of high importance when dealing with Complex Products and Systems as it makes knowledge available across project families in the organization. However, there are conducted few case-studies regarding this research field, and there is a lack of research on how Knowledge Management can be used in practice in organizations that develop Complex Products and Systems. Based on this, there clearly exists a need to obtain more knowledge and a deeper understanding of how Lean Product Development and Knowledge Management are used in organizations that develop Complex Products and Systems.

Several researchers have included knowledge and Knowledge Management as an important part of Lean Product Development. It is stated that an organization has to master knowledge and learning in order to be Lean in the Product Development Phase. On this basis, we are of the opinion that there is a need for a deeper understanding of how Lean Product Development and Knowledge Management are used during engineering of Complex Products Systems in projects, as well as how the two influence each other. Our research question is formulated as follows:

"How do organizations use Lean Product Development and Knowledge Management when engineering Complex Products and Systems in projects?

- *how do the two concepts influence each other?"*

Having examined existing theory in relevance to the research question, Lean Product Development and Knowledge Management were divided into respective sub-categories. Lean Product Development is split into three sub-categories, efficiency, standardization, and waste reduction. Knowledge Management is split into four sub-categories, knowledge creation, transfer, storage, and application. The relationship between Lean Product Development and Knowledge Management is viewed in relation to the same sub-categories as Lean Product Development.

A qualitative research approach with case study as research strategy, is used to examine how Lean Product Development and Knowledge Management are used during engineering of Complex Products and Systems in projects, as well as how the two concepts influence each other. It is used a holistic multiple-case design, and each case has been selected based on their relevance to the research question. Two different organizations have been studied in this thesis, which both develop and produce Complex Products and Systems. Organization 1 is a global company in the oil and gas industry, while oorganization 2 is a global company in the maritime and energy sector. Informants are selected based on their knowledge and experience related to Lean Product Development, Knowledge Management, and engineering in conjunction with projects. Data has mainly been collected through semi structured interviews. All interviews have been transcribed and coded prior to the actual analysis.

We have found that organization 2 has a higher focus on Lean Product Development, while organization 1 has a higher focus on Knowledge Management, which influence the organizations approaches regarding the two concepts. Lean Product Development is mainly used in both organizations to standardize products, processes, procedures, tools etc., as well as locating, removing and/or prevent waste, in order to increase efficiency. It seems evident that knowledge creation, transfer, storage, and application are intertwined, and must therefore be viewed as an interacting whole. If one of them are managed poorly it will affect the others. Several initiatives regarding Knowledge Management are implemented in both organizations, most in relation to knowledge transfer and storage. Knowledge creation is regarded important, but do not seem to be clearly facilitated, while knowledge application is of fluctuating focus. Knowledge Management is mainly used to increase efficiency and lower cost, by reusing knowledge and avoid making the same mistake twice.

Knowledge Management is advantageous in Lean Product Development regarding efficiency, standardization, and waste reduction. Knowledge, information, and experience are made available through Knowledge Management and contribute to standardize products, processes, procedures etc., as well as locating, removing and/or prevent waste, in order to increase efficiency. Lean Product Development is advantageous in Knowledge Management as it contributes to standardize how knowledge is transferred, stored, and applied, as well as to increase the focus on removing non-value-adding information stored in knowledge systems.

Our theoretical contribution is an increased understanding of how organizations make us of Lean Product Development and Knowledge Management separately when engineering Complex Products and Systems in projects, as well as how the two concepts enhance each other. Further, practical examples of how Knowledge Management influence and enhance Lean Product Development (standardization, waste reduction, and thus efficiency) in the engineering phase, as well as how Lean Product Development influence and enhance Knowledge Management (knowledge transfer, storage, and application) in the engineering phase, is provided.

Sammendrag

I dag er organisasjoner opptatt av hvordan de kan produsere produkter av høy kvalitet til lavest mulig kostnader, for å kunne være konkurransedyktige i et svært konkurransepreget marked. Lean og Knowledge Management har vist seg å være viktige konsepter for å kunne oppnå et konkurransefortrinn. Komplekse produkter og systemer blir produsert i små partier eller enkeltstående prosjekter med lang utviklingsledetid, er ansett for å være programvareintensive, samt for å bestå av dyr teknologi. Det er dermed viktig at prosjektene gjennomføres effektivt og problemfritt, slik at konkurransedyktige produkter og systemer både kan utvikles og produseres til lavest mulig kostnader.

Det eksisterer lite forskning angående hvordan Lean Product Development kan benyttes i organisasjoner som utvikler komplekse produkter og systemer. Den litteraturen som finnes, antyder derimot at Lean Product Development er viktig for å kunne utvikle produkter av høy kvalitet på en effektiv måte, noe som også er avgjørende ved utvikling av komplekse produkter og systemer. Knowledge Management anses som svært viktig i forhold til utvikling av komplekse produkter og systemer, da det gjør kunnskap tilgjengelig på tvers av ulike prosjekter i organisasjonen. Det er derimot gjennomført få casestudier i forhold til dette forskningsfeltet, samt at det er manglende forskning på hvordan Knowledge Management kan benyttes i praksis i organisasjoner som utvikler komplekse produkter og systemer. På bakgrunn av dette er det tydelig at det eksisterer et behov for å fremskaffe mer kunnskap, samt en økt forståelse for hvordan Lean Product Development og Knowledge Management blir benyttet i organisasjoner som utvikler komplekse produkter og systemer.

Flere forskere har inkludert kunnskap og Knowledge Management som en viktig del av Lean Product Development. For at en organisasjon skal kunne være Lean i produktutviklingsfasen må den mestre kunnskap og læring. På bakgrunn av dette, er vi av den oppfatningen at det er behov for en dypere forståelse for hvordan Lean Product Development og Knowledge Management kan bli benyttet ved engineering av komplekse produkter og systemer i prosjekter, samt hvordan disse konseptene påvirker hverandre. Forskningsspørsmål vårt er formulert på følgende måte:

"How do organizations use Lean Product Development and Knowledge Management when engineering Complex Products and Systems in projects?

- *how do the two concepts influence each other?"*

Etter å ha gjennomgått eksisterende teori relatert til forskningsspørsmålet, ble Lean Product Development og Knowledge Management delt inn i respektive underkategorier. Lean Product Development ble delt inn tre underkategorier, effektivitet, standardisering og waste-reduksjon. Knowledge Management ble delt inn i fire underkategorier, kunnskapsproduksjon, kunnskapsoverføring, kunnskapslagring, og kunnskapsanvendelse. Forholdet mellom Lean Product Development og Knowledge Management er sett i forhold til de samme underkategoriene listet opp under Lean Product Development.

Det er brukt en kvalitativ forskningstilnærming med casestudie som forskningsstrategi for å undersøke hvordan Lean Product Development og Knowledge Management er benyttet ved engineering av komplekse produkter og systemer i prosjekt, samt hvordan de to konseptene påvirker hverandre. Det er benyttet et holistisk multiple-case design, og hvert case har blitt valgt ut på bakgrunn av dets relevans i forhold til forskningsspørsmålet. I denne studien har to ulike bedrifter, som begge utvikler og produserer komplekse produkter og systemer, blitt studert. Organisasjon 1 er et globalt selskap i olje- og gassbransjen. Organisasjon 2 er et globalt selskap i maritim- og energibransjen. Informantene er valgt på bakgrunn av deres kunnskap og erfaring i forhold til Lean Product Development, Knowledge Management og engineering i prosjektfasen. Data har i hovedsak blitt samlet inn ved bruk av semistrukturerte intervjuer, og alle intervjuene har blitt transskribert og kodet i forkant av selve analysen.

Vi har funnet at organisasjon 2 har et større fokus på Lean Product Development, og at organisasjon 1 har et større fokus på Knowledge Management. Dette påvirker hvilken tilnærming organisasjonene har i forhold til konseptene. Lean Product Development er i hovedsak brukt til å standardisere produkter, prosesser, prosedyrer, verktøy etc., i tillegg til å fjerne og/eller forhindre ikke-verdiskapende aktiviteter (waste), i begge organisasjoner. Dette gjøres for å bedre effektiviteten. Det virker tydelig at kunnskapsproduksjon, -overføring, -lagring, og -anvendelse samspiller og derfor må betraktes som en helhet. Hvis en av aspektene er dårlig administrert, vil det påvirke de andre aspektene. Flere tiltak vedrørende Knowledge Management er implementert i begge organisasjoner, men flest i forhold til kunnskapsoverføring og -lagring. Kunnskapslagring er ansett som viktig, men virker ikke å være tydelig tilrettelagt. Kunnskapsanvendelse er av varierende fokus. Knowledge Management er hovedsakelig benyttet til å øke effektivitet og redusere kostnadene, ved å gjenbruke kunnskap, samt ved å ikke gjenta feil.

Knowledge Management er fordelaktig i Lean Product Development vedrørende effektivitet, standardisering og å redusere waste. Knowledge Management gjør kunnskap, informasjon og erfaring tilgjengelig. Knowledge Management bidrar dermed til å kunne bedre effektivitet, ved å standardisere produkter, prosesser, prosedyrer etc., i tillegg til å lokalisere, fjerne og/eller forhindre waste. Lean Product Development er fordelaktig i Knowledge Management da det kan bidra til å standardisere hvordan kunnskap overføres, lagres og anvendes, i tillegg til å øke fokuset på å fjerne ikke-verdiskapende informasjon lagret i kunnskapssystemer.

Denne studiens teoretiske bidrag er en økt forståelse for hvordan organisasjoner benytter seg av Lean Product Development og Knowledge Management separat ved engineering av komplekse produkter og systemer i prosjekter, samt hvordan de to konseptene påvirker hverandre. Videre er det fremstilt praktiske eksempler på hvordan Knowledge Management påvirker og forsterker LPD (standardisering, waste reduksjon og dermed effektivitet) i engineering fasen. Det er også fremstilt praktiske eksempler for hvordan Lean Product Development påvirker og forsterker Knowledge Management (kunnskapsoverføring, -lagring, -anvendelse) i engineering fasen.

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Definitions of frequently used terms

In order to avoid misunderstandings, we have made a list of terms frequently used in this thesis, with associated definitions.

Complex Products and Systems (CoPS) is defined as high cost technology and software intensive products, systems, and capital goods, which are manufactured in small batches or one-off projects with long development lead time and many customized exclusive subsystems

Efficiency is defined as being able to accomplish something with the least waste of time and effort.

Engineering is defined as the application of scientific, mathematical principles and knowledge to the design, and operation of efficient and economical structures, machines, processes, and systems.

Engineering phase is defined as the part of a project in which engineering is conducted.

Explicit knowledge is defined as knowledge that can be expressed in words or in any other form, and that easily can be shared with others in a formal and structured way.

Knowledge is defined as a dynamic human process, and in that regard, a fluid mix of framed experiences, values, contextual information, and expert insight.

Knowledge application is defined as using knowledge to perform a task or solve the problem at hand

Knowledge creation is defined as developing new content or replacing existing content within tacit or explicit knowledge.

Knowledge Management (KM) is defined as a process of continually managing both explicit and tacit knowledge in the organization, which comprises the creation, storage/retrieval, transfer, and application of knowledge.

Knowledge storage is defined as knowledge residing in various component forms, including written documentation, structured information stored in electronic databases, codified human knowledge stored in expert systems, documented organizational procedures, processes, and products.

Knowledge transfer is defined as the conveyance of knowledge from one place, person, or ownership to another.

Lean mindset is defined as focus on efficiency and waste reduction without implementing specific Lean tools/aspects.

Lean Product Development (LPD) is defined as a systematic and continuous process of identifying and eliminating waste, as well as standardizing processes in all areas of the value stream, in order to enhance efficiency.

Project is defined as an endeavor designed to produce a unique product or system, service or result with a specified goal, within a specified budget and in stated timescales.

Standardization is defined as the process of developing and implementing processes, products, documents, etc., in order to ensure repeatability.

Tacit knowledge is defined as knowledge that is highly personal, not easily visible, and difficult to communicate to others, making it difficult to formalize.

Waste is defined as a non-value-adding activity.

Waste reduction is defined as actively finding and removing activities in a process that do not bring value to the customer.

1 Introduction

Today, organizations are concerned with how they can produce high quality products at the lowest cost, in order to stay competitive in a highly competitive market. Lean approaches and Knowledge Management (KM) have shown to be important concepts in organizations in order to achieve a competitive advantage. This makes them interesting to study further. In this chapter the background and our motivation for undertaken this specific study is explained. Further, the research question is presented, and clarifications related to the question of research are accounted for. Further, terms frequently used in this thesis are defined, and finally, it is explained what the master thesis comprises, and how it is structured.

The overall purpose of this master study is to gain an understanding of how Lean Product Development (LPD) and KM may be used in organizations that develop and/or produce Complex Products and Systems (CoPS), as well as how the two concepts influence each other.

1.1 Background and motivation

Today, organizational competition is tough and customer's demands higher than ever before. This makes it important for an organization to be cost-effective and to deliver high quality products. LPD focuses on eliminating waste, keeping non-value adding activities to a minimum, and standardize processes in order to make them more efficient. KM helps organizations to store, transfer, and reuse knowledge and experiences in order to increase efficiency and improve quality. Hence, both LPD and KM contribute to develop and produce products of high quality. For this reason, KM and LPD are viewed as important factors in order to improve the development of CoPS.

The authors' motivation for undertaking this field of study is primarily personal interest. Lean has been taught in several classes during our bachelor and master degree, and we both find this topic exiting as it is currently aspiring in several industries. KM is today viewed as an important part of any organization, as several scholars have acknowledged knowledge as the most essential resource of an organization (Grant, 1996; Hansen, et al., 1999). This makes KM interesting to study further. There are several reasons why we would like to examine how LPD and KM are used and exploited in CoPS. First, we have both been employed as interns at an organization

which develop and produce CoPS. This means that we are somewhat familiar with such organizations. Lean is usually associated with, and implemented in mass production organizations. We both think project based organizations which develops CoPS are more interesting than these types of organizations, due to its complexity and uncertainties. Second, as discussed in chapter 2, the fact that it is a lack of research on how LPD and KM are used in organizations developing CoPS, creates a need to obtain more knowledge and a deeper understanding of the phenomena. This field of research is quite broad, which makes it possible to address the phenomena with different perspectives.

LPD, which focuses on identifying and eliminating waste, keeping non-value adding activities to a minimum, and standardize processes in order to make them more efficient (Haque & James-Moore, 2004), is important in order to make the development process efficient. Knowledge is today viewed as the most valuable and important organizational resource, and the acknowledgment of the importance of creating, transferring, storing and applying knowledge in businesses has laid the foundations for the need of KM. Scholars argue that managing the use and storage of knowledge, data, and information is no longer an option, but a necessity in every business, in order to obtain a competitive advantage (Hansen, et al., 1999; Wiig, 1997; Zhao, et al., 2012).

Several researchers also include knowledge and KM as an important part of LPD (Liker & Morgan, 2006; Radeka, 2012; Lindlöf, et al., 2013) and it is stated that an organization has to master knowledge and learning in order to be Lean in the product development phase (Radeka, 2012).

As CoPS can be interpreted differently, we find it important to define the meaning of CoPS for this particular study. Hobday (2000) defines CoPS as "high cost technology and software intensive products, systems, and capital goods, which are manufactured in small batches or one-off projects". As CoPS tend to be produced in small batches or only for a specific user, the innovation process allows for a high degree of direct user involvement. CoPS typically involve many interconnected customized parts and components designed in a hierarchical manner, which cause high uncertainty in the design phase. Small design changes in one part of the system can lead to large alterations in other parts. Hansen and Rush (1998) defines CoPS as "A complex

system with high technical content and development cost, long development lead time, and many customized exclusive subsystems".

For the purpose of the further work with this thesis, we hybridize the definitions of Hobday (2000) and Hansen and Rush (1998) and define CoPS as high cost technology and software intensive products, systems, and capital goods, which are manufactured in small batches or one-off projects with long development lead time, and many customized exclusive subsystems.

There is a lack of research explaining the use of Lean and LPD in organizations that develop CoPS compared to the development of less complex products. However, the literature suggests that LPD is important in order to develop high quality products efficiently, which also is vital when developing CoPS. The focus of KM is of high importance when dealing with CoPS as it helps the organization to manage knowledge across project families or organizational boundaries (Oshri & Newell, 2005). However, as projects differ substantially from one another, it is difficult to develop steady routines in order to maximize knowledge flow and capture lessons learned from one project to the next (DeFillippi & Arthur, 1998; Hanisch, et al., 2009).

1.2 Research question

Based on the preceding discussion, LPD and KM may both be regarded as important concepts in organizations developing CoPS. However, there is a lack of research regarding how these concepts are being used in a CoPS context. In order to gain an understanding and generate more knowledge regarding this, we have chosen to examine how LPD and KM are used in practice in organizations that develop and/or produce CoPS. In order to narrow down the focus of this study, we have chosen to examine how LPD and KM are used during engineering of CoPS in projects. Engineering is in this thesis defined as the application of scientific, mathematical principles and knowledge to the design, and operation of efficient and economical structures, machines, processes, and systems. As the previous discussion also suggests that KM is important in order to be Lean in the engineering phase, we want to examine how this relationship unfolds in a CoPS setting. On this basis, the research question is formulated as follows:

"How do organizations use Lean Product Development and Knowledge Management when engineering Complex Products and Systems in projects?

- *how do the two concepts influence each other?"*

We are well aware of the fact that this is an extensive research question. We are also aware that both KM and LPD are terms consisting of multiple factors/aspects, and hence can be interpreted differently. However, as there is a lack of research on the question under study, we consider it as important to undertake a wide perspective in order to get a comprehensive insight. This will also make it possible to conduct further studies with other perspectives relative to the question under study, at another time. The goal is not to compare the way LPD and KM is used in different organizations, but to gain an understanding of how these concepts may be used.

As the research question is quite extensive we have found it necessary to operationalize it, in order to be able to answer the research question properly. The operationalization question is stated as followed.

1. How differences in terms of how LPD and KM are used when engineering CoPS, can be explained?

2a. If LPD is regarded as valuable in the engineering phase in projects, or not?

2b. If KM is regarded as valuable in the engineering phase in projects, or not?

3. If it is used specific initiatives or aspects regarding LPD or if it is more in terms of having a Lean mindset?

4a. If using LPD is something employees concern themselves with on an everyday basis, or if it is just underlying elements that is controlled by the management – a top-down approach?

4b. If using KM is something employees concern themselves with on an everyday basis, or if it is just underlying elements that is controlled by the management – a top-down approach?

5. If it is specific tools or aspects regarding KM the organizations emphasize?

6. How LPD and KM influence each other in the engineering phase?

1.3 Clarifications

As our research question states that we want to examine how LPD and KM is used when engineering CoPS in projects, we find it necessary to clarify what we consider engineering in projects are. A project consists of different phases depending on the company and the products they produce and sell. The following figure illustrates an example of the different phases a

project may consist of. As illustrated in the figure, the engineering phase is part of the project, which is the main focus area of this thesis.

Figure 1 Project phases

1.4 Presentation of the organizations

In order to preserve the anonymity, we only present a few general facts about the case-organizations. Organization 1 is a large global company in the oil and gas industry. The organization employ between 15000-20000 people globally, and their revenue at the end of 2015 was over 3,000 million USD. Organization 2 is a global company in the maritime and energy sector. The organization employ between 3000-7000 people globally, and their operating revenues in 2015 was over 1,000 million USD.

1.5 Thesis disposition

This thesis is disposed as follows. In chapter two a theoretical review is presented, in which existing theory in relevance to the research question, stated previous in this chapter, is presented and discussed. This creates a theoretical foundation, and underpin the need for this particular study. In chapter three, the methodological choices taken regarding research approach and study design, selection of case and informants, data collection, analysis and quality assurance is thoroughly explained and argued for. In chapter four, the case study organizations are shortly presented. In chapter five, an analysis of the data collected is conducted and the findings are accounted for. In chapter six, the final result is presented and discussed in relation to the theoretical framework presented in chapter two. Finally, a conclusion is provided, theoretical and practical implications, as well as reflections regarding the study are discussed, and suggestions for further research is accounted for.

2 Theory

In this thesis we examine how LPD and KM are used in organizations when engineering CoPS in projects, and how LPD and KM influence each other. The purpose of this chapter is to create a theoretical foundation, as well as to underpin the need for this particular study. In this regard, existing theory in relevance to the research question stated in the introductory chapter, is presented and discussed. The different search methods used to find relevant theory is further explained.

General databases like Oria and Google Scholar have mainly been used when searching for relevant articles regarding this study. However, we have also made use of databases like EBSCO Host, JSTORE and Web of Science. Articles, studies, and books used as references in this literature review have been carefully selected, by relevance and quality. Literature from different time frames, both older and recent publications, have been used. We have mostly used articles and studies from journals, but also a few relevant books. Literature with high citation rates has been used most frequently, but also some with lower citation rates, which we still found relevant and of good quality. We have also examined references in the literature used, in order to expand our theoretical research and confirm quality.

There exist lots of previous research on some of the topics in focus, and less on others. This have made the search for relevant literature quit challenging. We have also made a listing of the different articles and books used in this thesis, and their respective publishing channels, presented in appendix 1. This table also contains ratings of the different channels from the Norwegian Center for Research Data (NSD), as well as the number of citations each article have on google scholar.

Overall, this chapter explores existing knowledge of LPD and KM, as well as previous research in regards to how these concepts may be exploited during development of CoPS First, theory on the two main topics studied in this thesis, LPD and KM, and the connection between the two, are accounted for. Further, the role of LPD when developing CoPS and the role of KM when developing CoPS is explained. Finally, it is discussed how LPD and KM may both be used and exploited when developing CoPS.

2.1 Product development

Delivering the right products at the right cost with strong marketing support will ensure a company's competitiveness. In order to stay competitive, companies need to keep up with market trends, emerging technology, and refinements to existing products. A competitive product development strategy should include a company-wide commitment to creating items that fulfill particular consumer needs or characteristics. Product development can either involve improving existing products, or developing new products (Krishnan & Ulrich, 2001).

Many companies treat product development as if it were similar to manufacturing. This is not possible as they are two profoundly different processes. In manufacturing the objects are physical, the tasks are repetitive, activities are more or less predictable, and the items being created can only be in one place at the time. In product development on the other hand, tasks are unique, product requirements constantly change, and the output is information, which can reside in multiple places at the same time. The latter is due to the widespread use of advanced computer-aided design and simulation (Thomke & Reinertsen, 2012). Due to these differences there exists several recipes and strategies which undermine how to plan, execute, and evaluate product development projects.

We have in this theses decided to focus on how the theory of Lean Product Development, also called Lean Engineering, can be used in order to enhance the engineering phase of existing products and systems in projects. For the purpose of this thesis, engineering is defined as the application of scientific, mathematical principles and knowledge to the design, and operation of efficient and economical structures, machines, processes, and systems (Sols, 2014). We would like to base this study on engineering conducted in projects, which in turn means that we only will focus on the enhancement of existing products and not the development of completely new products. Project is in this thesis defined as an endeavor designed to produce a unique product or system, service or result with a specified goal, within a specified budget and in stated timescales (Sols, 2014). In short the focus of this study is on the engineering phase in projects, which we define as the part of a project in which engineering is conducted.

The theory regarding LPD will be discussed in detail in the upcoming chapter.

2.1.1 Lean Product Development

In this chapter the term LPD is explained, and existing research on the field is accounted for. First, an introduction to LPD is provided, before different theoretical approaches is presented. Finally, we present various definitions of the term, and presents a definition which is suitable for this theses.

2.1.1.1 Introduction

Efficiency has played a central role for manufacturing companies since the conception of the assembly line and the following development of the Toyota Production System (TPS) (Holweg, 2007). However, the "Lean" way of thinking is no longer restricted to shop floors, but has during the last decade also spread to other parts of the organization as well as other industries. Liker and Morgan (2006) argue that to be effective, "Lean", defined as a continuous process of improving and eliminating waste in the value stream, as well as a process of making the entire enterprise working together and striving for perfection, in order to give customers what they want, cannot stop at the shop floor. Management principles must extend beyond the shop floor, as they do at Toyota, and be found in the board room, the sales offices, and in the product development process. The book "The machine that changed the world" by Womack, et al. (1990), is primarily known for popularizing Lean Production, which can be defined as a set of practices focusing on reducing waste and non-value added activities from a firm's manufacturing operations (Womack, et al., 1990; Shah & Ward, 2003). However, they have later emphasized that the production floor only was one chapter of the book. In fact, the book was about an entire enterprise working together in order to give customers what they wanted, while simultaneously eliminating waste in the value stream and striving for perfection (Liker & Morgan, 2006). One example of this is LPD, which also was presented in the book. LPD is based on the fundamental goals of the TPS, which aim at continuously minimizing waste to maximize flow. Contrary to TPS, the focus of LPD is on the process of developing products and not producing them. Nevertheless, identifying "Lean waste", and eliminating it, keeping non-value adding activities to a minimum, standardize processes, and continuously improve are also key activities in LPD (Haque & James-Moore, 2004).

During the last two decades, the changing market conditions, increasing customer requirements, and growing technology have made the competition in the manufacturing industry fierce. Firms have, in order to survive in this competitive market, started to implement various elements of

Lean practices. Today, Lean is often regarded as the most important strategy for manufacturing firms desiring to achieve world-class performance (Fullerton, et al., 2013).

2.1.1.2 Lean Product Development principles

The principles of Lean can be implemented to an industry by the help of various tools and techniques such as; Total Productive Maintenance (TPM), Just in time manufacturing (JIT), Total Quality Management (TQM), Failure Mode and Effect Analysis (FMEA), 5S, Quality Function Deployment (QFD), Balanced Scorecard (BSC), Kaizen, Kanban, Value Stream Mapping (VSM), etc. (Braglia, et al., 2006). These are some of the most popular techniques in a Lean context in general. In the following paragraphs existing research specific to LPD techniques, tools and principles are presented.

According to Karlsson and Aahlstrom (1996) a company cannot achieve a LPD process simply by implementing some principles or techniques, rather a company must approach the different principles and techniques as elements of a coherent whole. In their approach LPD involves the following elements: supplier involvement, cross-functional teams, simultaneous engineering (overlapping of activities or processes), a focus on integration of activities instead of coordination, strategic management in terms of visions and objectives instead of detailed specifications, and black box engineering (developing complete modules of the product without detailed specifications). Haque and James-Moore (2004) criticises Karlsson and Aahlstrom's approach for lacking important elements. According to Haque and James-Moore (2004), another important part of LPD is information flow and the IT-systems used to transfer information. They state that an effective communication and data flow is important in order to ensure an effective and value-adding process. Further they state that the key activities that constitute a LPD system is to specify value, model the value stream, eliminate waste, make value flow, let the customer "pull", and continuously improve.

As earlier stated, Lean in general, and therefore also LPD, is based on TPS. Liker and Morgan (2006) outline and illustrate the management principles of TPS which can be applied to any technical or service process, including the product development process in a manufacturing organization. In contrast to Karlsson and Aahlstrom (1996) and Haque and James-Morre (2004), Liker and Morgan (2006) presents a more complex LPD approach with several dimensions. They define their approach as a "true systems approach that effectively integrates people, processes,

and technology—one that must be adopted as a continual, comprehensive, and coordinated effort for change and learning across the organization." Their system approach consists of 13 principles concerning the three categories process, people, and tools and technology. According to Liker and Morgan (2006), a good process defined by good process principles is important in LPD. They outline the following four main process principles: (1) establish a customer-defined value to separate value added from waste, (2) front load the product development process to thoroughly explore alternative solutions while there is maximum design space, (3) create a levelled product development process flow, and (4) utilize rigorous standardization to reduce variation, and create flexibility and predictable outcomes. The aim of these principles is to generate a process which focuses on customer value, keeping an even flow throughout the process, reducing costs through the product life cycle by avoiding choosing premature solutions, and continuously improvement through standardization. Further, Liker and Morgan (2006) presents the following six people principles of LPD: (5) develop a "chief engineer system" to integrate development from start to finish, (6) organize to balance functional expertise and cross-functional integration, (7) develop towering technical competence in all engineers, (8) fully integrate suppliers into the product development system, (9) build in learning and continuous improvement, and (10) build a culture to support excellence and relentless improvement. The aim of these principles is to have one chief engineer with final authority and responsibility of the product development process per project. This to make sure the engineers are competent with the right knowledge, and additionally to build in organizational learning, which is described as a necessary condition for continuous improvement. The last three following principles are related to tools and technology: (11) adapt technology to fit your people and processes, (12) align your organization through simple, visual communication, and (13) use powerful tools for standardization and organizational learning. The aim of these last three principles is to use simple, but powerful tools and technology which enables standardization and organizational learning.

Just like Liker and Morgan (2006), Letens, et al. (2011) characterised LPD as a complex system involving multiple organizational levels. They present the three following levels that according to them should be considered in LPD: the project-level, the functional-level, and the portfolio-level. They also state that there are two main principles that needs to be considered both within and across the three levels – value definition and work flow optimization. In their case study, Letens, et al. (2011) implemented practices and tools for defining value and optimizing flow in a

company, and reported their findings in relation to the conceptual framework of LPD. On the project-level the authors stress the importance of distinguishing between value-added and non-value added activities, as it is impossible to optimize value without knowing the difference. According to Browning (2003), activities are value-adding when they are linked to creation of deliverables that increase product development value and reduce project risk. Hines, et al. (2006) suggests that the process of defining value in product development also must integrate the perspectives of internal and external stakeholders. After the value-adding activities have been identified, Letens, et al. (2011) found other Lean improvement techniques which could be applied in order to improve the efficiency of the project process flow. These techniques are product development value stream mapping, concurrent engineering, integrated project teams, kanban, standardization, supplier partnership, and pull thinking. On the functional-level they found that value must be defined by the customer, and later translated into meaningful technical requirements. In order to achieve improved flow, several classical Lean improvements initiatives such as 5S, standard work, and pull thinking was identified. On the portfolio-level the objective was to select and deploy a valuable portfolio of projects that guaranteed long-term success in a global environment. In order to optimize flow at this level, the authors found it important to establish long-term relationships with customers and suppliers. This increased the flow of knowledge between the organization and its customers, and optimized the flow of materials, information and knowledge with supply chain partners. Long-term planning of critical resources was also found to be a technique for optimizing flow at the portfolio-level.

The theory presented in this section illustrates organizations and scholars increasing focus on LPD during recent years. The articles presented also makes it clear how the LPD theory has developed from being relatively simple with focus on only one dimension of the organization, to include several dimensions. The literature also illustrates an increasing focus on knowledge and knowledge flow in the product development process. In the following chapter, a definition of the LPD-term is provided.

2.1.1.3 Definitions

According to Hines, et al. (2004), the Lean-term is constantly evolving. This implies that "definitions" of Lean concepts are just a "still image" of a moving target, only being valid in a certain point in time.

LPD has very few direct definitions associated with it, but rather general definitions of the Lean-term that describe the overall purpose of the theory. Examples of definitions that describe LPD is presented in the table below.

Definition of Lean Product Development:	**Supporting literature:**
"The systematic removal of waste by all members of the organization from all areas of the value stream."	(Worley & Doolen, 2006)
"All business processes and functions integrate into a unified, coherent system whose single purpose is to continue to provide better value to customers."	(Grasso, 2005)
"An integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability."	(Shah & Ward, 2007)
"Lean is identified as a global model with fully fledged integration of: Totally committed management. (2) Highly trained, motivated and empowered employees working in a team. (3) Internal integration of operations with suppliers and customers. (4) Promotion of creativity and innovative culture. (5) Streamlining of processes and waste elimination."	(Vinodh & Joy, 2012)
"Lean Product Development is product developers systematically solving problems to maximize value and minimize waste across the entire system."	(Radeka, 2012)

Table 1 Definitions of Lean Product Development

For the purpose of our research, we combine the theory presented by Haque & James-Moore (2004) and the definition presented by Worley & Doolen (2006), and define LPD as a systematic and continuous process of identifying and eliminating waste, as well as standardizing processes in all areas of the value stream, in order to enhance efficiency.

In order to clarify the LPD definition, we have also defined waste, waste reduction, standardization, and efficiency. Waste is defined as a non-value-adding activity. Waste reduction is defined as actively finding and removing activities in a process that do not bring value to the customer. Standardization is defined as the process of developing and implementing processes, products, documents, etc., in order to ensure repeatability. Efficiency is defined as being able to accomplish something with as little waste of time and effort as possible.

2.2 Knowledge Management

In this chapter, the term KM is carefully explained, and existing research on the field is accounted for. Firstly, an introduction to KM is presented as well as the development of the term. KM emerged from the need of managing knowledge in businesses, and a definition of knowledge is therefore provided. Different definitions and perspectives on KM is further presented, and finally a definition suited for this literature review is provided and explained.

2.2.1 Introduction

The development of the term KM originates from the acknowledgement of the importance of storing and reusing knowledge in businesses. The current view of knowledge, being the most valuable and important organizational resource, has laid the foundations for the need of KM. Managing storage, transfer, and use of knowledge, data, and information is no longer an option, but a necessity in every business, in order to obtain a competitive advantage (Hansen, et al., 1999; Nonaka, 1991). Today customers are more demanding than ever before, and they expect their needs and anticipations to be constantly fulfilled. The businesses that own the latest knowledge, acquires more knowledge, update knowledge, and additionally are able to exploit this knowledge to the fullest, will fulfill customer needs, secure maximum value, and be able to achieve a superior competitive advantage (Wiig, 1997; Zhao, et al., 2012; Grant, 1996).

In family businesses, knowledge sharing has been done for hundreds of years, as wisdom has been transferred from the parents to their children. In other occupations, knowledge, ideas, and expertise have been transferred from skilled workers to their apprentices and between people in general (Hansen, et al., 1999). Today, knowledge is created, shared, and applied in all parts of the society and economy in an incredible speed (Ergazakis, et al., 2013). In organizations, knowledge is regarded as an important resource due to a shift in the foundation of industrialized economies from natural resources to intellectual assets. Nonaka (1991) argues that the success of organizations, is a result of their approach to managing the creation of new knowledge. It is therefore important for executives to examine the underlying knowledge in their businesses and how it is created, in addition to understand how to use this knowledge (Hansen, et al., 1999).

2.2.2 Development of KM

Since the mid-20th century, knowledge has been explored as an organizational resource, and KM was later used as a term for managing the organizational knowledge. KM is a natural result of the economic, industrial, and cultural developments that have taken place. Several historical

developments of economic activities have led to today's importance of KM. The Agrarian Economics, Natural Resource Economics, Industrial Revolution, and Product Revolution have led to the Information and Knowledge Revolution. The information revolution took place during the second half of the 20th century, where information technology (IT) became available. IT led to increased information gathering and information exchange between businesses, suppliers, and customers. Today the dominant economic activity and focus is called the knowledge revolution, as knowledge is acknowledged as the most important resource for competitive advantage (Wiig, 1997). Even though knowledge is regarded as the most important resource, scholars do agree that it is not the knowledge itself that lead to competitive advantage, it is how well it is managed.

2.2.3 Knowledge

Some of the world's greatest thinkers have tried to explain the term knowledge (Grant, 1996), and there exists several definitions, in which some of them is displayed in appendix 2. How knowledge is viewed depends on the context, as knowledge may be used in every aspect of life. In our opinion knowledge is something created by humans, in other words a human process. We do agree with the knowledge definitions of both Nonaka and Takeuchi (1995), and Davenport and Prusak (1998), and define knowledge as a dynamic human process, and in that regard, a fluid mix of framed experiences, values, contextual information, and expert insight.

Knowledge is commonly divided into explicit and tacit knowledge. Explicit knowledge can be written down, and hence easily stored in databases, while tacit knowledge is in the form of "know-how", skills and practical knowledge, which cannot easily be obtained or stored, and which is best taught through experience (Nonaka, 1991; Nonaka & Takeuchi, 1995; Grant, 1996). For the purpose of this thesis, explicit knowledge is defined as knowledge that can be expressed in words or in any other form, and that easily can be shared with others in a formal and structured way. Tacit knowledge is defined as knowledge that is highly personal, not easily visible, and difficult to communicate to others, making it difficult to formalize (Sols, 2014).

2.2.4 Knowledge Management

People possess a lot of knowledge, which they may not even realize might be of value to themselves or others. If organizations are able to manage the valuable knowledge of every single employee's possession, they will most certainly increase their performance. However, this is difficult, if not impossible to conduct, as human knowledge may be difficult to obtain and as

traditional database structures are unable to hold all available information. On the other hand, information technology is improving in a rapid speed, which helps to organize human knowledge and information, in order to make it accessible for others (Quintas, et al., 1997). Even though this statement is taken from an old source, we are of the opinion that this statements is as relevant today as it was almost 20 years ago. The overall goal of the organization should not be to obtain all knowledge of every employee, but to obtain that of value to the business. It is only the information which is actively processed in the mind of a person through reflection, enlightenment, or learning that can be useful to an organization (Alavi & Leidner, 2001). Gao, et al. (2008) argue that knowledge in organizations can be divided into personal knowledge owned by each one of the employees, and business knowledge which is practical or useful knowledge for management, production, service, and innovation owned by the organization. Organizations have an interest in using both the personal and the business knowledge.

2.2.5 Research contributions and definitions

Researchers and practitioners have approached KM with numerous different perspectives and several definitions exists, in which some are presented in the following table.

Definitions of KM	**Scholars**
"KM is a process of continually managing knowledge of all kinds and requires a company-wide strategy, which comprises policy, implementation, monitoring and evaluation" This policy should ensure the availability of knowledge at all times, and the acquiring of knowledge from both internal and external sources.	(Quintas, et al., 1997)
"KM is to manage effective knowledge processes by renewing the businesses knowledge assets constantly and then use these assets to maximize the business knowledge-related effectiveness and returns" Managing the effective knowledge process require understanding, focus, and systematic, explicit and deliberate managing of knowledge building, as well as renewal and application of knowledge.	(Wiig, 1997)
"knowledge management in a business organization means managing the activities of knowledge workers, which is achieved through facilitating, motivating, leading, and supporting knowledge workers and providing or nurturing a suitable working environment"	(Gao, et al., 2008)
"KM is to manage the intellectual assets of the organization as well as knowledge activities". Knowledge activities comprises knowledge acquisition, knowledge storage, knowledge sharing, knowledge integration, knowledge creation, knowledge diffusion, knowledge transfer, knowledge application and knowledge spillover etc.	(Zhao, et al., 2012)

Table 2 Definitions of Knowledge Management

"The Knowledge-Creating Company", a book written by Nonaka and Takeuchi, published in 1995, is by many seen as the starting point for one's general knowledge of KM as an international field of expertise (Sandvik, 2001), and hence play and important role in the development of the KM term. Nonaka and Takeuchi (1995) focus on knowledge creation in their book. They argue that new knowledge always begins with the individual and that it is continuously taking place in the organization. Further, they argue that the central activity of a knowledge-creating company is making personal knowledge available to others. In order to achieve this, knowledge must be expressed in such a manner as to be interpretable by the receivers (Alavi & Leidner, 2001).

Wiig (1997) suggest two objectives of KM: (1) To make the enterprise act as intelligently as possible to secure its viability and overall success and (2) to otherwise realize the best value of its knowledge assets. Wiig (1997) also refers to four areas of systematic KM of emphasis from a managerial perspective: "(1) Top-down monitoring and facilitation of knowledge-related activities; (2) Creation and maintenance of knowledge infrastructure; (3) Renewing, organizing, and transferring knowledge assets; and (4) Leveraging (using) knowledge assets to realize their value".

Alavi and Leidner (2001) argue that organizations consist of four sets of socially enacted knowledge processes: 1) Creation and/or construction, 2) Storage or retrieval, 3) transfer, and 4) application.

Zhao, et al. (2012) definition (presented in table X) is formed on the basis of the organizational knowledge management framework (PDCA promotion model). The framework includes several aspects of KM that will lead to organizational competitive advantage: The management of knowledge assets and activities, a knowledge management promotion process, a knowledge set of core competences, a PDCA (plan, do, check, act) quality assurance operation system, the use of IT, and integration of KM in the organizational culture. KM is also closely linked to the knowledge wheel, which is a circle that comprises the acquisition, integration, storage, sharing, transfer, application, and innovation of knowledge. Culture, IT, and management are key elements to promote the wheel of knowledge.

Based on previous research contributions, we define KM as a process of continually managing both explicit and tacit knowledge in the organization, which comprises the creation,

storage/retrieval, transfer, and application of knowledge. KM should also be a part of the organizational strategy and incorporated in the business, as well as supported by IT-tools. The four knowledge processes are further explained in the following subchapters.

2.2.5.1 Knowledge creation

In this thesis we use Pentland's (1995) definition of knowledge creation as a base, and define knowledge creation as developing new content or replacing existing content within tacit or explicit knowledge. Alavi and Leidner's (2001) view on how knowledge is created is based on Nonaka and Takeuchi's (1995) spiral process for organizational knowledge creation. In this spiral process the interaction between explicit and tacit knowledge, as the key dynamics of knowledge creation, takes place repeatedly on individual, group, and organizational levels. In order to create knowledge Nonaka and Takeuchi (1995) presents four major processes of knowledge conversion: 1) From tacit to tacit (Socialization), 2) From tacit to explicit (Externalization), 3) From explicit to explicit (Combination), and 4) From explicit to tacit (Internalization). The most difficult process of the four is converting tacit knowledge into explicit knowledge, as this entails finding a way to express the inexpressible.

The four knowledge creation modes are highly interdependent and intertwined (Alavi & Leidner, 2001). However, they usually occur in different environments through different transfer processes. The organizational knowledge creation process usually begins with socialization in a common place where individuals share experiences primarily through face-to-face interaction. Further, tacit knowledge is converted to explicit knowledge and shared among people through dialogue and collaboration, in the externalization mode. The combination mode often refers to a virtual space of interaction and corresponds to create knowledge. In the internalization mode a space for active and continuous individual learning should be entailed. Alavi and Leidner (2001) argue that information systems, e.g. systems designed for support of collaboration, coordination, and communication, may enhance knowledge creation in organizations.

2.2.5.2 Knowledge transfer

Transfer of knowledge to the people who need it is an important part of KM in organizational settings. It is information flows and communication processes that drive knowledge transfer in organizations. Knowledge transfer may occur at various levels, between individuals, from individuals to explicit sources, from individuals to groups, between groups, across groups, and from groups to the organization (Alavi & Leidner, 2001). Liyanage et al. (2009) define

knowledge transfer as the conveyance of knowledge from one place, person, or ownership to another.

Gupta and Govindarajan (2000) presents five elements of knowledge transfer: 1) Perceived value of knowledge, 2) Willingness to share knowledge, 3) Existence and quality of transmission channels, 4) Willingness to acquire knowledge, and 5) The receiving unit's ability to absorb and use knowledge. Literature often focuses on the third element, knowledge transfer channels, which according to several researchers may be informal, formal, personal, or impersonal (Alavi & Leidner, 2001; Gupta & Govindarajan, 2000). Informal transfer mechanisms may be informal seminars or meetings, or simply coffee break conversations. Examples of formal transfer mechanisms is meetings, training sessions, and plant tours. In this case there exists a formal knowledge coding which ensure greater knowledge distribution, but it may impede creativity. Personal channels are usually more effective for distributing highly context specific knowledge. This may be done by letting people immerse in others routines and hence gain tacit knowledge. Impersonal channels, e.g. knowledge repositories, are usually most effective for knowledge that can be generalized to other contexts.

IT may support all the four mentioned forms of knowledge transfer, and extend knowledge transfer beyond formal communication lines. According to Robertson et al. (1996), people should extend their network beyond there close-knit work networks in order to gain new ideas and new knowledge. Electronic bulletin boards and discussion groups create a forum that may contribute to extend individuals existing network by facilitating contact between those that seeks knowledge and those who possess that knowledge.

Liyanage, et al. (2009) presents a knowledge transfer process model which transfer personal knowledge into organizational knowledge. This process comprises five steps: (1) Awareness, which is identifying valuable knowledge. (2) Acquisition, where the source must be willing to share knowledge, and the receiver must be willing and able to acquire this knowledge. (3) Transformation, which is the conversion of knowledge into something useful for the receiver. (4) Associating, which involves relating the transformed knowledge to the organizational internal needs. (5) Application, in which the knowledge application is used where needed and hence creates value. Elements two, four, and five presented by Gupta and Govindarajan (2000) is covered by step two presented by Liyanage, et al. (2009). The former would we characterizing as

a pure knowledge transfer model, while the latter model comprises transfer as well as the transition between knowledge transfer and knowledge application.

2.2.5.3 Knowledge storage or retrieval

Organizations create knew knowledge every day, but this knowledge will also be forgotten if the organizations are not able to store this knowledge. According to Tan et al. (1998), knowledge storage, or organizational memory, is residing in various forms including written documentation, codified human knowledge stored in expert systems, structured information stored in electronic databases, and documented organizational procedures, processes, and products. In the literature a distinction between individual and organizational memory has been made. "Individual memory is developed based on a person's observations, experiences, and actions" (Alavi & Leidner, 2001). Organizational memory is how experience, knowledge from the past, and events influence current organizational activities. It includes structure, organizational culture, transformations, information archives, and ecology (Walsh & Ungson, 1991). Memory helps storing and reapplying workable solutions which are formed in standards and procedures. Alavi and Leidner (2001) also consider advanced computer technology and sophisticated retrieval techniques as effective tools in order to enhance organizational memory. If changes occur, the IT-systems may be updated and changes made available for all people involved.

2.2.5.4 Knowledge application

Knowledge itself is not the source of competitive advantage, but the application of it is (Alavi & Leidner, 2001). For the purpose of this thesis, knowledge application is defined as using knowledge to perform a task or solve the problem at hand. Grant (1996) identifies directives, organizational routines, and self-contained task teams as the primary mechanisms for the integration of knowledge, in order to create organizational capability. Directives refer to a specific set of rules, standards, instructions, and procedures with the purpose to convert tacit knowledge to explicit. Organizational routines refer to interaction protocols, performance and coordination patterns, and process specifications. When task uncertainty and complexity is high, self-contained task teams, consisting of individuals with different areas of expertise, can be formed for problem solving.

A concern with knowledge is that it may continue to be applied after its real usefulness has declined, hence when the knowledge is outdated. This is more likely to happen when

organizations operate in a changing environment, in which it is a need to continuously renew knowledge. In organizations that have a large number of rules and routines, it may also be a problem choosing which rules and routines to use in a specific setting, and keeping the routines updated. In order to prevent outdated information and routines, IT may be used to codifying and automating information and routines, and by that enhance the speed of knowledge application. IT can also be used to enhance knowledge application, by facilitating the capture, updating, and accessibility of knowledge. By increasing the amount of organizational memory available and the internal social network, IT allows organizational knowledge to be used across time and space (Alavi & Leidner, 2001).

The acknowledgment of knowledge as an important asset in organizations has led to the need to manage this knowledge. KM is not yet finally explored, but several researchers have contributed to the subject. This is mostly done by qualitative research methods in order to define what KM really is, as well as how to use it to utilize organizational knowledge in the best way possible. The aspects they all agree on are that knowledge is the most important organizational resource, and that the businesses that are able to manage knowledge, will obtain a competitive advantage. This makes KM an important field of research.

2.3 Lean Product Development and Knowledge Management

In this chapter the relationship between LPD and KM is explained from different researchers' viewpoints.

Knowledge is described as a natural part of product development (Radeka, 2012), and should therefore also be included in the theory regarding LPD. As chapter 2.1 illustrates, knowledge has become a part of the LPD theory during recent years. Therefore, existing empirical research regarding the relationship between LPD and KM is lacking. However, some researchers have attempted to connect these concepts.

Staats and Upton (2011) have investigated how to implement Lean practices in knowledge work, with emphasis on LP principles. As implementation of Lean in knowledge work was understood to be extremely difficult, Staats and Upton (2011) wanted to challenge this idea and illustrate that such work could in fact benefit from the principles of Lean. They found that some form of Lean principles can be applied to almost all kinds of knowledge work, including product development, and that the implementation of Lean principles could generate several benefits. Some of these

benefits are faster response time, higher quality and creativity, lower costs, reduced drudgery and frustration, and greater job satisfaction. Staats and Upton (2011) presents six principles that managers should follow in order to create the customized Lean approaches best suited to their organizations. These six principles are: (1) continually root out all waste, (2) strive to make tacit knowledge explicit, (3) specify how workers should communicate, (4) use a specific scientific method to solve problems quickly, (5) recognize that a lean system is a work in progress, (6) have leaders blaze the trail. Staats and Upton (2011) conducted their study on one large IT-company. It is interesting that their Lean basis was the principles of LP, as LPD hardly can be considered a new phenomenon. As the LPD theory presented illustrates, many authors before and after Staats and Upton's (2011) research have characterized knowledge as an important part of LPD. From a theoretical viewpoint, Stats and Upton's approach seems logical in terms of Lean theory, as well as feasible. However, we are "concerned" that this approach might be too simple as it fails to include multiple levels of the organization, in addition to the fact that it is not at all specific in terms of how to implement the six principles.

Radeka (2012) describes LPD as a process of maximizing value and minimizing waste in order to deliver the right product to the market, at the right time and the right price. This generates a competitive advantage for companies that focus on LPD. According to Radeka (2012) a company has to master knowledge in order to be Lean in the product development phase. The reason for this is that all organizations that develop products, create knowledge. However, very few of them have the capacity to learn from that knowledge. Further, Radeka (2012) argue that the greatest distinction between LP and LPD is that a failure in manufacturing is almost always waste, while a failure in early product development is a valuable learning experience. By being able to create, capture, share, and use valuable company knowledge, a company is able to spend more time on generating innovative products with high value and low risk through a fast, predictable, reliable, and innovative product development process. The strong bond Radeka (2012) ties between LPD and knowledge seems reasonable. A project based company that develop products will naturally create a lot of knowledge. If that company is able to learn from their mistakes, they will be able to reuse that knowledge in the next project, and prevent the same mistakes from happening again. This will make the company able to spend more time on generating great innovative ideas for their customers, instead of spending time on repeating the same mistakes. However, like Staats and Upton's (2011) research, Radeka (2012) is also very unspecific in terms of how the

organization can learn from their mistakes. The question is then, how the company can save that knowledge and make it reusable in the next project.

Lindlöf, et al. (2013) confirms the theoretical importance of KM in LPD. They combine the spiral process of knowledge creation (socialization, externalization, combination, and internalization), as discussed in chapter 2.2.5.1, with LPD and demonstrate their compatibility. Further, Lindlöf et al. (2013) identify the following three Lean principles and methods to support the transfer of knowledge in a product development setting: mentorship, the chief engineer, and visualisation. The mentor, or leader, in an LPD system should act as a supporting teacher or coach, enabling the employees to learn by doing. The mentors should be the most experienced in their departments, and they should guide their subordinates towards methods rather than results. This principle is strongly related to the socialization mode in the spiral process of knowledge creation, where tacit knowledge is transferred from one person to another. The chief engineer (CE) is described as a "heavyweight project manager with the total responsibility for the development project", and as a result identified as an important part of LPD. The CE has to grasp the needs and wants of the customer, and further be able to communicate this tacit knowledge to the rest of the organization. This is mainly done through concept papers, where the CE makes the tacit knowledge explicit, which is the externalization mode of the spiral process of knowledge creation. The last LPD principle is visualisation, which has proven to be a powerful method where knowledge work is concerned. This is an important principle as the brain is usually able to process images easier than text. Visualization of information can be used to sort, add, combine, and categorise explicit knowledge, and be a tool for helping employees to communicate and acquire information easier. As a result, the visualization principle is strongly combined with the combination mode and the internalization mode. As visualization also can be a helpful tool for transferring tacit knowledge into explicit knowledge, we argue that this principle can be related to the externalization mode as well.

Lindlöf, et al. (2013) illustrates that the combination of LPD and the spiral process of knowledge creation form a methodical foundation that promote knowledge transfer. They also illustrate how knowledge can be transferred from one person to another, but their approach lack information on how the organization can save this knowledge in order to reuse it. Just like Staats and Upton's (2011) approach, Linflöf, et al. (2013) approach does not include several dimensions of the

organization. Nevertheless, it can be argued that this approach is more complex as it combines four modes of KM and three principles of LPD in order to ensure good knowledge transfer in an organization. In contrast to Staats and Upton (2011) and Radeka (2012), this approach is very specific in terms of how an organization can transfer knowledge.

2.4 Lean Product Development in Complex Products and Systems

In this chapter the LPD theory is discussed in relation to development of CoPS.

We have not been able to find any existing research specifically regarding how LPD may be used in a CoPS context. However, the previously presented theory states that implementation of Lean-principles are vital for firms desiring to achieve world-class performance, as well as survive in a competitive market (Fullerton, et al., 2013). There is no reason to believe that this is any different when CoPS are concerned. As a result, we are of the opinion that LPD also is important when developing CoPS. The main differences between development of CoPS and less complex products are that development of CoPS usually requires involvement of multiple process levels, more people, and more resources in general. Based on this, we believe that implementation of LPD principles are even more important in a CoPS context in order to systematically enhance the efficiency of the processes.

LPD, which focuses on identifying and eliminating waste, keeping non-value adding activities to a minimum, and standardizing processes in order to make them more efficient (Haque & James-Moore, 2004), is important in order to make the development process efficient. There is no reason to believe that this is any different when CoPS are concerned. Further, the literature suggests that LPD is important in order to develop high quality products efficiently. This is just as vital in CoPS development as in development of less complex products and systems.

In relation to the LPD principles presented in chapter 2.1.1.2, we are of the opinion that they will be more complicated when they are implemented in an organization which develops CoPS. This because it usually requires the involvement of several levels of the organization, multiple suppliers, larger teams, as more people with different skills and knowledge needs to be involved, more advanced and probably difficult engineering, a larger and more complex value stream, etc. As the development of CoPS usually involve more complex processes and more stakeholders compared to the development of less complex products, it is reasonable to believe that it is more difficult to standardize these processes, and to define value. However, this will not be a focus

area in our research as we are only concerned with how LPD is used in practice in project-based CoPS development.

Although research concerning this topic is lacking, we are of the opinion that implementation of LPD principles also are important during development of CoPS. This is based on the previously presented theory, as well as the preceding discussion. Further, as we were not able to obtain any existing theory regarding this subject, research in regards to how LPD might be implemented in a CoPS context is needed.

2.5 Knowledge Management in Complex Products and Systems

In this chapter, the role of KM in organizations developing CoPS is explained from different scholars and studies viewpoints, and certain frameworks are presented.

Literature on KM is heavily based on a mass-production context, and little is known about the role of KM in CoPS (Hanisch, et al., 2009). Even though little is known about the role of KM in CoPS, we have obtained literature that show a consensus regarding the importance of KM in CoPS and project success. CoPS are usually developed in projects where only one or a small batch is supplied. The focus of KM is of high importance when dealing with CoPS, as it helps the organization to manage knowledge across project families or organizational boundaries (Oshri & Newell, 2005). However, as projects differ substantially from one another it is difficult to develop steady routines that maximizes the flow of knowledge and capture lessons learned from one project to the next (Hanisch, et al., 2009). Poor project success analysis, and lack of proper documentation of the results of previous projects, are due to the absence of KM systems for identifying and transferring knowledge to future projects (Todorovića, et al., 2014).

In addition to the difficulties related to KM, another reason for poor KM may be that the organization thinks that developed knowledge will not be of value again. This may be true in some cases, but usually, all or some of the knowledge evolving from working on CoPS, will be of value for other complex projects at some point in time. An analysis conducted by Todorovića, et al. (2014) shows that documenting aquired knowledge from previous projects contributes to a more efficient planing-process, faster task execution, improved problem solving, and a decrease in resource consumption. This seems logical as stored knowledge from previous projects may act as an overall guide for CoPS development processes. Hence, using knowledge from previous CoPS-projects will save the project from wasting valuable time and resources. During a project it

can be revield what kind of people that should be included in different tasks and activities, and what type of competence and skills they should obtain. Experiences related to problemsolving may provide a “best practice” for solving different problems, including which people to involve, what type of problemsolving method to use, etc. The examinnation of previous problems solved may also provide solutions for similar problems in order to prevent wasting resources on similar problems twice. There is a planning-phase in every project and experiences obtained during this phase will certainly provide guidence for other projects, and hence shorten time spent on planning. This will include both tacit knowledge that is gained through experience, and explicit knowledge that will be possible to store for reapplication.

It is important for KM in a CoPS context to codify, store, and distribute learnt experiences, as well as creating a linkage between knowledge and practice (Marshall & Brady, 2001). In order to codify and exploit tacit knowledge, a shared system of meaning for understanding, accepting, and deploying this knowledge is required (Bresnen, et al., 2003) According to Hansen, et al. (1999) the organization must choose between a codification strategy or a personalization strategy. If products are customized, innovative, and tacit knowledge is commonly used to solve problems, the organization should choose a personalization strategy. When following this strategy, the focus lies on the dialogue between individuals in brainstorming sessions and on conversations between team-members, instead of codifying and storing knowledge in databases. IT is not used for storing knowledge, but mainly to create a link for direct information exchange of tacit knowledge, which is well suited in a CoPS context (Marshall & Brady, 2001). CoPS are usually satisfying Hansen’s, et al. (1999) criteria of customization, innovation, and the use of tacit knowledge when solving problems, and should hence follow a personalization strategy.

We are of the opinion that choosing a strategy is more nuanced than what Hansen, et al (1999) suggests. Additionally, we believe that choosing either a personalization or a codification strategy may be difficult in today’s competitive environment. For organizations that develops CoPS, it is important to share tacit knowledge and to achieve an effective problem solving environment. However, the downsides of tacit knowledge are the difficulties related to codifying and storing it for later use. This makes it necessary to codify the knowledge that is possible to codify, making it available for to use by other during the project phase, or by other CoPS-projects.

In CoPS-networks all actors are dependent on each other for a successful development, as they all have individual capabilities and skills. As an example may informal communication between engineers contribute to maintain technical consistency, as well as find new resource or activity combinations for unexpected situations (Gann & Salter, 2000). However, different disciplines also have their own knowledge base and language, which makes effective codification and knowledge transfer problematic (Bresnen, et al., 2003). It is therefore important to create a tight personalization linkage among actors to create an effective knowledge flow (Ngai, et al., 2008). Frequent communication of information, joint decision-making, and the flexibility of the network is important for knowledge creation, problem correction, and the overall successful development of CoPS (Nielsen, 2005).

This states how important KM is in a CoPS context, especially related to the management of the flow of tacit knowledge. In a CoPS-development environment, consisting of people with different specialized competences, the flow of communication and information between all actors must be a priority, giving the opportunity of a holistic understanding for every project member. IT-systems must be adjusted to fit in an environment where sharing of tacit knowledge is crucial for the project progress and overall success. The management must be involved and facilitate a knowledge-sharing environment, in order to successfully create a knowledge linkage between all actors involved in CoPS development. In fact, the project team's ability to implement what is learned, increases when the members and management share the vision of the project, and are willing to invest in relation specific assets (Lynn, et al., 2000).

A study conducted by Hanisch, et al. (2009) strongly supports the assumption of high relevance of KM in project-based organizations, even though it is not sufficiently used. Knowledge systematization IT-systems and a systematic approach towards KM, which fit the project needs and the organizational structure, is found to support successful management of project knowledge. However, even the best IT-systems for supporting storage and transferring knowledge is useless if the employees resist using them. This is why organizational culture, as well as the top management functioning as role models, seems to be a critical factor for successful KM in project-based organizations. If the organizational culture is primarily based on tacit knowledge, fancy IT-systems is probably not a good idea, as tacit knowledge is hard to articulate. In this situation it will be more appropriate with a simple information exchange system

of tacit knowledge, which give the employees access to email, skype, etc. The organization should rather facilitate an environment that supports the culture of tacit knowledge sharing through discussion, brainstorming-meetings, etc. If the organizational culture is built on explicit knowledge, an appropriate IT-system will underpin the organizational culture, and hence be exactly what the organization needs and what the employees will use.

Ngai, et al. (2008) contributed with a preliminary framework of how KM may reinforce project performance in CoPS. First, a collaborative atmosphere must be created among network members involved, which includes the establishment of mutual trust and commitment. Technical meetings and site visits, as well as the improvement of mutual communication and interaction will enhance problem solving. The use of KM to manage knowledge flow will have a positive effect on CoPS performance, which makes it necessary for someone to be in charge of liaison and knowledge filtering. An appropriate IT-system must be set up to allow knowledge flow across borders, and support posting of development progress and relevant data. In this way, other network members can update their understanding of the product or system at all times. The case-study conducted by Ngai, et al. (2008) do not specifically separate tacit and explicit knowledge, even though they underpin the importance of both. Their suggestions for meetings, site visits, and mutual communication and interaction is aiming for the creation and sharing of tacit knowledge, and it seems that their suggestions for the use of IT-systems support both.

Some scholars have examined how KM may be used in CoPS and some suggestions for initiatives and actions have been presented. There are mainly conducted case-studies and qualitative research of how KM may be deployed in CoPS. Studies included in this literature review have analyzed data gathered from few respondents, and hence several case studies in different industries with different organizational sizes are needed, as well as empirical research. There are suggested a few frameworks showing which specific actions that need to be undertaken to manage knowledge in CoPS. Hence, this is an area with several research opportunities.

2.6 Lean Product Development and Knowledge Management in Complex Products and Systems

Lean does not only apply to production of products, as commonly believed, but to the organization as a whole. Lean is used to eliminate waste in the entire value stream in order to give the customer what they want (Liker & Morgan, 2006). In other words, Lean is also of use in the product development stage, then called LPD. In this thesis LPD is defined as a systematic and

continuous process of identifying and eliminating waste, as well as standardizing processes in all areas of the value stream, in order to enhance efficiency. Key activities that constitute a LPD system are eliminating waste, keeping non-value adding activities to a minimum, letting the customer pull, standardizing processes in order to make them more efficient, and to continuously improve (Haque & James-Moore, 2004). Haque and James-Moore (2004) also argue that another important part of LPD is information flow and the IT-systems used to transfer information. Radeka (2012) describes LPD as the process of maximizing value and minimizing waste in order to deliver the right product to the market at the right time and the right price.

Liker and Morgan (2006) presented a LPD approach that consist of 13 principles concerning the three categories process, people, and tools and technology. There are four main process principles aiming at generating a process focusing on customer value, keeping an even flow, reduce costs through the product life cycle by avoiding choosing premature solutions, and focus on continuous improvement through standardization. There are six people principles, in which the aim is to have one chief engineer with responsibility of the product development process per project, to make sure that engineers have the right knowledge and skills, and to build in organizational learning. Finally, there are three tools and technology principles, in which the aim is to use simple, but powerful tools and technology which enables standardization and organizational learning.

There is little research explaining the use of LPD in CoPS development compared to the development of less complex products. We are of the opinion that the use of Lean principles is even more important when developing CoPS, due to the involvement of multiple process levels, more specialists, multiple suppliers, and more resources in general, compared to less complex products and systems. In these complex environments it is important to focus on streamlining processes in order to be efficient.

The current view of knowledge, being the most valuable and important organizational resource, has laid the foundations for the need of KM. In this thesis KM is defined as a process of continually managing both explicit and tacit knowledge in the organization, which comprises the creation, storage/retrieval, transfer, and application of knowledge. Nonaka and Takeuchi (1995) presents a spiral process for organizational knowledge creation, which comprises four modes, the socialization mode (tacit to tacit), the externalization mode (tacit to explicit), the combination mode (explicit to explicit), and the internalization mode (explicit to tacit). Gupta and

Givindarajan (2000) presents five elements for knowledge transfer: 1) Perceived value of knowledge, 2) Willingness to share knowledge, 3) Existence and quality of transmission channels, 4) Willingness to acquire knowledge, and 5) The receiving unit's ability to absorb and use knowledge. Organizations create knew knowledge every day, and this knowledge will be forgotten if the organization is not able to store this knowledge into organizational memory, which influence the organizations current activities. IT tools are regarded as effective to enhancing organizational memory. Knowledge itself is not the source of competitive advantage, but the application of it is (Alavi & Leidner, 2001). A concern with knowledge is that it may continue to be applied after its real usefulness has declined, or that there are too many rules and routines in the organization, making it difficult to know which one to use in specific settings. IT can also be used to enhance knowledge application, by facilitating the capture, updating, and accessibility of knowledge.

The theoretical review suggests that KM is vital in businesses that develops CoPS, especially in and between projects. However, as projects differ substantially from one another, it is difficult to develop steady routines that maximizes the flow of knowledge and capture lessons learned from one project to the next. Lessons learned is said to contribute to a more efficient planing-process, faster task execution, improved problem solving, and a decrease in resource consumption (Todorovića, et al., 2014). The management must be involved and facilitate a knowledge-sharing environment, in order to successfully create a knowledge linkage between all actors involved in CoPS development, in order to improve the knowledge flow (Lynn, et al., 2000; Ngai, et al., 2008).

In a project scenario a lot of the information is tacit, thus it is stored in the workers heads and taught through experience. The challenge is to make the tacit information explicit in order to store it for later use and hence, save valuable resources. This is considered to be a difficult process, and is according to Nonaka and Takeuchi (1995) done through dialog and collaboration.

Frequent communication of information, joint decision-making, and the flexibility of the network are important for knowledge creation, problem correction, and the overall successful development of CoPS (Nielsen, 2005). It is crucial that IT-systems are adjusted to fit a knowledge sharing environment, the project needs, and the organizational structure, in order to

achieve project progress and overall success. It is also important that employees are willing to use the organization's knowledge systems (Hanisch, et al., 2009).

Several researchers also include knowledge and KM as an important part of LPD, and Radeka (2012) states that a company has to master knowledge and learning, in order to be Lean in the product development phase. By being able to create, capture, share, and use valuable company knowledge, a company is able to spend more time on generating innovative product with high value and low risk through a fast, predictable, reliable, and innovative product development process. She also argues that a failure in early product development is a valuable learning experience. If an organization is able to learn from their mistakes, they will be able to prevent the same mistakes from happening in the next project.

Lindlöf, et al. (2013) identify three LPD principles and methods to support the transfer of knowledge in a product development setting: mentorship, the chief engineer, and visualization. The mentor is a specialist that should act like a coach, enabling employees to learn by doing. The chief engineer has the total responsibility for the project and is responsible for communication and making tacit knowledge explicit. Visualization of information can be used to sort, add, combine, and categorize explicit knowledge, and be a tool for helping employees to communicate and acquire the information more easily.

We are of the opinion that the LPD process is more complex in CoPS development in terms of knowledge. This is due to the fact that there usually is a higher need for knowledge creation, transfer, storage, and application in order to develop CoPS efficiently in a complex environment. In order to manage both tacit and explicit knowledge, there is a need for well-functioning knowledge systems. As there generally is created a lot of tacit knowledge in projects, the engineering of CoPS will not only depend on explicit knowledge stored in the organization, but the knowledge and experience of the workers as well. For this reason, it will be beneficial for organizations that develop CoPS to identify all knowledge that can be made explicit, and standardize knowledge processes as well as possible, in order to save both time and resources.

The theory presented illustrates that there exists a connection between LPD and KM, and that to successfully implement a LPD-strategy requires management of knowledge. KM is regarded as an important aspect when developing CoPS, but there is a lack of specific research in regards to the importance of LPD when developing CoPS. Nevertheless, as the literature suggest that LPD

is of importance when developing products in general, we are of the opinion that LPD is beneficial in organizations that develop CoPS as well. That being said, the implementation of KM and LPD in organizations developing CoPS is most likely to be more difficult than in organizations that produce less complex products. Both CoPS development and knowledge processes are likely to be more difficult to standardize in order to make them more efficient in a complex environment. Both LPD and KM is wide terms that can be interpreted in many different ways. For this reason, it is important to clarify what we emphasize with both terms in this study. Based on the previous literature study and the definitions provided, we emphasize three aspects related to LPD, namely efficiency, standardization, and waste reduction, and four aspects related to KM, namely knowledge creation, knowledge transfer, knowledge storage and knowledge application. The theoretical review also illustrated that there exists a connection between LPD and KM when developing CoPS. This is illustrated in the following figure.

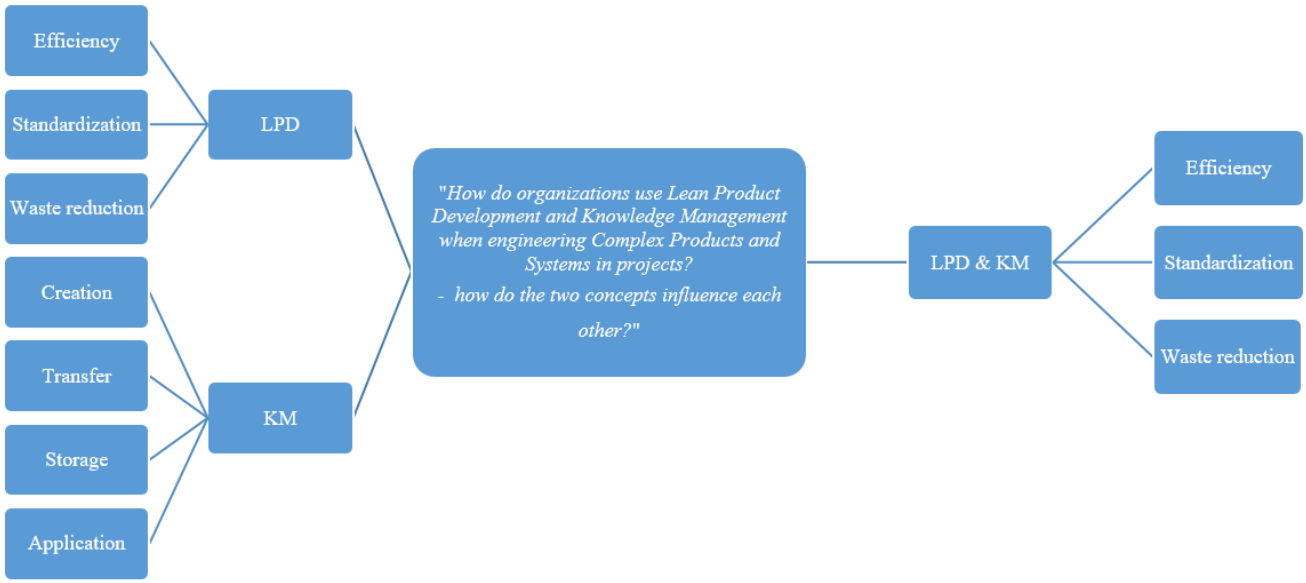

Figure 2 Analysis structure

3 Method

The purpose of this chapter is to describe the methodological choices this thesis is based on. These choices are mainly based on the purpose of the study and the research question. The main purpose of the study is to gain an understanding of how LPD and KM may be used in organizations that develop and/or produce CoPS, and how the two concepts influence each other. The research question is stated as follows, *"How do organizations use Lean Product Development and Knowledge Management when engineering Complex Products and Systems in projects, and how do the two concepts influence each other?"*. We have also taken the resources we had at our disposal into consideration when making methodological choices.

There exist many varieties of paradigms, perspectives, approaches, and methods regarding research, which may be viewed as both a strength and a weakness. The rich range of research choices may represent multiple ways of understanding the phenomenon of research. However, it may also be overwhelming and confusing to both new and experienced researchers (Savin-Baden & Major, 2013). Our choices taken in regards to this particular research study is carefully explained and argued for in the following chapters. This chapter is initiated by clarifying our philosophical stance. Further, it is explained how the study is framed, and which research approach that is selected for this particular study. Next, the data collection methods are carefully described, and argued for. Finally, it is explained how this study is conducted, how the quality criteria are maintained, and which ethical considerations that have been taken.

3.1 Choice of research approach

In this chapter the research approach chosen, is accounted for by clarifying our philosophical stance and study design.

3.1.1 Inhabiting a position

Inhabiting a position involves clarifying the researchers' view of reality – ontological view, and the researchers' view of knowledge – epistemological view. These clarifications are important as the researchers' views of reality and knowledge will influence the research approach and how the study is conducted (Savin-Baden & Major, 2013). As we are of the opinion that different philosophies regarding social inquiries should be applied for different situations and contexts, we have chosen to adopt a situationalist orientation. Our ontological and epistemological views, as well as our final research perspective, are therefore mainly guided by the phenomenon under

study, namely how LPD and KM is used during engineering of CoPS in projects, and how the two concepts influence each other. All three concepts are explained below.

3.1.1.1 Views of reality

Realism and idealism are the two extremes of the ontological view. Realism is an objective perspective, suggesting that there is an objective external and knowable reality that exists independent of individuals' means of perceiving it. Idealism is a subjective perspective, which suggests that the reality is constructed by individuals and groups (Savin-Baden & Major, 2013). As we believe that both LPD and KM are concepts that are affected by the way individuals perceive them, and that individuals mentally constructs the reality surrounding the use of lean and KM, our ontological view is idealism.

3.1.1.2 Views of knowledge

"Epistemology comprises theories of knowing and the relationship between the researcher and the researched, and serves as a guide to develop understanding of the phenomenon under study" (Savin-Baden & Major, 2013). Savin-Baden and Major (2013) presents seven different epistemological views – philosophies that address the nature of knowledge: 1) Empiricism, 2) Rationalism, 3) Historicism, 4) Instrumentalism, 5) Experientialism, 6) Structuralism, and 7) Existentialism. We believe that knowledge may be created in several different ways. However, for the purpose of this study, we believe knowledge is created through experience in a constantly changing reality. This is aligned with the experientialism view. As most organizations today operate in high competitive markets with rapid evolvement, continuous improvement of products and processes is vital in order to stay competitive. This illustrates that the reality surrounding organizations are continuously changing. As LPD and KM, as mentioned earlier, are perceived differently by different people, the way they are utilized in organizations is based on the management's and employees' intelligibility and experience.

3.1.1.3 Research perspective

Researchers have different perspectives on their work, either objective, intersubjective or subjective. The objective and subjective research perspectives are opposites. An objective perspective on research assumes that reality is external and that research is unbiased, impartial, and based upon facts. On the other hand, the subjective perspective on research assumes that

reality is constructed by individuals and that research always is personal and based on the researcher's values and perceptions. An intersubjective perspective on research lies somewhere in between the two, and suggests that research is mutual and co-arises from the engagement of interdependent individuals. In other words, a mutual agreement among a group of people about what is real (Savin-Baden & Major, 2013). In relation to our ontological and epistemological views, our approach is likely to be subjective, which is also the research perspective chosen. The main reason for this is that we ourselves have taken all relevant choices regarding what to research and how, which makes the research personal.

3.1.2 Study design

Grenness (2012) argues that there are three different types of studies, namely explorative, descriptive, and causal. The explorative design aims at exploring and creating an understanding of a phenomenon and topics that there currently exist little or no knowledge about. Descriptive and causal designs often aim at describing or explore relationships and correlations between variables (Grenness, 2012). As the topics under study in this thesis are in early stages in regards to theoretical development, we have chosen to use an explorative design.

3.1.3 Research approach

Our philosophical stance, as explained above, and the objective for this thesis, which is to understand how LPD and KM may be used in organizations that develop and/or produce CoPS, and how the two concepts influence each other, indicates that a qualitative research approach is appropriate for this particular study. In general, qualitative research is used when searching for an understanding of human knowledge and experience (Yin, 2014; Savin-Baden & Major, 2013). As the purpose of the study is to gain knowledge and an understanding about how lean and KM is perceived and used by individuals, it is reasonable to use a qualitative research method. Additionally, qualitative research questions are often initiated by "how", "why", or "in what way" (Yin, 2014), and the research question presented in this thesis starts with "how".

During research work, one must choose between an inductive or a deductive approach. When selecting an inductive approach, theory is systematically generated from data. The deductive approach involves developing propositions from current theory and make them testable in the real world by creating hypothesis (Dubois & Gadde, 2002). The purpose of this study is to gain knowledge about how KM and LPD is used when engineering CoPS in projects, and how the two

concepts influence each other. Hence, the aim for this study is not to test the theory through propositions, but to generate theory from data. As a result, an inductive approach is chosen.

3.2 Framing the study

In this chapter the research strategy is accounted for, and the context specifications and content clarifications is explained.

3.2.1 Research strategy

Qualitative research comprises several research strategies, including pragmatic qualitative research, grounded theory, case studies, phenomenology, ethnography, action research, narrative approaches, art-based approaches, collaborative approaches, and evaluation (Savin-Baden & Major, 2013). In this thesis case study has been chosen as the most appropriate research strategy, as explained in the following section.

Case study as research strategy

In the introductory chapter the background and our motivation for undertaken this study are presented, as well as the research question. Based on this, the unit for data collection and analysis is organizations that develop and/or produces CoPS, with emphasis on the engineering phase in projects. Case studies are usually used when the unit of analysis is an individual, a group, or an organization. Further, the research question often starts with “how” or “why”. As the unit of analysis in this thesis is organizations, and as the research question starts with the word “how”, it is regarded appropriate to choose case study as research strategy. Using case study as research strategy requires that the researchers have no control of behavioral events, and that it is focused on contemporary occurrences. In addition, the context of the phenomenon of study is significant and there are usually multiple variables and sources of evidence (Yin, 2014). In this thesis contemporary events are under focus, and the authors have no control of behavioral events. Additionally, the context in which the phenomenon is studied is significant and the case is complex with several variables. This underpins our decision to use case study as research strategy.

Yin (2014) argue that conducting case study research is a linear, but iterative process, as illustrated in the figure below. This process is used as a base during the execution of this case study.

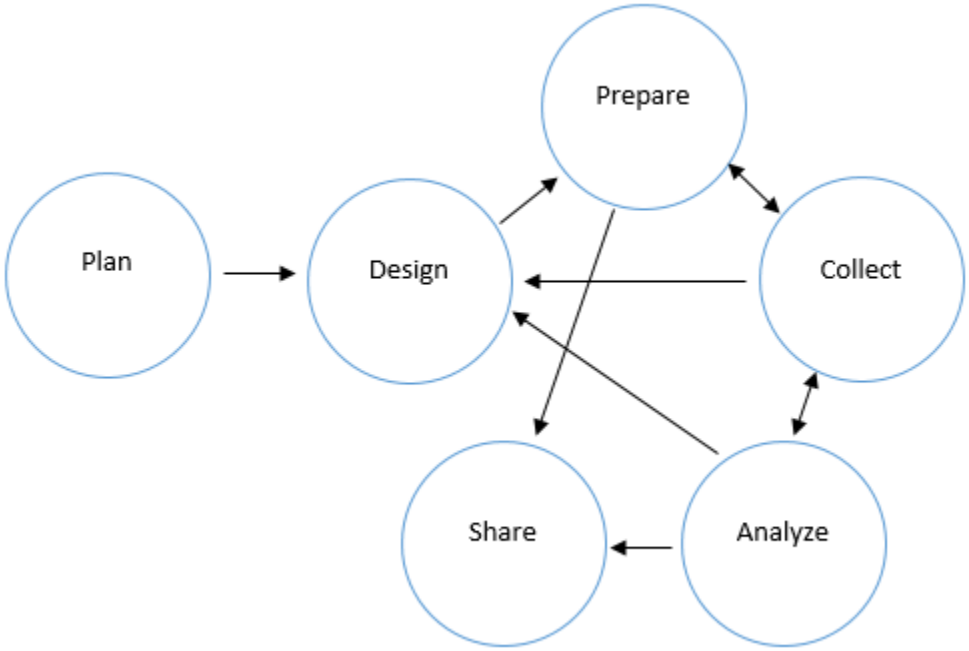

Figure 3, Case study research process (Yin, 2014)

There are a number of advantages with case study research. It is flexible, it allows for depth of investigation, it is thorough, responsive, and it has a wide appeal. There also several challenges associated with case study research. Walker (1983) suggests the following three concerns: Case study research can be viewed as an invasive intrusion in subjects' lives, it can lead to a simplistic and incorrect world view, and it is an approach through which it is possible to harm those who are constantly changing practices. Savin-Baden and Major (2013) adds three concerns to Walker's (1983) list: The dependence on a single case, the boundedness of a case, and the eclectic nature of case studies. These concerns may be actual, but there is a huge difference between researchers' views on case study research concerns. As an example, Flyvbjerg (2006) addresses and correct five misunderstanding about case study research. We are of the opinion that there are weaknesses associated with performing a case study research, but that it all comes down to what the purpose of the study actually is. In this particular study, we are of the opinion that case study research is the appropriate choice as our goal is to gain knowledge of how LPD and KM is used in the organizations under study.

3.2.2 Context specifications and case clarifications

As this study is a master thesis, we were provided with a strict time limit of approximately four and a half months to complete it. This is an important limitation that must be accounted for. Further, as we attempt to gain knowledge and understanding regarding how organizations use LPD and KM during engineering of CoPS in projects, we consider the engineering phase, and everything associated with it, as part of the case. The remaining project phases, as well as the rest of the organization, are not included in the case.

Yin (2014) presents four different case study designs: 1) Holistic (single-unit of analysis) single case design, 2) Embedded (multiple units of analysis) single case design, 3) Holistic multiple-case designs, and 4) Embedded multiple-case design. Single cases offer the opportunity to provide an in-depth analysis and are appropriate to use when exploring critical, unusual, revelatory, typical, or longitudinal cases. On the other hand, multiple cases offer the opportunity to replicate the study (Yin, 2014; Savin-Baden & Major, 2013).

Due to several aspects, a holistic multiple-case design was chosen for this thesis. Generally, evidence from multiple cases are often considered more compelling, which makes the overall study considered more robust (Yin, 2014; Savin-Baden & Major, 2013). Due to the research question presented in this thesis, we considered it useful to have several cases, instead of a single case, in order to create more width. As KM and LPD are terms and theories which are affected by the way individuals perceive them, it is reasonable to believe that the use of KM an LPD will differ in some extent between different organization. This can be due to organizational structure, culture, and individuals involved. The goal of this thesis is to gain an understanding of how LPD and KM may be used in practice. This can be done by conducting a single case study. However, that will only generate knowledge about how that particular organization makes use of these concepts Conducting a multiple case study creates the opportunity to gain knowledge about how several organizations make use of LPD and KM, which will generate a broader contribution to the existing theory. A multiple case study usually requires more time and resources compared to a single case study (Yin, 2014; Savin-Baden & Major, 2013). This made it difficult to include several cases in this study, as we had limited resources and a strict timeframe. With this in mind, we chose to conduct our research on two different organizations which operate in two different

industries. In other words, this thesis includes two separate cases, on which the same case study is conducted.

When conducting case study research, the cases are selected based on their relevance to the area of research (Eisenhardt, 1989). The goal is to choose cases that most likely will generate knowledge about the phenomenon under study. In this thesis, we wanted to examine organizations that develop and/or produce CoPS. Hence, this was the main criteria when we discussed which organizations to contact. It was also vital that the organizations were familiar with, and used KM and LPD to some extent, that they were approximately the same size, and with somewhat comparable project structures. As our aim was to examine how LPD and KM were used during the engineering phase in projects, we were dependent on project-based organizations which conduct some engineering of products or systems in order to satisfy specific customer needs. Both case study organizations in this study develop and produces CoPS. Further, they both, to some extent, customize these CoPS during engineering in projects.

3.3 Data collection methods

There exist several different methods in order to collect data in qualitative research and case studies. A common characteristic is that the data is non-numeric, in the form of words, pictures, drawings, movies, video, sound etc., instead of numbers like in quantitative research. Yin (2014) presents six methods that he terms sources of evidence in case study research. These are documentation, archival records, interviews, direct observations, participant observation, and artifacts. It is important to note that this is not an exhaustive list of qualitative data collection techniques. In this thesis, the main source of data collection is interviews. However, diverse documentation will also be used in order to provide additional information to the research.

3.3.1 Documents

Documentation can be personal documents, written reports, administrative documents, formal studies, or news clippings. Since documents can contribute with valuable data in many forms it is likely to be relevant in most case studies (Yin, 2014). The strengths of documents are that they can be reviewed, they are not created for the case study, and they are specific and broad. The weaknesses of documents are selectivity bias, reporting bias, and gaining access to them. In this thesis documents were used to gain general information about the organizations under study. An overview of the project structure and project tasks have been used to better understand how the

projects operate. As the documents collected only were used to gain general information about the cases, and not as data for the analysis, we are of the opinion that this study is not threatened by either selectivity or reporting bias.

3.3.2 The Interview

Interviews are one of the most important and commonly used data collection methods in case studies, and resemble guided conversations (Yin, 2014). Interviews are an effective way of gaining information about the research topic and the informants' perception of a specific phenomenon. On this basis, we have chosen to use interviews as the main source of data collection. During interviews, it is easy to focus directly on the research question as the interviewer guides the conversation. The researcher also has the opportunity to ask follow-up questions, and to clarify any ambiguities that may arise during the interview. The strengths of interviews are, as earlier mentioned, many. However, it is also important to be aware of the downsides with interviews, in order to be prepared and to prevent them. Potential downsides with interviews, as well as cautions taken to prevent them in order to make them less threatening and influential, are discussed in the following sections.

In order to prevent misinterpretation and misunderstandings, we spent a lot of time on preparing well-articulated questions for the interview guide. Further, as informants may be tempted to answer what he or she believes the interviewer would like them to answer, it is vital not to ask leading questions or act like the answer given was unexpected or wrong. In order to prevent affecting the informants with either words or body language, we formulated non-leading questions and tried to act as neutral as possible during every interview.

As an interviewer it is hard to tell if the informant is honest or not, and it is therefore difficult to do something about it. Nevertheless, if the researcher is able to create a connection with the informant and in that way make the informant trust him or her, the chances of dishonesty from the informant is less likely. We are not of the opinion that we have been lied to during interviews. The questions asked are not personal and it is unlikely that the informant think that questions about the organizations current LPD and KM processes is intimidating or that the answers provided may cause a threat to the organization. It is therefore little or no reason for the informant to lie.

The informant may also be preconceived, which will affect the answers. This is out of the researchers' control, but it may be possible to detect during the interview or the analysis, and thus it can be taken into account. However, it is tricky to detect preconceptions, which makes them difficult to handle. At the same time, we do not believe that this bias is threatening to this particular study, as the impact of preconceptions about a specific process will have limited influence on the answers.

Further, the informant may not remember correctly, and hence give misleading answers. There is no way to prevent this. However, we have taken notice of any uncertainties or hesitations during the interviews, and considered these during the analysis.

Savin-Baden and Major (2013) presents four primary types of interviews, namely structured, semi-structured, unstructured, and informal. In a structured interview, a preset script is followed and each interviewee is asked the same questions using the same words. When conducting a semi-structured interview, the researcher follows some preset questions, as in structured interviews, but also includes additional questions in response to the interviewees' comments and reactions. In an unstructured interview, the researcher has a plan and a goal in mind, but does not follow an interview protocol. These interviews are spontaneous, as they arise from the context. In informal interviews, the researcher talks with people in the field informally, without an interview protocol. Structured, semi-structured, and unstructured interviews are usually recorded, while researchers conducting informal interviews rather rely on memory and informal notes.

In this thesis, semi-structured interviews are conducted. An interview protocol covering topics in a specific order, was made in order to ask all the informants the same questions. The protocol starts with personal information and some introductory questions about the organization. Further, the questions to gather in-depth data are divided into two main topics, namely LPD and KM. The questions are developed based on the theory review chapter and the research question. It started as a brainstorming process where we wrote down topics and suggestions for questions. Then we went systematically through every theme and formulated the questions carefully, in order to make sure they would be correctly understood by the informants. We kept the same structure for both the LPD and KM questions. Most of the questions are open-ended, which gives the informant the opportunity to reflect and speak freely. Additionally, we have asked follow-up questions in response to the informants' answers. This was done in order to clarify or specify the answers

given, or to give the informant the opportunity to elaborate about interesting comments. The interview protocol is enclosed as appendix 3.

Semi-structured interviews were chosen due to several reasons. As this was our first time conducing a case study, we considered ourselves too inexperienced to conduct unstructured or informal interviews. Additionally, using an interview protocol makes it easier to focus on the research question and avoid derailments, as well as compare the data from the informants. It was also important for us to ask open-ended questions in order for the informants to talk freely and share their perspectives, as well as asking follow up questions for elaboration.

3.4 Selection of informants

In qualitative research, informants are selected on the basis of how well they may contribute with relevant information and knowledge to a particular study. As there are relatively few informants in qualitative research, it is important to choose the informants carefully (Savin-Baden & Major, 2013). This thesis aims at generating knowledge and understanding of how LPD and KM is used during engineering of CoPS in projects. In order to gather relevant information, it was crucial that the informants possessed knowledge about LPD and/or KM, as well as how they are used in the engineering phase in projects.

In qualitative research, it may be difficult to tell when you have collected enough data. However, generally the data collection continues until there is little or no new information gained on the subject, which is the point of data saturation (Savin-Baden & Major, 2013). Despite the strict timeframe, we were able to conduct interviews until we reached the point of data saturation. In total, seven informants were interviewed from organization 1 and four from organization 2. As we, during the interviews in organization 1, learned which type of people who gave us the most information, we were able to reach the point of saturation after only four interviews in organization 2. It was difficult to find informants that had knowledge about all three areas, namely LPD, KM, and the engineering phase in projects. As a result, we had to interview people with different knowledge and different perspectives on the research question. We believe this gave us a broad set of data, and contributed to a better understanding of the how LPD and KM is used during the engineering phase in organizations that develops CoPS. We chose informants that had knowledge about KM and LPD in order to gain information about how these terms where viewed in the engineering phase in projects. This was important in order to understand which

tools and aspects that were used during engineering. The most valuable information came from informants that directly worked in the engineering phase in projects, as this information was directly relevant in relation to the research question. The following table illustrates the informants and their knowledge areas. This table is only meant as an illustration of each informants' knowledge area, and will not be emphasized further in this thesis.

	LPD	**KM**	**Engineering**
Organization 1			
Informant 1.1		X	
Informant 1.2		X	
Informant 1.3	X		
Informant 1.4	X		
Informant 1.5			X
Informant 1.6			X
Informant 1.7			X
Organization 2			
Informant 2.1	X		
Informant 2.2	X		X
Informant 2.3	X		
Informant 2.4		X	X

Table 3 Selection of informants

3.5 The execution of the study

This thesis has been executed over a period of four and a half months, from January until mid-May in 2016. During January we contacted organizations and scheduled the interviews, and mainly focused on processing the theoretical groundwork and the methodical approach. During February and the beginning of March we completed the theoretical framework and conducted interviews with key personnel in the organizations under study. We also transcribed and coded all interviews consecutively. March was mainly spent analyzing the collected data, and discussing our findings. During the last months, April and May, we completed writing the last chapters, and finalized the thesis

3.5.1 Preparations

During preparation for this thesis, we conducted a literature review during the spring of 2015, in order to gain knowledge about Lean and KM, and their role in organizations developing CoPS. The theoretical gaps we found in the existing literature laid the basis for the research focus chosen in this thesis.

We started the work with this thesis by notifying the Norwegian Social Science Data Service about our work. This was required as we during the work with this thesis had to process personal data. Before we started collecting the necessary data by conducting interviews, some preparations were needed. Initially we contacted different organizations and asked if they wanted to participate in our study. The next step was to inform the contact persons in the organizations we chose of what was expected of them, and have them find key personnel who we could interview about our selected topics. Further, the interviews were scheduled with each of the chosen informants. Thus far, all communication was done by e-mail and telephone, except from one informational meeting with our contact person in organization 1.

As previously mentioned, we prepared an interview protocol that we used as basis and framework when performing the interviews. This interview protocol was tested in a pilot interview with our contact person in organization 1. We used our own experiences as well as feedback from the pilot interview to make small adjustments in the interview protocol.

3.5.2 The interviews

The interviews were held during February and March 2016. Before the interviews were conducted, all the informants were given some information about the phenomena under study. The interviews were held at the informants' organizations at pre-scheduled times. As we are two students collaborating on this thesis, we both participated in all the interviews. Additionally, we alternated between the roles of interviewer and observer.

Before conducting the interviews, all informants signed a declaration of consent, which can be found in appendix 4. The declaration stated what the informants participated in, as well as their right to withdraw their involvement in the study at any given time during the process. All interviews were held in Norwegian and were voice recorded. The latter was both agreed upon and approved by the informants before the interviews, as they had signed the declaration of consent. We chose to conduct the interviews in Norwegian despite the fact that our actual thesis is written

in English. We chose this as we felt that it would be easier for the informants to both talk about, and express themselves in their native language. The informants where informed that the interviews would be anonymous, and that the information we gathered could not be traced back to them. The timeframe of the interviews was between 45-80 minutes. However, one of the interviews only lasted for 30 minutes. The timeframe mainly depended on the amount of knowledge each informant had in relation to the use of LPD and KM in the engineering phase, as well as the informant's personality and willingness to share of their knowledge.

Although the interview protocol was used as a base in all the interviews, we also asked individual follow up questions. This was done in order to get the informant to elaborate, and to avoid misunderstandings. We also wrote field notes in order to capture the informant's behavior.

3.5.3 Transcription and data analysis

Transcription is the process of converting speech into text. This is a very time consuming part of the analysis. However, it makes it possible to save all valuable information, which strengthens the credibility of the study. Another benefit of transcribing is the possibility to withdraw direct citations from the interviews. As this was our first time performing a case study, we did not want to omit any information that might have been of importance for our study, hence we chose to do full transcriptions of the interviews.

All interviews were transcribed and coded consecutively. The data was coded in nVivo in order to systemize our findings and as preparation for the analysis. We coded based on the main topics of the interview protocol: general questions about the organization and project phase, LPD, and KM. We also made subcategories under each of the three main topics. As we are two students working on this thesis together, we went through the transcripted interviews separately, before we coded them together. In our analysis we have included citations from the informants, as well as summarizing tables and figures in order to get a better overview of our findings.

3.6 Quality criteria to evaluate research

The terms "validity" and "reliability" have traditionally been associated with quantitative research, and there have been mixed reactions regarding whether or not these concepts should be applied to qualitative research. Some qualitative researchers have argued that the traditional criteria for validity in quantitative research is not applicable in qualitative research. Others argue that that the goal of finding plausible and credible outcome explanations is critical to all research.

As some qualitative research is better than others, the terms validity and reliability are used to differentiate between what is considered a well-conducted qualitative study and what is not. Some also argue that the terms validity and reliability are appropriate, but that they need to be adapted to fit qualitative research (Johnson, 1997; Savin-Baden & Major, 2013). We are of the opinion that reliability and validity are of use when evaluating the quality of qualitative research, and in this chapter both terms will be discussed in relation to this particular study. First, the two terms reliability and validity, including the issue of generalization, is thoroughly discussed. At the end of the chapter other considerations taken during data collection, is mentioned.

3.6.1 Reliability

Reliability is obtained to the extent that there is consistency and repeatability of the research procedures used in a case study, whether it concerns different observers in the same situation or the same observer in different situations (Yin, 2014; Savin-Baden & Major, 2013; Hammersley, 1992). Thus, reliability is based on dependability and whether or not one can have confidence in the findings obtained in a study (Ryen, 2002). Ryen (2002) mention several strategies to strengthen the reliability of the research process. One of her strategies is to sound record all interviews during data collection, which is a strategy we have made us of. When analyzing, Ryen (2002) suggest that various researchers categorize and compare the same data material. As we are two students collaborating on this thesis, we have separately gone through the data material and discussed and categorized it together. When reporting the study, Ryen (2002) suggests that procedures for data collection are explained and that larger excerpt from the data is presented. The latter is to maintain a low inference level. In this thesis, the data collection methods used are carefully explained, and citations is frequently used to support the analysis in order to maintain a low inference level.

As we have sound recorded all the interviews, separately gone through the data material, carefully explained the procedures for data collection, and frequently used citations during the analysis, we conclude that we have maintained the reliability of this thesis.

3.6.2 Validity

As previously mentioned the term “validity” has traditionally been associated with quantitative research. However, when the term “validity” is used in terms of qualitative research it is often referred to as research that is plausible, credible, trustworthy, and therefore, defensible (Johnson, 1997; Savin-Baden & Major, 2013)

When discussing different types of validity in relation to our thesis, we have chosen to base this discussion on an article written by Johnson (1997). Johnson (1997) distinguishes between five types of validity; descriptive validity, interpretive validity, theoretical validity, internal validity, and external validity. Most frequently used in qualitative research is internal and external validity (Savin-Baden & Major, 2013). These five types of validity are covered in more detail in the following paragraphs.

3.6.2.1 Descriptive Validity

Descriptive validity refers to how accurate and correctly actual events, objects, behaviors, individuals, and settings, are described (Johnson, 1997). It is important to take into consideration how accurate the researchers are capable of describing and reporting what actually happened. An effective strategy used to obtain descriptive validity is called investigator triangulation (Johnson, 1997). This strategy involves the use of multiple researchers, as they bring different expertise and viewpoints which can be used to describe and interpret the informants' behavior, and the context in which they are located (Johnson, 1997; Eisenhardt, 1989). As we are two students working together on this thesis, we have both been participating when collecting data, mainly through interviews. There are two key advantages with investigator triangulation. First, team members often have different perspectives and complementary insights which add richness to, and an increased understanding of the collected data. Second, the convergence of several investigators builds confidence in the findings (Eisenhardt, 1989). We have found it extremely useful to be two students working together on this thesis, as we have had someone to discuss our thoughts and interpretations with when analyzing data. We are of the opinion that being able to discuss data and finding with each other have increased the quality of this study. One strategy of using investigator triangulation is to visit the case study sites in teams, and have one investigator handling the interview, while another observes and takes notes of body language and other factors (Eisenhardt, 1989). This is also a strategy we chose to follow during interviews, and we switched between the two roles so we both got to experience how it was to be the interviewer and the observer. We both wrote down some notes after each one of the interviews conducted and compared these, when data were analyzed. We have also taken incidents which have happened before or under the interview into consideration, as this might have affected the informant's answers. Based on the preceding discussion, we conclude that we have been able to maintain the descriptive validity in this thesis.

3.6.2.2 Interpretive Validity

Interpretive validity requires an understanding of the minds of the people participating in the study. Thus, interpretive validity refers to "the degree to which the research participants' viewpoints, thoughts, feelings, intentions, and experiences are accurately understood and portrayed by the researcher" (Johnson, 1997). To be able to understand and portray the participants as accurately as possible, the researcher must be able to look through the participants' eyes, and see and feel what they do. In other words, the researcher must be able to get inside the participants' heads (Johnson, 1997)

Johnson (1997) presents two possible strategies to obtain interpretive validity. The first strategy, participant feedback, is to let the participant confirm the researcher's interpretation or to clear up any misunderstandings. This is not always a clever strategy, as some participants may regret what they originally said or interpret things differently than the researcher, thus valuable data might be deleted (Johnson, 1997; Savin-Baden & Major, 2013). In terms of feedback from the informants, we asked a lot of follow up questions during the interviews in order to make sure that we understood what the informants meant. We also considered sending the citations we chose to use in our analysis back to the informants for confirmation. However, we were of the opinion that this was not necessary, as we concluded that the citation used are relatively easy to interpret. Further, as we were interested in the terms LPD and KM we also asked all the informants what they associated with these terms, before we gave a short description of what we focused on. This in order to make sure we had the same understanding of the concepts. The second strategy is maintaining low inference descriptors. When using this strategy, the reader can experience the participants' actual language, dialect, and personal meanings. We have in order to obtain the interpretive validity fully transcribed all the interviews, and used direct citations in our analysis. This enable the readers to make their own interpretation of the data presented. Even though the citations presented in our analysis is translated to English, our actual analysis is based on the Norwegian citations. As we have presented directs citations from the interviews in the analysis, we conclude that we have been able to maintain the interpretive validity in this thesis.

3.6.2.3 Theoretical Validity

Johnson (1997) describes theoretical validity as "the degree of consistence between explanations based on research results and the collected data." This means that the better the theoretical explanations fit with the collected data, the higher the theoretical validity is. Johnson (1997)

presents a number of strategies in order to obtain theoretical validity; extended fieldwork, investigator triangulation, theory triangulation, negative case sampling, pattern matching, and peer review. Due to the limited timeframe, we were not able to make use of all of these. However, we did use the investigator triangulation strategy, as mentioned under descriptive validity. We did also make use of the peer review strategy, which regards discussing the study with someone not directly involved in the study (Johnson, 1997; Savin-Baden & Major, 2013). We were prior to this study assigned a supervisor that has given us feedback on our work throughout the entire process. Further, as we base our findings on several different theoretical approaches, we have also used theory triangulation. As we have used the investigator triangulation strategy, peer review strategy, and theory triangulation, we conclude that we have been able to maintain the theoretical validity in this thesis.

3.6.2.4 Internal Validity

According to Johnson (1997) internal validity refers to the degree to which a researcher is justified in concluding that an observed relationship is causal." By this, Johnson (1997) means whether we as researchers are able to justify our claims about the existence of causal relationships between phenomena. Internal validity mainly concerns explanatory case studies, when examining a cause and effect relationship (Yin, 2014). Qualitative researchers are usually not interested in such studies, nor have we examined cause and effect relationships in this study. However, in case studies internal validity extends to a broader problem of reaching a conclusion based on analyzing the findings (Yin, 2014).

Johnson (1997) presents several strategies useful to obtain the internal validity; researcher as "detective", extended fieldwork, low inference descriptors, theory triangulation, method triangulation, investigator triangulation, data triangulation, participant feedback, peer review, negative case sampling, and pattern matching. As earlier mentioned, we have made use of low inference descriptors, theory triangulation, investigator triangulation, and peer review. Researcher as "detective" refers to the importance for a researcher to maintain a critical view of both the findings and the decisions made. This was something we focused on while conducting this thesis. It was also helpful being two students working together in order to maintain a critical view through frequent discussion. As we also were provided some written documents from the organizations, we have also made use of the data triangulation strategy. Based on the preceding discussion, we conclude that we have been able to maintain the internal validity in this thesis.

3.6.2.5 External Validity

External validity is according to Johnson (1997) important when the goal is to make the findings transferable. In other words, the external validity is obtained to the extent that it is possible to transmit the findings of the study to other individuals, settings, or times (Savin-Baden & Major, 2013). The external validity can thus be equated with generalization. Maxwell (1992) describes a study's generalizability in the following way: "generalizability refers to the extent to which one can extend the account of a particular situation or population to other persons, times, or settings than those directly studied." Johnson (1997) argues that the issue of generalization plays a different role in qualitative research than it does in quantitative and experimental research. He further provides two different reasons for this statement. The first reason is related to the fact that the people and settings studied in qualitative research are rarely randomly selected, and usually the best way to generalize is by sampling. The other reason is related to the fact that the goal of many qualitative researchers is to show what is unique about a certain group of people or events, rather than generating findings that are broadly applicable. Johnson (1997) further presents two types of generalizations, based on Stake's (1990) and Yin's (2014) discussion on the subject; naturalistic generalization and the replication logic. Naturalistic generalization is based on similarity. The larger similarity between the phenomena under study and the phenomena you want to generalize to, the more justifiable is the generalization. Replication logic is defined as "the logic for selecting two or more cases in a multiple-case study" (Yin, 2014). According to Yin (2014) replication logic comprises two different logics, theoretical replication and literal replication. Theoretical replication regards choosing cases that are predicted to have contrasting findings. Literal replication regards choosing cases that are predicted to have similar findings. The logic behind literal replication is that the more times research findings are proved to apply to different individuals, settings, and times, the more we can trust that the findings can be generalized beyond the original study (Johnson, 1997). In this study, we have used literal replication by choosing a holistic multiple-case design, conducting our study in two organizations in which we predicted to find somewhat the same findings. This has contributed to maintain the external validity.

3.6.3 Other considerations

A consideration that should be mentioned is that one of the interviews was conducted with two informants. This applies to informant 1.6 and 1.7. We thought we were going to interview one

person, but then two showed up to the interview. However, we agreed to conduct the interview as we considered it the most effective way to interview both informants during a hectic period of time for them. We also considered the benefits of doing such an interview greater than the possible disadvantages. It was evident that the informants had not been in contact prior to the interview, and thus they would not have had the opportunity to discuss the study up front. If they had discussed the study up front, it could have had an impact on their answers. During the interview we felt that the informants challenged each other and influenced each other in a positive way. The data collected in this interview, we consider as more extensive than if we only had interviewed informant 1.6 alone. In addition, it gave our study further depth. However, it is important to be aware of that the informants must have had an influence on each other's answers, and that the answers might not have been the same if they were interviewed separately. There are also other considerations that must be taken into account during such interviews, and social control is one of them. In some instances, the second informant might demand to participate in order to control what the first informant is saying. We have discussed this, but as the sensitivity of our topic is low we did not find this likely. Additionally, the second informant did not attempt to disrupt or correct the first informant. There might also be a risk that the first informant had the desire to include an additional informant in order to have someone to lean on, in order not to be responsible for uttering the organization's viewpoint alone. As the two informants did not seem to know each other, and as the interview was facilitated by their superior, this is highly unlikely. Additionally, all informants were informed about anonymization from the beginning, which removes the responsibility from each informant. On this basis, we are of the opinion that this interview is not regarded as a methodological weakness in this study. However, we are aware of the distortions it might have caused.

3.7 Ethical considerations

Due to a number of ethical scandals during research work, mainly in the US, ethics has become an important topic when conducting a research study (Savin-Baden & Major, 2013). As a result, ethical guidelines have been made for research studies where there is direct contact between the research object and the researcher. A very important topic regarding good ethics, deals with personal data and information relating to the persons participating in the project. Savin-Baden and Major (2013) argue that it is important to ensure that participants have given informed

consent. This can be done in writing or orally. The participants must also be allowed to withdraw their candidacy at any given time during the research process. This is particularly important when interview and observation is used as data collection methods. We have in our study made all participants sign a declaration of consent, stating that they know what they are participating in, and that they agree to participate. We have also provided our contact information to all participants in case they had questions or wanted to withdraw their participation. We additionally informed all participants that if they wanted to withdraw their participation, all data collected of them would be deleted.

Another important ethical aspect is the requirement for privacy and confidentiality. Privacy means that unauthorized people are not able to look at the collected data material. Confidentiality ensures that informants are anonymized if they want to, once the result of the study is presented (Savin-Baden & Major, 2013). Anonymity is especially important under the conditions where informants provide sensitive information. With this in mind, we have decided not to refer to the informants by name, nor naming the organizations used in this study. Informants are referred to by using numbers; informant 1.1 means organization 1, informant 1, informant 2.1. means organization 2, informant 1, and so forth. We decided to do it this way, as it is likely that the informants will be more willing to share more if their name and company is not attached to the information.

Finally, a fundamental principle for the scientific probity is to avoid plagiarizing other's work. Good referral ethics is therefore important. In this study we have used a variety of sources, and referred to the author and year of publication in the text, while the complete citation is found in the reference list.

3.8 Summary of methodical choices

Based on the purpose of this thesis and the formulation of the research question, it is used a qualitative research approach with an explorative design. As we wanted to examine how different organizations use LPD and KM in practice during engineering of CoPS in a project context, we decided to use case study as research strategy. A holistic multiple-case design is used as we chose to perform the study in to different organizations. The context for this thesis is organizations which develops and/or produces CoPS, and the area of study is the engineering phase in projects.

Thus, it has been crucial that the organizations selected fit this description. Informants were chosen based on their knowledge and experience of LPD, KM, and the engineering and project phase. We chose to use interviews as our main method for data collection, and a total of 11 informants were interviewed. In this study, we chose to focus on depth rather than width, which among other is reflected in the research approach, research strategy, data collection method, and the number of informants.

4 Analysis

We will in this chapter present and analyze our collected data. This is done in order to compare our findings to the theory we have presented, and to be able to answer our research question, stated as follows:

> *"How do organizations use Lean Product Development and Knowledge Management when engineering Complex Products and Systems in projects?*
>
> *- how do the two concepts influence each other?"*

As the research question states, the data collected in this thesis regards to the engineering phase in projects. However, some of the data analyzed and findings later discussed, might also concern the projects and organization in general.

This analysis is based on the two concepts LPD and KM and how they are used when engineering CoPS in projects, as well as how the two influence each other. In order to get a structured overview of the study, we first present our findings regarding LPD, then we present our findings regarding KM, before we close this chapter by presenting our findings regarding how these two topics relate. This structure is visualized in the figure below.

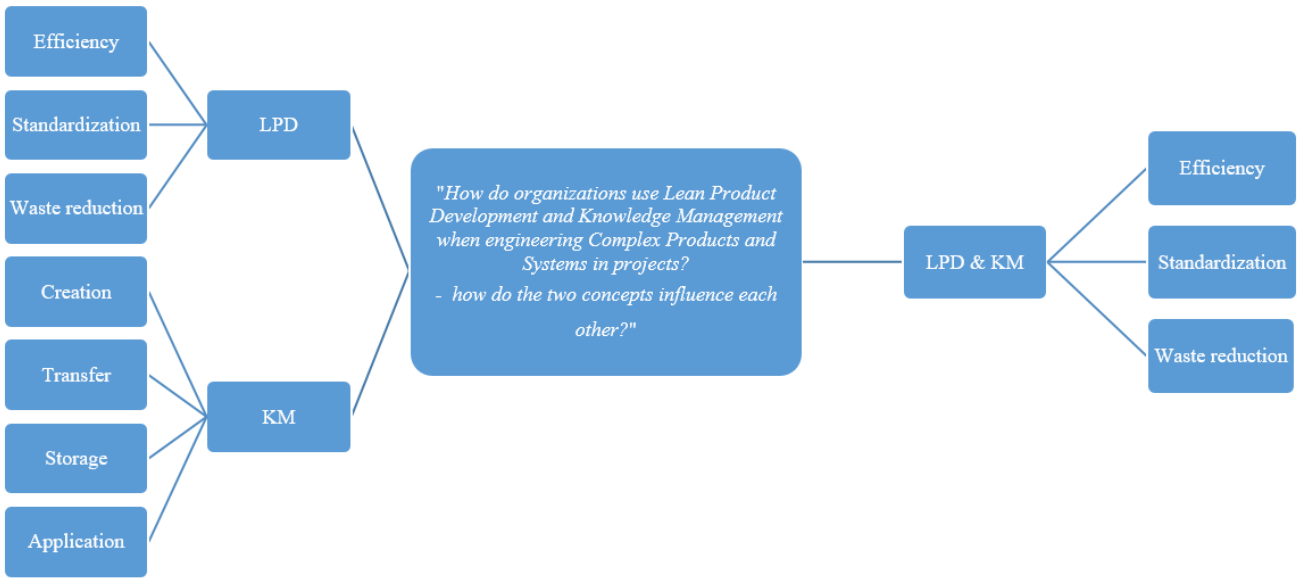

Figure 4 Analysis structure

The interview guide is designed based on the theory presented regarding LPD and KM. As we consider the KM theory to more intricate than the LPD theory, the interview guide contains more questions regarding KM than LPD. As a result, we got more information regarding how the organizations use KM in contrast to how they use LPD. This has made the analysis regarding KM more extensive than the analysis regarding LPD.

We have chosen not to include full transcripts of data in this thesis, simply because there are too much data to present. However, selected citations from the interviews are presented. In this analysis the informants are numbered according to the order they were interviewed and the company they belong to. In order to protect the informants and the organizations they represent, information that might be revealing is censored in some citations, and replaced with "NN". This information is not essential for the general context.

4.1 Analysis Lean Product Development

In this chapter we present our findings regarding the organizations' use of LPD in the engineering phase in projects. Our findings regarding the organizations' implementation of LPD are discussed in the order presented in the figure below. We start by discussing the focus of LPD in the companies, how they ensure efficiency, how and what they standardize, and lastly how they reduce waste. None of the informants had any prior knowledge about the theory of LPD. This was surprising as both organizations have implemented Lean initiatives in the engineering phase. However, almost everyone had some knowledge about the theory of LP. As Lean may be interpreted differently, we preceded all the interviews by asking the informants to explain what they associated with the terms Lean and LPD. In cases where the informants' associations and knowledge were lacking, we gave a short description of the theory. This was done in order to ensure that we had the same understanding of the concept. A summary of our findings is visualized in the table in appendix 5.

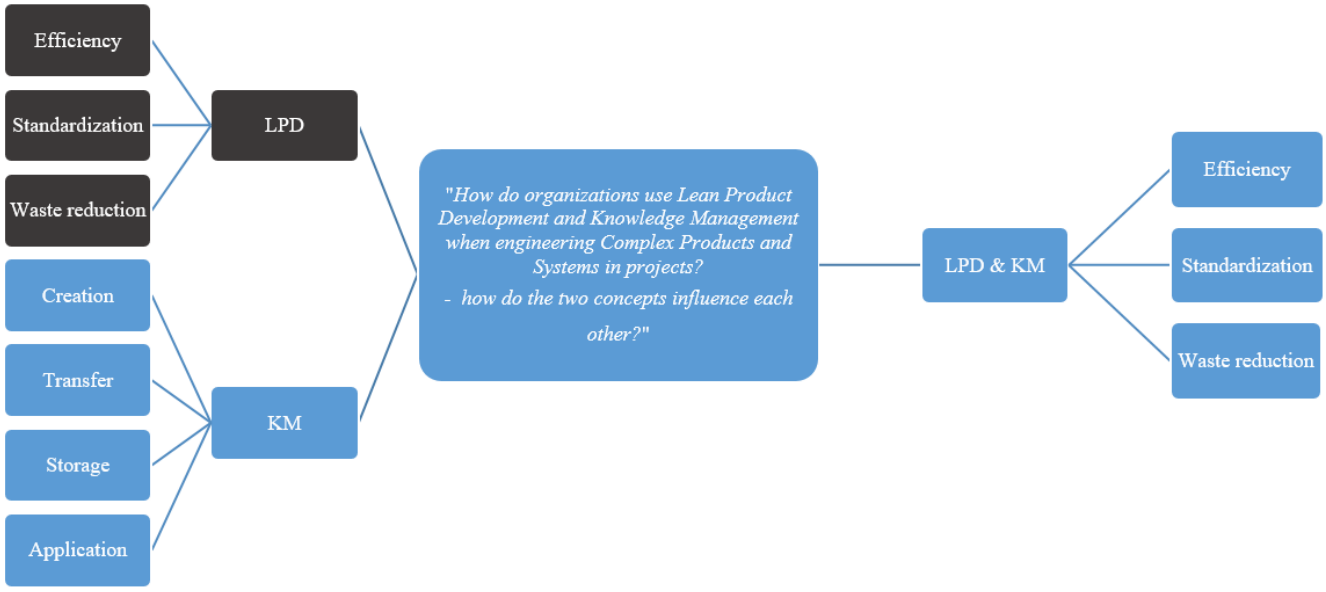

Figure 5 Analysis structure LPD

4.1.1 Focus

Both companies have implemented principles of LPD in the engineering process, although it is more prominent in organization 2 than organization 1. Even though both organizations have implemented LPD initiatives in some extent, none of the them uses “Lean” as a term. In organization 1 the informants have different perceptions of the extent to which LPD is implemented or not. Organization 2 has implemented a continuous improvement initiative which focuses on continually improving processes and tools in projects, software engineering, and hardware engineering, in which everyone in the projects and different departments participate. This is therefore described as a bottom-up process.

The focus of this initiative is to get the employees to define problems and find solutions in order to reduce waste, enhance efficiency, and improve products continually. This approach also includes the use of methods like five why, root cause analysis, value flow analysis, and A3’s. The first step in the continuous improvement initiative is gathering different problems by brainstorming. The problems are defined by both managers and employees, and written on post-it notes, which then are hung up and structured on papers on the wall. The second step is to classify these problems in terms of severity and occurrence, in order to prioritize the ones with a high grade of both. The next step is to find solutions, delegating responsibility and stating a timescale for when the problem should be solved. As a means to keep this process going, the department

managers host weekly mandatory whiteboard meetings with their employees, in which the latest updates on each problem are discussed. These meetings also include stating new problems and classifying them, as well as evaluating different KPIs and discussing the focus for each week. As all employees are involved and participating in this project, it is described as a source for motivation. Organization 2 was also nominated for a Lean-award for their continuous improvement initiative.

Organization 1 on the other hand, focus on improving their processes by making them zero defect capable. However, as the engineering process is mostly done virtually it lacks a visible flow, which makes it difficult to implement Lean-initiatives. Organization 1 has solved this problem by continually trying to optimize parts of the engineering process in order to make it efficient. A consequence can be sub-optimization, but this is something the company is aware of and try to prevent. During the actual project execution, the company does not make use of specific Lean-initiatives, but they try to make use of the Lean mindset, defined as a focus on the underlying elements of Lean instead of specific Lean-tools. This, however, is not something that the entire project team is aware of, but rather something that the managers focus on when executing a project, as exemplified in the following citation.

> *«...Lean is not necessarily what we in the projects concern ourselves with on an everyday basis, (...) we use it more in connection with the establishment of processes and standard processes, and you can say the creation of teams and other tools in connection with the project execution."*
>
> Informant 1.6

Further, both organizations' focus on efficiency have increased considerably in recent years due to increased competition and a period of recession in the industries. This will be discussed further in the chapter below.

4.1.2 Efficiency

All the informants agreed that Lean contributes to a more efficient project execution. Efficiency has played a central role in both organizations for an extended period of time. For organization 1, the focus on efficiency is more important now than ever before due to the period of recession in the industry. As a means to ensure an efficient project execution, processes, procedures and tools are continually improved. However, some of the informants mentioned that these processes and

procedures have become too detailed, and therefore work against their actual cause, as exemplified in the following citation.

> *«…one works with processes, process improvements continually, and it's obvious that it's a lot of ISO-standards, a lot of requirements which gradually has made these processes very detailed and complex. And we are a global organization which has tried to create equal global processes, (...) and it's the local differences that make it, sometimes it feels like it is not Lean and more efficient, but almost the opposite."*

Informant 1.5

Organization 1 also tries to reduce waste in order to enhance the efficiency. They do this by measuring time used on different processes, trying to prevent doing the same mistake twice, and follow standardized processes. They also claim that the Lean mindset is used when putting together a well-functioning project team that makes the project tasks flow efficiently.

Organization 2 believes that it is important for the employees to have an attitude towards efficiency. Nevertheless, engineers do not focus on enhancing the efficiency of work tasks on an everyday basis. They rather do what project managers tell them to do in whatever time it takes to complete the task. Their approach on efficiency enhancement is a continuous parallel process to engineering and projects through the continuous improvement initiative, in order to improve processes and tools. As mentioned earlier, this is a bottom-up process where the employees take part in the problem and improvement process. An efficient project execution is ensured by improving, documenting and standardizing processes and procedures to be followed, in order to prevent wasting time on unnecessary activities. In addition, they occasionally develop their own software in order to increase the efficiency and standardization of individual tasks, as exemplified in the following citation.

> *"… we try to develop software that can do these things faster and more standardized, so that you can almost just put in a contract and push a button and you will get the NN document (…) but this is not developed as part of a project. We work on it outside the projects and implement it in the projects when we have found a better solution. But, so it is a continuous parallel process to the projects in order to improve individual tasks."*

Informant 2.4

Further, both organizations use different KPIs in order to measure how efficient processes are, and they both standardize in order to be more efficient. The latter will be discussed further in the upcoming chapter.

4.1.2.1 Summary

Efficiency has become increasingly important in both organizations. Both organizations focus on enhancing efficiency through continuously improving and standardizing processes, reducing waste, and measure KPIs. Organization 1 focus on putting together well-functioning project teams that make the project tasks flow efficiently. For organization 2, however, we found that they focus on improving processes and tools through the continuous improvement initiative, which function as a continuous parallel process to engineering and projects. We also found that the engineers do not normally focus on efficiency on everyday basis, rather on following standardized processes and procedures.

4.1.3 Standardization

In terms of standardization, our findings were more or less similar for the two organizations. Both organizations have mostly standardized processes, procedures, documents, as well as having increased the focus on standardizing products. The informants disagreed about the latter. However, the majority in both organizations, including all the informants working in projects, were of the opinion that their products have become, and are constantly becoming more standardized, as exemplified in the following citations. This means that the engineering phase has evolved from involving a high degree of product customization to involve less product customization, while still fulfilling the customer needs. It is important to note that satisfying customer needs can include easy product adjustments, as well as complex product customization.

> *«…through time the subsea industry has been known to deliver what the customer asks for, and that might be something we want to change. It is, and that they deliver on our specifications, that we can deliver. A system will always be made according to customer requirements, but our wish is to engineer these systems with standardized solutions."*
>
> Informant 1.3

> *«…you can say that we traditionally have been a tailor, and we have measured the person and if he came back a few weeks later we had to measure him again. This time he might have put on some weight, and we have without any additional cost altered the suit. The next time he comes by he might have lost a*

few pounds, and we have altered the suit again until he gets exactly what he wants at the time. This is very time-consuming, so we now try to make more and more brand suits. Let's say you get the brand suit "NN" and it fit and we will just have to alter the arms and legs for it to fit, be good enough. (...) we are trying to give the impression that you get exactly what you want, but by choosing a standard (...)"

Informant 2.3

Further, both organizations have had a rapid growth over the past decades. As a result, they have been forced to standardize and globalize processes and procedures. This is done in order to make the processes more predictable and to ensure that all the engineers follow the same processes and work in somewhat the same way. Even so, it became apparent during the interviews in organization 2 that there is room for the engineers to make up their own processes and do things their own way. Nor is standardization something the engineers think about or notice on an everyday basis, as exemplified in the following citations.

«…engineers are way to, we like to do our own thing and just invent things and find solutions for ourselves. So you have to have that kind of processes to streamline the way you work. Actually everyone should work more or less similarly, um, and that's why such processes are very important."

Informant 2.4

"… I don't know if anything more is standardized. I think a lot has become more standardized, but I think it has happened gradually. They just slightly alter the way we work (…) but we will not feel or notice that in any way. We just, we work, and if we are supposed to get better at something we just follow that order. At least 80% of us do."

Informant 2.4

Both organizations stress the importance of standardization and structuring in order to be efficient as the organization grow. The distinction between the two organizations in this relation, is that organization 1 focus on standardizing processes and procedures in order to make them zero defect capable, whereas organization 2 has applied a continuous improvement initiative, in order to better improving and standardize processes and procedures. However, one of the informants in organization 2 insinuated that although the continuous improvement initiative is effective for improving and standardize processes and procedures, it does not necessarily mean that these procedures are read or followed by the employees. This is exemplified in the following citation.

"Our Lean initiative is about defining problems that we detect on a sticky note, and then work on that problem until we have found a solution, and then try to implement that solution. ...Although we may have solved, I do not know how many such problems we have solved, but probably about 50/60 problems or something like that, it might just be two or three of those 60 that has had a really good effect. A lot is like: "yes, we have now created a procedure that explains how to do this and that", but no one reads that procedure anyway."

Informant 2.4

Standardizing processes is difficult. As mentioned earlier, standardizing the engineering process is especially difficult due to the lack of a visual flow, as exemplified in the following citation.

«… a visual flow makes it easier to implement Lean initiatives. This is one of the problems in the engineering part of the project, right. There is, there is a lot done virtually and so on, on computers and IT-systems and so forth. And it is difficult to, in a way, the process often becomes somewhat invisible, or you at least have to do a job in order to make it visible. And that makes it challenging in a way."

Informant 1.3

Organization 1, claims, as mentioned earlier, that their standardized procedures have become very detailed and complex due to ISO-standards. As a result, some employees may become too focused on following the process descriptions and "forget" to think for themselves and make individual necessary adjustments. They are now working on simplifying these processes.

Both organizations have made use of several IT-systems in an effort to become more structured in terms of documents. The IT-systems are, among other things, used to store procedures, process descriptions, check lists. The purpose of using IT-system is that employees easily shall find different documents when needed.

4.1.3.1 Summary

Both organizations agree that the need for standardizing and globalizing processes increases as the organizations grow. Our findings regarding standardizations is more or less the same for both organizations. Both have mostly standardized processes, procedures, documents, as well as having increased the focus on standardizing products. The latter has evolved from involving a high degree of product customization to involve less product customization. Both organizations also use IT-systems in order to structure where documents and information can be found. The

main difference between the two organizations in terms of standardization is that organization 1 has a separate department which focus on improving and standardizing processes, whereas organization 2 standardize through their continuous improvement initiative.

4.1.4 Waste reduction

It does not seem like organization 1 has a strong focus on waste reducing activities, but they have initiated some measures in order to reduce waste. Organization 2, however, focus on waste reduction in the continuous improvement initiative, as previously mentioned. In organization 1, price of non-conformance is measured in order to detect waste-inducing processes and activities which can lead to rework or product failure. Further, one of the informants did argue that there is a focus on reducing waste during project execution, as explained in the following citation.

> *«Lean appeared as a concept, uhm, I don't remember exactly when it appeared as it has been known for a while, but it appeared as a concept and we had already established our processes and, uhm, where doing our thing long before Lean arrived. But Lean, at least what I experienced in the beginning was that what Lean represented was in many ways what we had tried to achieve, and someone had managed to put that into a sensible system and describe it. That does not mean that we follow and use all Lean initiatives, but I think somehow it's, to reduce waste, at least that's my way of thinking, is something we have always tried to do. But you can say it, it's a bit depending on how far you can deduct Lean. In other words, you could say that one thing is to build on principles, and another thing is whether we have implemented all the, all that is related."*
>
> Informant 1.7

Organization 2, on the other hand, focus on reducing waste by defining problems and develop solutions through their continuous improvement initiative. They also try to root out waste by repeating success and correcting mistakes in the next project, as illustrated in the following citations.

> *"Our continuous improvement initiative is about defining problems that we detect on a sticky note, and then work on that problem until we've found a solution, and then try to implement that solution."*
>
> Informant 2.4

> *«We try to repeat good, if we have done something well once we aim at repeating that success. And if we have done something wrong we try to correct*

it next time. If we see that the process in which we work can be improved, then it shall be improved. We try to make our way of working more and more similar every time so it becomes more predictable."

Informant 2.1

Further, during the interviews in organization 2, it became apparent that it was more or less up to the employees themselves to avoid spending time on tasks that could be characterized as waste. One of the major problems regarding waste is found to be documents. The engineers spend a lot of time drafting up project documentation from scratch every time they get a new project. This is characterized as a source of annoyance for engineers, and they try to develop solutions that solves the problem, making the process more efficient. This is exemplified in the following citation.

«…a major obstacle is that I have to sit and write a lot myself, instead of having some sort of IT-system making the documents for me based on all the information we have. And that's the sort of thing that annoy us, and then we begin to devise solutions on how we could do this, and maybe, in the long term, that solution gets implemented in the project."

Informant 2.4

It also seemed like several efforts to make new solutions were shelved due to lack of time and resources. This can be characterized as a source of waste rather than an effort to reduce waste.

Organization 2 has also reduced the amount of information sent to the customer regarding system specifications, down to a single page with simple explanations and illustrations. This is to make sure that the customer understands the system specifications and to prevent rework in a later project phase or after installation. We will categorize this initiative as waste reduction, as they have stopped making information that does not bring value to the customer.

"…we have previously, earlier projects documented and released too much documentation, while the customer really only needs a few answers. We've given the customers too much information, and as a result confused them a bit. We've said, everything is available, just read your way through it, but it's a telephone book of information. The customer really only needs one page, and we've given them information overload in a way. This is something we try to cut down on, somehow be more, the one page you get is what you need, instead of a big book."

Informant 2.3

«Uh, well, now, we've started, it's a thing that is happening these days, but we are going to create data sheets, as it's called, for all our features. And a data sheet is in a way an A4 sheet which tend to have a headline: this is the function, it does this, here are some photos of what it looks like. It is a bit like to see, show the customer (...)"

Informant 2.4

Both organizations have also established several document reviews in order to interpret customer specifications correctly and by that prevent misunderstandings. Nevertheless, we were still told that some errors occasionally pass through due to misinterpreted requirements. Even though more document reviews should prevent errors, one can also argue that more document reviews decrease project efficiency. On the contrary it can be argued that it is more efficient using time and resources up front to make sure specification is clearly understood, than using a lot more time and resources on correcting potential misunderstandings in a later phases of the project. We were also told that organization 1 reviews the same documents for a frequently bought product every time that product is sold. This can be characterized as waste as it should be unnecessary to review the same document over and over.

Further, as both organizations are project-based they can be characterized as pull-organizations. This means that they do not initiate a project until the product is sold. As, the pull-system strives to eliminate unnecessary activities, it can be characterized as a source of waste reduction.

4.1.4.1 Summary

It is evident that organization 2 has a stronger focus on waste reduction than organization 1. Organization 1 measures PONC, and use the Lean mindset of waste reduction during project execution. Organization 2, on the other hand, do have a clear waste reducing focus through their continuous improvement initiative. Organization 2 has also tried to develop software, which can reduce time spent on drafting more or less the same documents several times. Additionally, has organization 2 reduced the amount of information sent to customers. Lastly, as both organizations are pull-organizations, this can be categorized as a source for waste reduction.

4.1.5 Conclusion

Lean can be interpreted in many different ways by different people. While some look at Lean as a tool with clear guidelines and standardized methods, others look at it more like a mindset in order to enhance efficiency, standardize, and reduce waste. In this thesis there is a clear difference between the two organizations under study regarding the use of LPD. While one of the organizations has implemented a continuous improvement initiative and weekly conduct whiteboard meetings, the other asserts to be more focused on using the Lean mindset and not specific Lean tools. Even so, it is evident after conducting this analysis that both efficiency and standardization are major focus areas in both organizations in terms of LPD. However, the focus on waste reduction is stronger in organization 2 than in organization 1.

In order to enhance efficiency, both organizations claim to focus on continuous improvement of processes, procedures and tools, standardization, and waste reduction to some extent. Organization 2 also has a focus on developing software in order to become more efficient. As a result, we categorize continuous improvement, standardization, waste reduction, and software development as key findings regarding efficiency. In terms of standardization we summarize our key findings as standardization of processes, products, documents, and IT-systems. In terms of waste reduction, we believe our key findings are the continuous improvement initiative of organization 2. We also include the pull-system as a key finding regarding waste reduction as it strives to eliminate unnecessary activities. Our key findings regarding how the organizations use LPD in order to enhance efficiency, standardize, and reduce waste is summarized in the figure below.

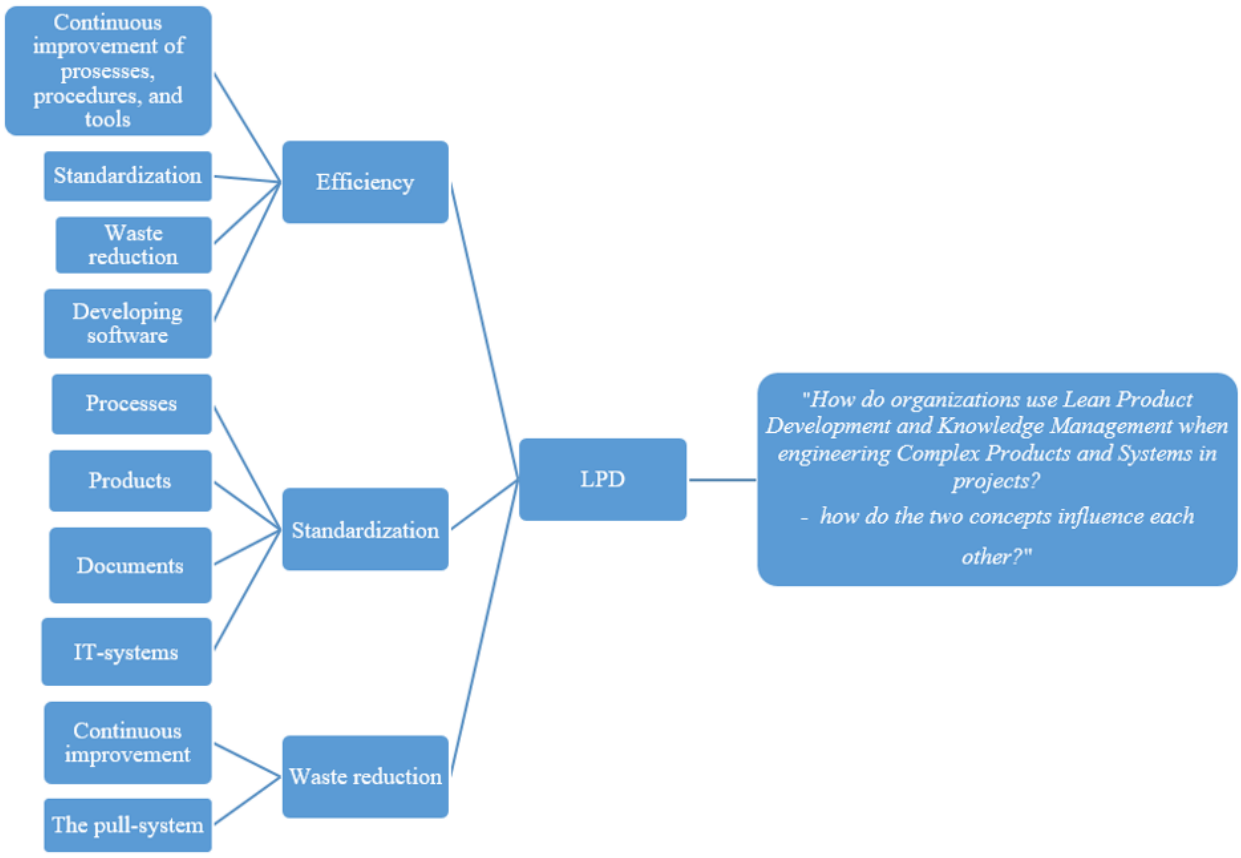

Figure 6 Summary of key findings LPD

4.2 Analysis Knowledge Management

In this chapter, an analysis of the data collected regarding the use of KM in the organizations under study is presented, and the final findings are accounted for. First, findings regarding the focus of KM in each organization is explained. Then the findings regarding the four different stages of KM emphasized in this study, knowledge creation, transfer, storage and application, is accounted for. Findings from each organization is presented in appendix 6. The analysis and findings are structured in accordance with the following figure.

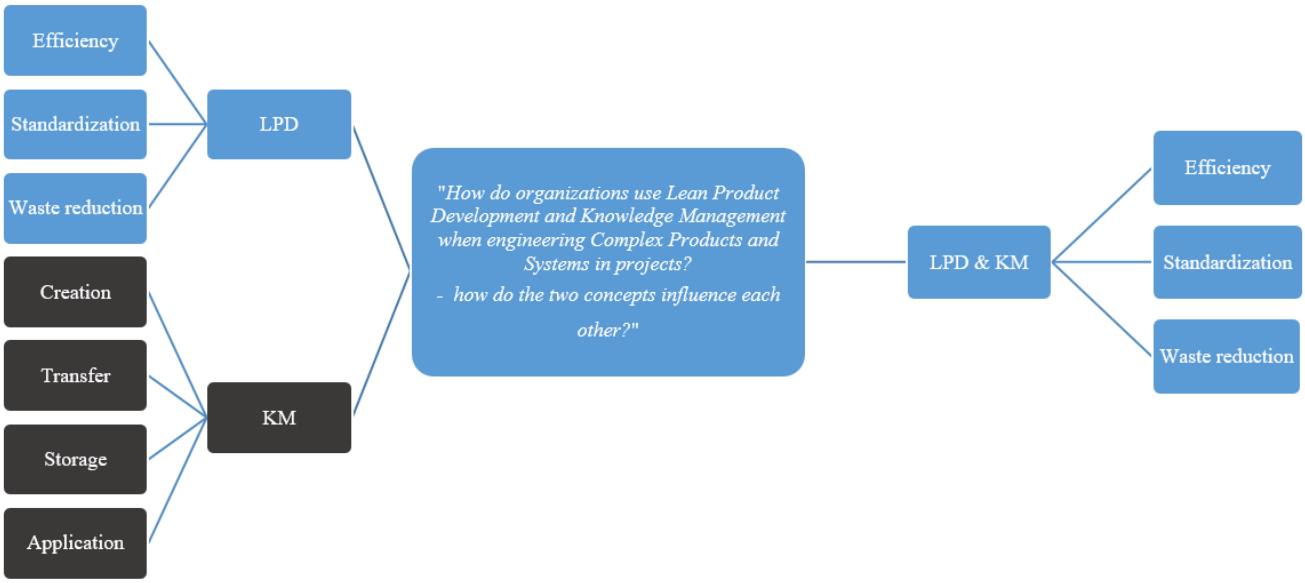

Figure 7 Analysis structure KM

4.2.1 Focus

In order to avoid misunderstandings and to make sure we and the informants had the same understanding, every informant was asked about their associations regarding the term KM. By asking this question we were able to grasp what the informants associated with KM and how much knowledge they possessed about the topic. After the informants had explained their associations, we described what our main focus regarding KM is in this thesis, namely to examine how knowledge is created, transferred, stored, and applied in the organizations under study. KM is extensive and the informants in both organizations had different associations and knowledge in relation to KM. In organization 1, six out of a total of seven informants had a perception in accordance with the focus of this study, whereas in organization 2, this was only the case for one out of a total of four. The reason for this is probably that it is a higher focus on KM in organization 1 than in organization 2. Organization 1 developed a KM-department in 2012, and have by that increased their focus on KM during the last years. There were also three of the informants interviewed in organization 1 that worked directly with KM on a daily basis, in contrast to none in organization 2. Both organizations think of themselves as knowledge organizations, and it is claimed that KM and knowledge systems are important for an efficient project execution. Knowledge has always been an important part of the organizations, as a whole, and especially in project execution. Although, the focus on KM has increased the last decade, due to changes in the industries. Today, there is less demand for the organizations' CoPS than before,

which increases the need for efficiency and profit maximization through standardization and reusing knowledge. Organization 2 also underpins that KM is a complex and continuous process, which takes up a lot of resources.

4.2.2. Knowledge creation

Overall, it seemed like it was quite difficult for the informants in both organizations to explain how knowledge was created in the project engineering phase. Even so, it was emphasized that the majority of new knowledge was created in projects and the engineering phase in order to satisfy new customer specifications, as exemplified by the following citation.

> *"…often knowledge does not arise in P&D as they are called, Product and Development, but it actually arises in the project itself, because that's where the need is reported."*
>
> Informant 2.2

As both organizations are working on making their products more standardized, special customer requirements do not arise as frequently as before. This decreases the need for knowledge creation in the project engineering phase. Even so, knowledge creation also occur as products must be updated on a regular basis in order to meet current standards.

Several informants in both organizations explained that knowledge creation arise both individually and in teams, through discussions or, as mentioned in organization 2, operative trial and error. Teams are often used due to the complexity of the products and systems developed. It is often need for specialists from different fields in order to come up with a satisfying solution to solve problems related to customer specifications. The following citations illustrates how knowledge may be created.

> *"…most products in the product lines have, uhh, lets almost say an element of different technologies, and thus it is very often team based what we, what we have to do, because we need the expertise from the specialist areas, so to a great extent it is team based. Of course in some areas it's, it's individuals that retrieve things within their area of expertise, but to a great extent we are team, both based and dependent."*
>
> Informant 1.6

> *"…I experience that one can have group meetings such as where one discusses some things and the ball starts rolling and one may get a little "aha" (a revelation), so in, I think that new knowledge often arises in some meeting*

setting where the conversation might have some free flow, or where you have a problem that you need to solve, when it is allowed to think a bit different, right."

Informant 1.5

The previous citation illustrates that knowledge creation also depends on the environment and the people you discuss with. When there is room for thinking a bit different and the group is open for discussing all types of ideas, new knowledge is likely to arise. Knowledge creation was also said to happen in interaction with the customer, e.g. when discussing specifications.

The informants did also have difficulties explaining the difference between tacit and explicit knowledge creation, which is in fact really difficult to separate. In general, tacit knowledge was perceived as experiences gained during the project execution, through discussions, problem solving and by performing tasks. However, explicit knowledge may be created in the same situations. For example, when a product or system is designed, both explicit and tacit knowledge is created. The explicit knowledge created will be reflected in the final design, while tacit knowledge will be connected to the actual design execution, as exemplified by the following citation.

"…explicit knowledge in connection with for example new products, new systems, we establish both in terms of product descriptions, system descriptions, and most often also as a part of technical training or training programs. But it's evident that those who participate in that part of the activity, is left with some tacit knowledge as well."

Informant 1.6

Informants from organization 1 believe that it is created more tacit knowledge than explicit knowledge in projects, precisely because of the amount of experience gained throughout the process.

All informants in organization 2 mentioned coffee breaks as an important arena for knowledge creation and knowledge transfer. This is exemplified in the next chapter about knowledge transfer.

Organization 1 also has a web-tool used for knowledge creation, which replace a physical brainstorming meeting with boards and yellow notes. Every web-meeting has its own facilitator and all participants may contribute with suggestions anonymously. The benefit of making

participants anonymous, which is impossible in a physical meeting, is that people usually are less afraid to write their opinions.

4.2.2.1 Summery

Most informants are of the opinion that it is created a lot of tacit knowledge in engineering and projects, and that tacit knowledge is gained through experience during project execution. Almost all informants said that knowledge was created due to new customer requirements and specifications. In order to satisfy customer demands new solutions must be found, and hence new knowledge is created. We found that knowledge is basically created in four different contexts, namely during breaks or random socialization, individually, in teams and different types of groups, and through knowledge tools. The latter was only mentioned used in organization 1. Knowledge creation is also said to depend on the environment, e.g. the openness of a group.

4.2.3 Knowledge transfer

Knowledge is shared and transferred in many different ways in organizations, the same is the case for organizations that develop CoPS. Both organizations under study in this thesis are global companies with thousands of employees, which makes knowledge transfer difficult and complex. Several informants in both organizations underpin that the need for structuring knowledge transfer, increases with the size of the organization. Consequently, both organizations have had a focus on synchronizing processes globally so that employees perform tasks the same way, as exemplified with the following citations.

> *It's clear that we as a growing organization have to structure us better and better because we get larger and larger, more and more people, and larger activities involved.*
>
> Informant 1.7

> *It's not easy to inform everybody about everything at all times, uuh, but that's why we try to synchronize processes so that one works equally, and then, and obtain knowledge from the same place.*
>
> Informant 2.3

> *And then you globalize and then you change, try to put in place global standards in some areas. That's, that's commonly an element when you grow, to try standardizing things.*
>
> Informant 1.1

Knowledge is transferred both unsystematic, which we define as knowledge that is not systematically stored in knowledge systems, and systematically through different knowledge channels. Unsystematic knowledge transfer comprises face to face communication in different settings, e.g. in formal or informal meetings, in the hallway, and in the cafeteria. It also comprises communication by the use of telephone, mail, chat-functions etc. In organization 2, mail may also be characterized as systematic knowledge transfer as mail-in databases are used. In these databases, mail correspondence logs are stored. Share point solutions, organizational Wiki-pages, minutes of meetings, servers, procedures, product descriptions, planning tools, various documents, checklists, and forums are all examples of tools used in both organizations to systematically store and transfer knowledge. One of the advantages of using knowledge systems and other channels for knowledge transfer and storage, is that information is made available for many people at the same time.

Organization 2 uses data sheets This is a single page which contains illustrations of what a specific product looks like, as well as short explanations of its functions. The purpose of the data sheet is to make it easier for the customers, as well as the employees, to understand the company's products and their functions.

Both organization also have the opportunity to use forums to transfer knowledge, by sharing and discussing problems with each other virtually. Evens so, it seems like forums is more frequently used and systematized in organization 1 than 2. In organization 1, every forum has one or several network coordinators who make sure that people use the forums, and that there always is someone who answers the questions. The people answering are specialists who are encouraged to share their knowledge in order to preserve it in the organization.

In organizations 2 a Monday meeting is hosted every week among the engineers, in order to discuss last week's occurrences, as well as other aspects. However, it varies how many that participate in these meetings. In order for everyone to stay updated on information shared during these meetings, a minutes of meetings document is written and shared globally. How many who actually takes the time to read this document varies, hence some miss out on new information that might be of importance.

Colloquia is another frequently used knowledge tool in organization 2, in order to transfer knowledge from specialists, and preserve their expertise within the organization. In the colloquia

different themes is discussed each time, and participation is voluntary. When colloquies are carried out in offices abroad a specialist on the field function as a contact person that is available to answer any questions that may appear.

In organization 2, knowledge is also transferred during coffee breaks and otherwise by word of mouth. Sharing knowledge when drinking coffee is also regarded as part of the organizations culture, which makes the coffee breaks important for the employees, as illustrated in the following citation.

> *"…some might say that we drink a little too much coffee. Sitting and drinking a little bit too much coffee, but that have always been a cultural thing, when drinking that coffee cup a lot is exchanged, uhh, important information and tips and tricks that often is, which is what one may call tacit knowledge."*
>
> Informant 2.4

Both organizations claim that sharing knowledge and helping each other is part of their culture. Although people help each other and usually share their knowledge with people when asked, an organization may also have people that protect their knowledge in order to stay important, especially in difficult periods, as exemplified in the following citation.

> *"But it's clear that an organization always consist of individuals and such as the phase we're in now, a period of recession in the industry, you notice that people want to protect their knowledge as they want to be important….so it's not sure it's that, that, or it can be very unconscious that one isn't sharing, but it regards that you want to be clever, you don't want to ask for help, you want to take on a lot to show how diligent you are."*
>
> Informant 1.5

In order to ensure that people transfer knowledge and experience, organization 1 have implemented several measures. Among other, a network composing of professionally qualified people that is encourage to share their experiences and knowledge with other engineers, has been established. This is exemplified in the citation below. The specialists that frequently transfer knowledge and experiences are reworded.

> *"…We have created a network of really professionally qualified people, uh, called the fellows, the engineering fellows, and this is people who then gets an award (…) Will then have as a job to share experience and influence other*

engineers as well, so they see the value of sharing their knowledge. So, so we have many of those small…processes trying to make people share with others."

Informant 1.2

Different work groups are connected to various professional networks of interest. Communication takes place through announcements on the website. At that point mail alerts are sent to the employees in the connected work groups. On the other hand, organization 2 preserve valuable knowledge by having experienced engineers, called lead-engineers transferring their personalized expertise into organizational knowledge. This is done by improving existing work processes and check lists.

Informants in organization 2, argue that it is easier to know and located who to ask in the Norwegian offices, than among the different global offices. In order to transfer more knowledge among offices in organization 2, Norwegians are sent abroad to share their knowledge and experience. Informants from organization 2 also said that it is generally transferred more knowledge within departments that deliver the same products, than between departments.

Informants directly involved in projects in organization 1, are of the opinion that processes and tools for knowledge transfer are established and formalized better within projects than in the rest of the organization. An important part of project execution is to preserve experiences and knowledge gained. As there is a lot of tacit knowledge arising during project execution, making this knowledge explicit in order to transfer it to other projects, is crucial. This is stressed in the following citation.

"That's what we continuously strive for, to bring the tacit knowledge into explicit knowledge which then is transferred to the next project and the organization in general."

Informant 1.7

There is a lot of knowledge transfer in projects, happening on different levels. Informants in organization 1 stated that a project consists of a team who are placed in the same physical space. This makes the oral communication flow easy and frequent. People that have worked on other projects before will bring their experience into new projects, and share their knowledge with other team members. The projects also consist of people from different disciplines, hence the

team frequently communicate and transfer knowledge with different departments as well. The following citation illustrates the different levels of knowledge transfer in projects.

> *"...when we put together a project we pick specialists from these pools and put together a team, and then we move to a dedicated place and start working, and it's apparent that these people that we borrow in a projects context, they come from an environment, and they, they don't leave that environment even if they physically move to work together on the project, they still communicate internally with their colleges and, and it's clear that a lot of information exchange is happening in these environments simultaneously, and, yes."*

Informant 1.7

Organization 1 has also developed project manager forums, where project managers share experiences monthly, as illustrated in the following citation.

> *"I do have my project manager forum in which I have meetings and talk to the other project managers, and mostly we spend time on exchanging experiences. We actually do that monthly."*

Informant 1.7

In projects, lessons learned are an important part of transferring knowledge from one project to another. Lessons learned is a document made at the end of each project, consisting of experiences gained during project execution. Lessons learned are taken back to the different product groups, making it possible to use the experience gained in projects to update products, processes, procedures etc. In organization 1 it is possible to filter projects out from what type of experience you are looking for, and lessons learned is frequently used as a basis for risk analysis in new projects. The importance of knowledge transfer between project is exemplified with the following citation.

> *"Knowledge transfer from project to project is of huge focus, and it comprises two elements, as we say lessons learned, that's a very, it's a relatively detailed process on how to conduct a lessons learned. And then there's links to risk analysis, or risk management. It's evident that you have to use these lessons learned, and it, and use it as a basis for a risk-analysis, is, is, is an appropriate way of doing it."*

Informant 1.7

In organization 2 experiences gained in projects may also be taken back to the continuous improvement initiative, which also helps transferring knowledge to all other projects eventually. There also exist a database where problem and improvements is reported in order to improve project processes.

An important part of knowledge transfer is training of new employees. Training is important in order to prevent costly mistakes and dissatisfied customers. In both organizations training consist of both explicit and tacit knowledge transfer. Explicit knowledge is mainly gained through formal training upfront, while tacit knowledge is mainly gained gradually through experience, as illustrated by the following citations.

> *"I think that generally in the organization you, there is typically a combination of learning by doing the task, and in a way do training upfront."*
>
> Informant 1.3

> *"…when we train people we sit together with them and configure the system and teach them. Someone experienced is sitting with them so they actually get a mix of both explicit and tacit. It relies on having, having someone with you to do what should be done both here and out. Especially out when, when there is someone with you that show how you should behave and what is important…"*
>
> Informant 2.2

Engineering may be characterized as a craft, hence experience gained through both explicit and tacit knowledge is important in order to be successful.

Both organizations use mentors in relation to training, but in different extent. While organizations 1 claims to often use mentors when training new employees, organization 2 claims to always use mentors. Organization 2 also use colloquia for training. The main reason for using mentors is to transfer tacit knowledge, as exemplified with the citation below. On the other hand, Colloquia, is used to transfer both explicit and tacit knowledge.

> *"…now for example I'm a mentor for a project manager, that's for, for that precisely, to transfer that, of that, more that tacit information."*
>
> Informant 1.7

The level of skills and the quality of mentors have a huge impact on how the new employees will perform their future work tasks. It is therefore important to assure that the mentors chosen are

skilled in what they do, and that they do not poses critical bad habits that may be transferred to new employees. Organization 2 has had some problems with the latter, but have recently developed a certification program in order to better assure the quality of mentors.

Several informants in both organizations claim that there is a lot of tacit knowledge in projects, and that this knowledge may be both difficult to transfer and to acquire for the receiver. New knowledge is commonly gained in everyday work, even without noticing, as it simply becomes a part of how work tasks is conducted. Therefore, it is possible for people to not be aware of all the knowledge they possess, or that other people do not have the same knowledge or experience. In order to acquire tacit knowledge, it is important to know who possess the knowledge you are looking for, as exemplified in the following citation.

> *"...when I started in "NN", I was certainly in no doubt that the most important skills I needed in the first period was to know who to ask, because I wasn't capable of finding the information I actually needed because it wasn't there. It was, it was tacit knowledge."*
>
> Informant 1.6

How well one is at acquiring new knowledge is mentioned by one informant to be related to the recipient's maturity and ability to reflect.

There is also important to transfer explicit knowledge when training new people. Organization 1 have established an organizational University which focuses on the formal part of training and education in relevance to the job position, as illustrated with the following citation.

> *"...and due to the establishment we have had through "NN" University for a couple of years ago, it has been an increased focus on formal education and formal training within quit a few different areas..."*
>
> Informant 1.6

Explicit knowledge is found in various knowledge systems and documents. Especially for people working in projects, in particular engineers, it is a lot of product information and user manuals to have knowledge about. Due to the variation of different information and knowledge needed to be acquired, it takes a long time to be fully trained, especially for engineers working with software. As product information is frequently updated if changes are made during the project, keeping up with new information is a continuous process.

A couple of the informants in organization 1 are of the opinion that the organization has reached a point of saturation in relation to transferring knowledge through mail, meetings, and various documents. Performing meetings and making documents takes up a lot of resources, and is therefore an inefficient way of transferring knowledge. Communication through mail is criticized as only the people included in the correspondence log will be exposed to the information, have the opportunity to store the information, and have the opportunity to apply and reuse the information. This is exemplified in the following citations.

> *"We have reached the point of saturation by taking it through meetings, mail, and documentation, so we need to find another way to do it."*
>
> Informant 1.1

> *"One of the worst interaction killers is actually email because you think you interact, but you really just talk with, uhm, a handful of people that you know, so that the people hired tomorrow can't take a part in the knowledge that they exchange. And very often in an email uhm correspondence one is asking – how do you do this? – and it's not sure that any of the recipients know it. So if one had posted it in a discussion forum instead, one would have a much larger audience."*
>
> Informant 1.2

4.2.3.1 Summary

It is understood that the need for structuring knowledge transfer increases with the size of the organization. As the organizations under study are global businesses with thousands of employees, there is a strong need for a well-structured knowledge transfer process. In order to structure knowledge transfer, both organizations use various knowledge channels. Sharing knowledge and helping each other is regarded as part of the organizational culture in both organizations. Preserving knowledge of specialists and lead-engineers is also of focus in both organizations. A project team consist of people with different expertise and experience, gathered in a physical space. This facilitates a good communication flow between team members. Members share their experience, in addition to transfer knowledge between projects and the departments they belong to, during project execution. Knowledge is also transferred between projects through project manager forums, in which project managers share problems and experiences. Lessons learned is also used to transfer knowledge from one project to the next, in addition to update products, processes and procedures. Transferring tacit knowledge is important

in projects, but also difficult, as one might not be aware of the tacit knowledge one possess, or that other people do not possess the same knowledge. Further, new employees have to learn both explicit and tacit knowledge during training, in order to perform their tasks in a satisfactory manner.

4.2.4 Knowledge storage

Informants are of the opinion that a lot of knowledge is stored in both organizations. Different types of knowledge and information is stored in various knowledge systems and channels, as mentioned in chapter 5.2.3. It is understood that well-functioning knowledge systems are important for an efficient project execution. However, this is dependent on how the systems are being managed, and how easy it is to retrieve the stored information. This is exemplified in the following citations.

> *"Yes, appropriate knowledge systems are very useful for an efficient project execution. But then again you have the inexpedient that is inhibiting."*
>
> Informant 1.1

> *"...when you mobilize a tremendous project in two months, we could never have done that if we didn't have well-functioning systems as a base to do it. And everything you do in that phase will influence your everyday thereafter. If you have been clever and configured your project well, then, then your everyday becomes easier in the execution phase. So it's very, very important that we have uh, that we have both systems and knowledge exchange between projects."*
>
> Informant 1.7

In addition to documents stored in different knowledge systems, knowledge is also continually baked into tools and stored in processes, products, working procedures etc., as exemplified in the following citation.

> *"...explicit knowledge related to such as new products, new systems, we establish both in terms of product descriptions, system descriptions and usually also as a part of technical training or training program."*
>
> Informant 1.6

This regards knowledge generated from the organization as a whole, as well as projects. In other words, stored knowledge is usually not project specific, as the same knowledge is used across

different projects and in different departments involved in projects. Hence, new knowledge stored in tools, products, processes and working procedures on a general basis, affect the project configuration and execution. Project specific knowledge is stored regardless of its value for the organization, mainly because it is the property of the customer.

Even though there is a lot of knowledge stored in different knowledge systems, there is also a lot of information that must be remembered in order to conduct tasks the right way. This information might be forgotten by the engineers, which may result in errors discovered in later on, as exemplified in the following example.

> *"When I configure a completely new project I have a, a document that describes how I should do it, but then there are always some extra things that you must remember. And of all these things to remember, I maybe remember nine out of ten, and then another remembers nine out of ten, and a third maybe just four out of ten, and then there's another that remembers some others four out of ten. So it's very easy to introduce these minor defects, right, because we have a little problem with, that everybody knows, everybody can't know everything, but it has to be a place one can go to in order to acquire the information."*
>
> Informant 2.4

As earlier mentioned, both organizations have several knowledge systems, and hence information is spread in many different systems. This makes them difficult to deal with for employees, as exemplified in the following citation.

> *"And then we have a Monday meeting, we have email, we have Wikipedia, we have an old software database that's still used occasionally, uh, and we have operating manuals, and we have uhm information coming from our product department on how our products should work, right. I've already mentioned six places where there exists information about something that I can find. Ideally it should only be one place (…) Yes, and then we have Lync, that's skype for business, right, so it's a chat function, and then it is like knocking on the neighbor's door and just, yes, what was that again?"*
>
> Informant 2.4

Even though using many different knowledge systems and channels can be problematic, it is also difficult to avoid storing knowledge in different systems. This is due to the complexity of the organizations. On the other hand, using different knowledge systems and channels increases the

need to managed them well. According to one of the informant in organization 2, there is a lack of clear guidelines on which knowledge system to use in different situations, who that is responsible for using them, and when to use them, as illustrated in the following citation.

> *"There are a dozen different ways to exchange information, but it isn't managed in any way. Just, yes and wiki, that's a good idea, then we start using that, no guidelines(...) I wish we had a manager that kind of said that you should write this in wiki, you must write it in and have it done within next Wednesday. There's too few, there's not enough requirements regarding how we are supposed to retain information. It's often more up to ourselves, and then, then we have better things to do. It's kind of difficult when you work in a project and are supposed to deliver to the project all the time, so no matter what you're doing it's the delivery of that project that is most important(...) We have the opportunity to have forums and stuff, and tomorrow they could have said that, yes, start using forums. What are we supposed to use it for? It must be clear guidelines on were different types of information should be stored. What should be stored in a spec, what should be stored on the server, what should be stored in Wikipedia, what should be sent on mail? We are very poor at this, but we are working quit hard on this via the continuous improvement-initiative in order to improve it."*
>
> Informant 2.4

This problem has been brought into the continuous improvement-initiative in hopes of improvement.

In organization 1, it seems like knowledge storing is better managed than in organization 2. However, it is believed that certain systems are outdated as there exist better ways to manage knowledge storing today, as exemplified in the following citation.

> *"…I would rather say we're a little bit old fashioned compared to the use of tools and how it could have been. We use it correctly in relation to what we, not quite, but largely correct in relation to what the organization officially wants us to do. Then I say that "NN" is a little obsolete in, there exist more modern approaches to things."*
>
> Informant 1.1

Nevertheless, it is emphasized that it is advantageous having today's knowledge systems and channels rather than not having them at all.

Organizational Wikipedia, a procedure system, minutes of meetings, a system for product specific information, and servers are examples of knowledge systems and channels used in both organizations. They are all further explained in the following sections.

The organizational Wikipedia is a knowledge channel that is similar to the Wikipedia site available for everybody on the internet. This knowledge channel is used to store articles about different subjects related to the work in the organizations. It should then be easy for employees to search and find the articles they are looking for. Informants in organization one stated that every article has an owner who must review the article annually, making sure it is updated. Everyone may edit the articles, but then the owner of the article will get a notification and must review the document and approve of the changes.

Both organizations also have a IT-system where all types of procedures can be found. In organization 2 it has been an increased focus on updating and ensuring the quality of these procedures, as exemplified in the following citation.

> *Those documents that are placed there, they are correct because it's actually that way we work and should work. So it's a, it's a value in that.*
>
> Informant 2.2

Minutes of meetings are frequently written after different types of meetings and then stored in both organizations. Organization 1 store minutes of meetings in an IT-system where it can be shared within different groups. Every document is searchable, but it is only possible to find documents stored in the groups you are a member of.

All technical and product specific information, which again is tied up to the products part number, is stored in a specific system in both organizations. Servers are also frequently used in both organizations to store various documents. As an example, excel and word files are frequently stored in servers in order to function as some kind of support document, or for temporary storage. Some knowledge is also stored simply for personal use in everyday work.

Most of the informants claim that the organization store more explicit knowledge than tacit. In other words, it could be a higher focus on making tacit knowledge explicit in order to store it. However, storing tacit knowledge is complex due to several aspects. First of all because it is difficult to articulate, explain, and write down, as exemplified in the following citation.

"Our processes describe the explicit knowledge and, and there's no doubt that there's a lot of knowledge in this organization that we aren't able to describe either in processes or in product descriptions or in our training systems."

Informant 1.6

Another aspect is being able to identify tacit knowledge within yourself and others. When working, new knowledge is probably gained every day, even unnoticed. It just becomes a part of how each individual perform their tasks. Therefore, it may be difficult to sort out what tacit knowledge that might be of value to the organization, and then being able to write it down. It is not possible to find and transform all tacit knowledge into explicit, and focusing too much on doing so may take up more resources than it brings value back to the organization. Organizations must put up with the fact that some knowledge is impossible to find and write down, and an organization will therefore always relay on the people possessing tacit knowledge. It is more important to facilitate tacit knowledge transfer, rather than using a lot of resources on making it explicit. This is exemplified by the following citation.

"That's where you have to consider cost, cost/benefit. That's difficult, it, it can be very extensive and costly trying to find and carve out the explic, no the tacit competence. And we, we will always depend on that competence that those in the organization have. So, kind of a balance would, how much of the tacit competence do you have to, is it beneficial trying to make explicit, and how much do we simply have to accept that, that's tacit competence, and rather facilitate the exploitation of tacit competence as, through network, through mentoring, uh, mechanisms or other, other mechanisms to, yeah team, facilitate communication to, in order to exploit the tacit competence. We also need to look at it as a, as a tool and not, if we can, if we try to, I almost say, try to transfer all competence and knowledge into explicit we will drown in information and not be able to find it, so…"

Informant 1.6

Making tacit knowledge explicit, in order to store it, is difficult. Nevertheless, informants in both organizations are of the opinion that tacit knowledge is gained through experience and that some of this experience is stored in tools, processes, products, working procedures etc.

It is understood that informants are of the opinion that a lot of knowledge is stored in both organizations. However, there are also various opinions regarding how valuable the knowledge stored actually is, as illustrated in the following citations.

"It is quite a lot, it is, but I think we need everything. I believe that."

Informant 2.2

"We probably store too much, uhh, unnecessary, I think at least."

Informant 2.3

It is difficult and resource consuming to evaluate what type of knowledge that might be of value to the organization, and hence important to store. As a result, it is probably easier to save all knowledge possible rather than to sort out that of value. It is also difficult to find reasonable ways to store different types of information in order to make it easy to retrieve and use. What seems like a good idea for the management, in terms of knowledge storage, might not be regarded as a good idea by the people who actually use the information. For the management it may seem like the problem is solved when a new document is created and stored in a knowledge system. However, the concern is not only to store the knowledge, but also to make it easy to retrieve and apply. This is exemplified in the following citations.

"I feel it's very easy for the manager to say – now we have made documents - great, problems solved, right. So now it's a document you are supposed to use, the problem is solved. Unfortunately, that's not have it works for real."

Informant 2.4

"…the knowledge you put in that document, it becomes unavailable when you put it into the document and store it on, in a documentation management tool, it's as good as invisible."

Informant 1.1

Using more resources on managing knowledge transfer, storage and application may result in less non-value-adding information stored in the organization, as exemplified in the following citation.

"I think if we've had a more, a strategy for information sharing, made a good structure for that, then I think we could reduce our storage considerably."

Informant 2.3

We are of the opinion that storing all knowledge possible indicates poor KM. An important part of knowledge storing is to continuously remove non-value-adding information, in order to limit

the total amount of knowledge stored. The larger the amount of stored knowledge, the more difficult it is to retrieve information needed, as exemplified in the following citation.

> *"That's also one aspect of, that we are struggling with. Because it's stored so much, and the way to find documents is to search, and the more waste we have the harder it is to retrieve that document."*
>
> Informant 1.2

Finding non-value-adding information is difficult. Even if a document is not used by some people in the organization, it may be frequently used by others. The products produced in the organizations under study, do also have a long lifetime, which makes product specific documents important to store a long time after the products are sold and delivered to the customer.

Informants in both organizations claim that there is a lack of focus on removing knowledge that is not of value to the organization. However, one of the informants working directly with KM in organization 1, informed us that they recently have started a project to remove non-value-adding information on the organization's intranet. Owners of documents that have not been used in a certain number of years will be contacted, and must decide if the information is still relevant or if it can be removed. This is illustrated in the following citation.

> *"And this project's focus is to clean up, and what's going to happen first is simply to remove documents that haven't been used in x number of years. And at the same time we uh, we will find, try to find all of the information owners so they can relate to – they must take a stand, do you still want this, or may we remove it?"*
>
> Informant 1.2

It is also important to update documents frequently, in order to ensure that knowledge does not get obsolete. In both organization, some document types are reviewed and updated on a regular basis, while others are not. Some documents have its own owners and reviewers that are responsible for updating the documents regularly, and in some systems it is possible to request updates on documents. This is exemplified by the following citation.

> *"We probably lack sufficient formal processes on, on some of it, in some areas we have formal processes, so with global work instructions, or work instruction for example we have a routine for them to be reviewed regularly to make sure they are up to date. That also applies to processes in general. But on some of*

the more informal arenas for knowledge exchange there's a lack of that type of, that type of formal, formalism around it. Where you might risk that information becomes obsolete for example."

Informant 1.6

As the same information is stored in documents in several systems, it is likely that some of the documents is updated and others not. This may result in someone using an old version of the document, which may lead to errors discovered later on.

Organization 1 has in some cases made standard document lists explaining which documents that are necessary to produce in certain settings, in order to reduce the number of documents made. These lists have become quit long and detailed, and in some cases it is not necessary to produce all the documents on the list, thus it is counterproductive.

4.2.4.1 Summary

The informants agree that huge amounts of information are stored in various knowledge systems and in tools, products, processes, working procedures etc. in both organizations. It is understood that well-functioning knowledge systems and channels are important for an effective project execution. The downside of using several different knowledge systems and channels is that it makes it difficult for employees to know which system to use. In organization 2, it is said to be a lack of clear guidelines on which knowledge system to use in different situations, who that is responsible for using them, and when to use them. Some of the informant in organization1 claim that there exist better ways to store knowledge than the knowledge systems and channels used today. Nevertheless, it is emphasized that it is better having today's knowledge systems and channels rather than not having them. It seems to be a lack of focus on transforming tacit knowledge to explicit knowledge, as this is both difficult, time consuming and costly. Removing non-value-adding information lacks focus in both organizations. However, there is a slightly higher focus in organization 1, due to the newly started project, with the purpose of removing old documents. In both organizations some documents are frequently updated while others are not.

4.2.5 Knowledge application

Reusing knowledge is understood to make the projects execution more efficient. The informants from both organizations have very different opinions in terms of how often employees retrieve information from knowledge systems. Most of the informants claim it is done frequently, almost every day, while some stresses that stored information retrieval is quite poor. The frequency does

also seem to vary between different document types. Some are used for application on a regular basis, while others are not. Lessons learned is one of the document that is frequently retrieved and applied in new projects, especially in organization 1, as exemplified in the following citation.

> *"…at least in a project context I would say that we're relatively good at it because we have processes that, that, where, where we for example, as an important part of the project mobilization you must do a, a, a, a scanning or a, an examination of what that exist of experience transfers. You should pull it in, put together, the teams perform a risk management, uh, uh, yes, so mapping and analysis, and then you should use that experience which is located, which you have dug up from earlier that should, that you can decide whether it's, it's a risk for your project. You must set up a so-called mitigating action in order to try avoid it from happening. Or if it's opportunities, because it can also be that. Then you must set up an action trying to ensure that it occurs."*
>
> Informant 1.7

In organization 1, it is possible to filter projects in terms of what type of experience that is needed, and in that way find projects similar to the one being configured. Lessons learned will explain what problems that arose during the project execution and how they were solved. This prevents the same mistakes from being made twice, as illustrated in the previous citation.

Knowledge retrieval and application happens on the employees own initiative. It cannot be expected that employees read all available information and know everything, nor is it necessary. What is of importance is that people know where to find the information needed. Knowledge is made available for application through different knowledge systems in both organizations. However, it varies how easy it is to find and retrieve information stored in the different knowledge systems, as exemplified in the citations below. Some basic knowledge about the system is needed in order to know how to search and find the information needed.

> *"We do manage to retrieve the information eventually, but it's impossible that everybody knows everything all the time. So that you, that you get a hold of it when you need it, and that the right persons get a hold of the right information at the right time that's, that's not easy."*
>
> Informant 2.2

> *"There's a problem with that as a document, because the knowledge you put into that document, it becomes unavailable when you put it into that document*

and put it in, in a documentation management tool, then it's as good as invisible."

Informant 1.1

It is common to ask colleges for help before searching for documents to retrieve information. If one knows who to ask, and that person has the ability to answer, it may be a more efficient way of finding an applying knowledge. When one does not know who to ask, well-functioning knowledge systems and channels is probably more efficient to use in order find the information of interest.

Organization 1 has a system that helps finding people who possess different types of knowledge. Organization 2 has also tried to make such a system, but it was shelved before it was finished.

It is also said in organization 1, that certain systems are outdated as there exists better ways to manage knowledge storing today, which makes it easier to retrieve and apply information. In order to achieve this, the organization has started to tag documents, making it easier to search for them.

A lot of information is also carried within products and stored in processes, work procedures, tools etc. This should make it easier for everyone to retrieve information, as exemplified in the following citation.

"We wish in a way that the products we develop shall, shall carry a lot of the information and knowledge so that one should not have to look around for it, but more that the product carries information about itself, so it's easy to find it and easy to read it."

Informant 2.3

As already mentioned, both organizations also have a IT-system where all types of procedures can be found. In organization 2, it has been an increased focus on updating and ensuring the quality of these procedures, and making sure they are followed. Even so, informants in both organizations have different opinions of how well formulated these procedures are, how often they are used, and how efficient they are. Informants with management positions seem to believe that these procedures are followed, as exemplified in the following citation.

Those documents that are placed there, they are correct because it's actually that way we work and should work. So it's a, it's a value in that. And people use the system to find procedures for what, their job.

Informant 2.2

On the contrary, an informant working in the engineering phase who is supposed to use these procedures, said that very few of them actually is used.

"There are extremely many documents in our procedure-system, and we use very few of them. We are probably supposed to use more of them, but it's kind of, it says, it says so much. Thus it, what our department need to know from a document exactly, then you often have to pick every second paragraph through the entire document, right. So it becomes really cumbersome. And it's because we're so big that it's really difficult to, really difficult to in a way, to concretize that information we need from these documents (…) it has something to do with those who make those documents, they should, they have to think carefully before they start writing the document. Because it's a little bit like, I feel, in this organization that one doesn't plan enough, one just start right away."

Informant 2.4

Even if it is easy searching for knowledge and finding the right documents, it may not be easy to apply the knowledge found, as exemplified in the previous citation. Information and knowledge is often documented because one is told to do so. The person storing the knowledge might not take into account that what is stored should be easy to understand and use for others, which may result in complex and less user friendly documents. This makes reusing knowledge retrieved from stored documents difficult. Some documents are also standardized in order to contribute with information to several disciplines and departments, which makes it time consuming to find relevant information within the different departments. Due to the size and complexity of the organizations under study, it is difficult to ensure the quality of different procedures. This makes proper planning vital, also as exemplified in the previous citation.

4.2.5.1 Summary

Reusing knowledge is regarded as important for an efficient project execution, and knowledge is made available through different knowledge systems. In both organizations it varies how often stored knowledge is retrieved and applied. Lessons learned is one of the documents frequently retrieved and applied in projects, especially in organization 1. There are also varying opinions on

how easy it is to search and retrieve information from systems, or to find the people possessing the knowledge needed. In order to make it easier to find information, organization 1 use a system for finding people possessing the knowledge needed and they have started tagging documents. In some situation it might be easier to search for information, while in other situations it might be easier to ask someone for help, depending on the availability. It is also stated in organization 2, that even though the information needed is found, it is not always easy to apply this knowledge. This is due to the fact that documents contain a lot more than just the information needed. As a result, the engineers must sift out the needed information, which may be time consuming.

4.2.6 Conclusion

KM is difficult to grasp and explain, and people may have very different associations and interpretation of KM. We are of the opinion that the main reason for this is that KM is a very extensive term which involve multiple factors and aspects. However, KM is considered important in order to make project engineering more efficient. Managing knowledge storage and transfer is complex especially in large organizations, which also makes it necessary to prioritize KM. In this study, organization 1 had a KM-department while organization 2 did not. From the data collected it seems like organization 1 is generally able to manage knowledge in a better way than organization 2. Hence, the increased focus on KM is reflecting in how knowledge is managed in the organization. Knowledge systems are used in order to better manage knowledge storage and transfer. However, it is important that these systems are managed properly and that there exist clear guidelines regarding which knowledge systems to use in different situations, who that is responsible for using them, and when to use them.

It seems evident after conducting this analysis that knowledge creation, transfer, storage, and application is intertwined, and can therefore not be viewed separately, but rather as an interacting whole. If one of them are managed poorly it will affect the others. Knowledge creation is fund to mainly be triggered by the customer, through specifications, and is basically created in four different contexts: during breaks (socialization in the hallway, cafeteria, etc.), individually, in teams/groups, and through knowledge tools. There is created a lot of tacit knowledge in a project-context, and tacit and explicit knowledge creation is found to be intertwined. Sharing knowledge and helping each other is regarded as a part of the organizational culture. Knowledge is transferred face to face and through several knowledge channels. A well-functioning knowledge

flow within engineering and projects is facilitated, and lessons learned, as well as project manager forums are used to transfer knowledge between projects. Knowledge is stored in various knowledge systems or channels in addition to tools, processes, products, working procedures etc. Some documents are frequently updated and reviewed, while others are not. Additionally, there is generally a lack of focus on removing non-value-added information. Where and how information is stored affect how easy it is to retrieve and apply this information. KM may also have an effect on the organizations efficiency when used to standardize product, processes, work procedures, tools etc., as discussed in the next chapter.

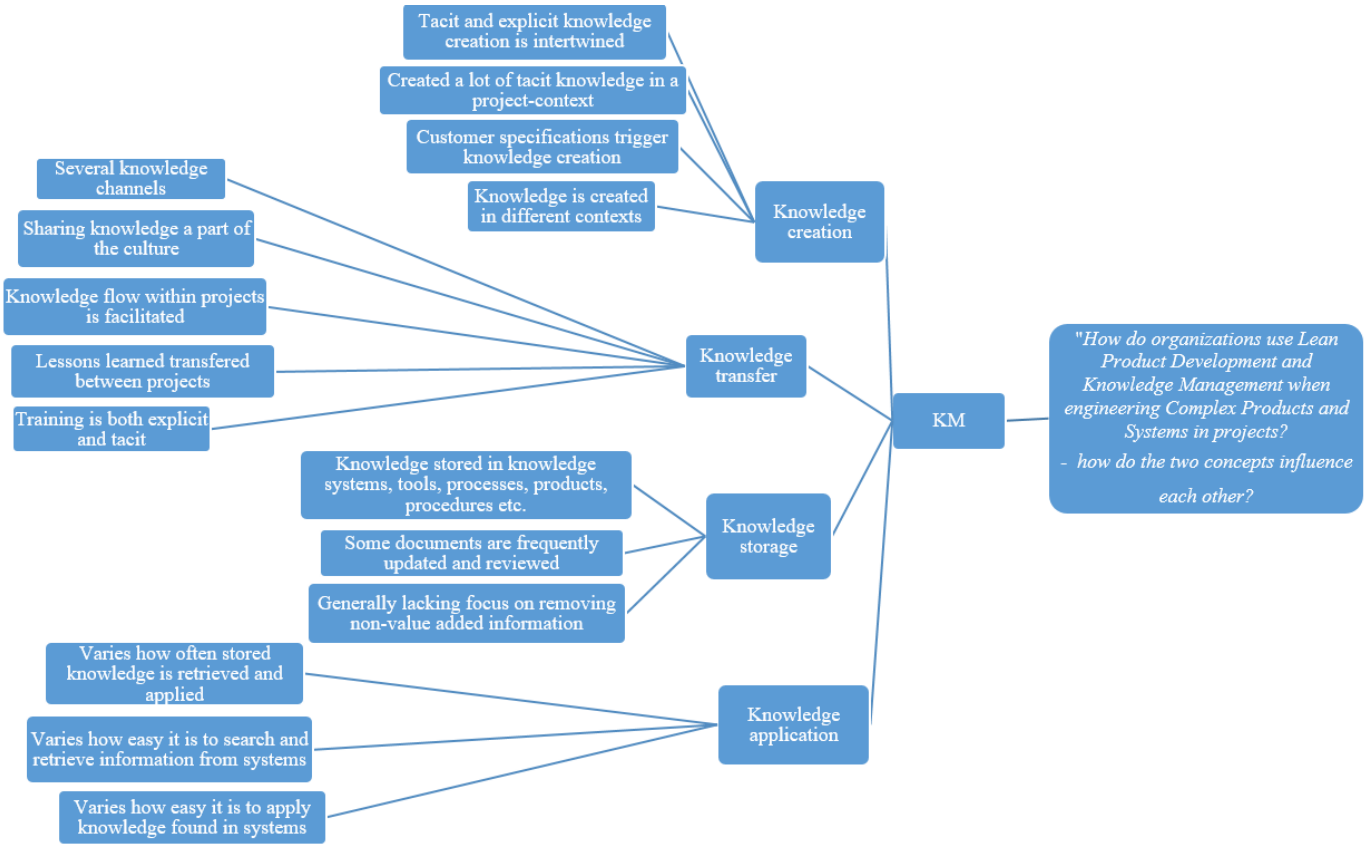

Figure 8 Summary key findings KM

4.3 Analysis Lean Product Development and Knowledge Management

As discussed in the previous chapter, knowledge plays a central role in the engineering process, and as discussed in chapter 5.1 LPD may be used to enhance the engineering process. In this chapter the findings regarding the relationship between the two and how they together may enhance the engineering process is presented. Our findings will be discussed in the order

presented in the figure below. We start by discussing how LPD and KM together influences efficiency, then how and what is standardized in terms of knowledge, and lastly how LPD and KM together is used to reduce waste. We found that the combination of LPD and KM can be interpreted in two ways: (1) how KM influence LPD in engineering, by using KM to increase efficiency, by standardization and reducing waste, and (2) how LPD influence KM in engineering by standardizing and streamlining KM-processes, as well as reducing KM waste. In order to illustrate the difference, we have separated our findings in appendix 7. However, we will not discuss our findings separately during the analysis, as they are intertwined.

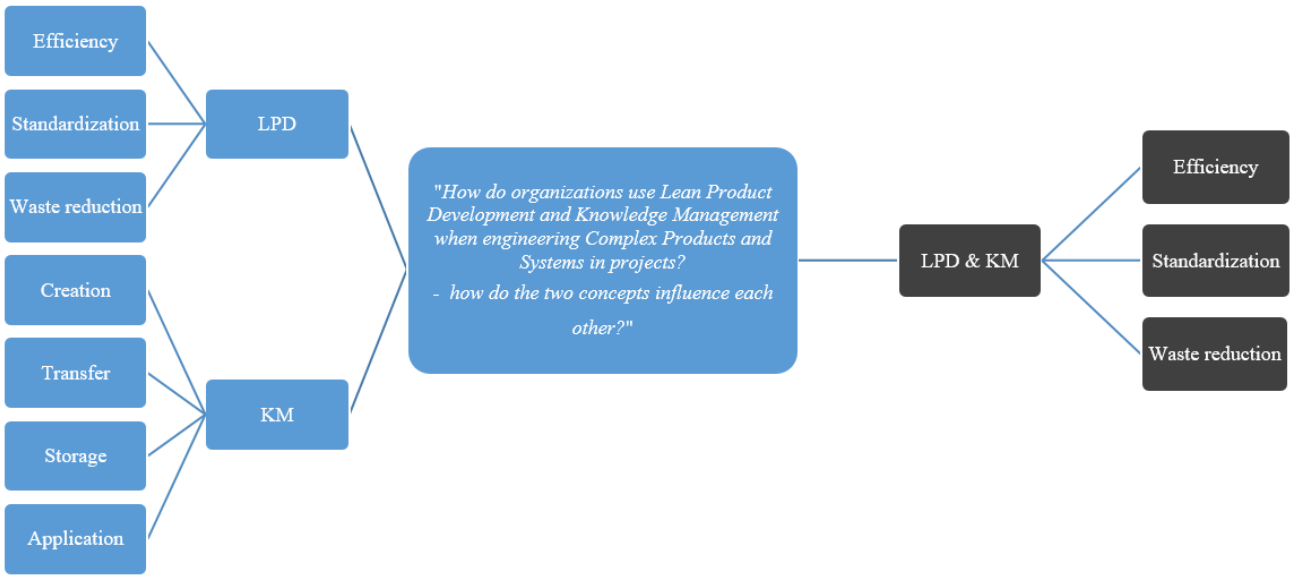

Figure 9 Analysis structure LPD & KM

4.3.1 Efficiency

As knowledge is an important part of both organizations, they agree that poor KM can cause inefficiency in the engineering process. Both organizations have implemented several knowledge systems and knowledge transfer channels in an attempt to manage knowledge. These systems are supposed to make sure that valuable knowledge is stored in the organization and that information is available when needed. We found that both organizations have implemented more or less the same systems, but as mentioned in chapter 5.2, it may seem that organization 1 is able to manage their knowledge systems in a better way than organization 2. This makes it easier for organization 1 to find and reuse knowledge, which again enhances the project efficiency as it prevents making the same mistake twice. However, organization 2 focus on improving KM by using their continuous improvement initiative. Additionally, there is also stored and transferred a lot of

knowledge through this initiative, in which different departments share and visualize knowledge that is used to improve processes that are used across projects.

One of the informants in organization 2, pointed out that storing knowledge and information in many different systems may be inefficient, as it makes it difficult for the employees to know what to store where, and where to retrieve needed information. The same informant also pointed out that the knowledge-storing process lacks clear guidance from the management. This is illustrated in the following citation.

> *"And then we have a Monday meeting, we have email, we have Wikipedia, we have an old software database that's still used occasionally, uh, and we have operating manuals, and we have uhm information coming from our product department on how our products should work, right. I've already mentioned six places where there exists information about something that I can find. Ideally it should only be one place (…) Yes, and then we have Lync, that's skype for business, right, so it's a chat function, and then it is like knocking on the neighbor's door and just, yes, what was that again? There are many different ways to transfer information, but it isn't being managed in any way (…) There's too few, there's too few requirements regarding how we are supposed to retain information. It is often more up to ourselves, and then we, we have better things to do. It is kind of difficult when you work in a project and are supposed to deliver projects all the time. Whatever you are doing, it is the delivery of that project that is the most important thing."*
>
> Informant 2.4

Experience is also something that both organizations focus on. Organization 1 argues that experience is important when participating in a project, as it will cause inefficiency if the employees have to read the project procedures every time they are going to perform a task. This is exemplified in the following citation.

> *«…it's not effective if every time you are going to execute a project you have to read what to do. One wants people to have enough experience to, to know what to do without going into a knowledge system and read about it. So then the balance is to find out how people are so self, so self-driven that they don't have to use the system while simultaneously noticing all the changes."*
>
> Informant 1.5

Further, both organizations aim to use experience and knowledge as a source for updating and standardizing products, processes, procedures, rule sets, utilities/tools, etc., making knowledge

easier to retrieve and reapply, which enhance efficiency. This is exemplified in the following citation.

> *"We wish in a way that the products we develop shall, shall carry a lot of the information and knowledge so that one should not have to look around for it, but more that the product carries information about itself, so it's easy to find it and easy to read it."*
>
> Informant 2.3

Finally, product standardization and updating of products will lead to less customer-specific adaptions in the engineering phase of projects.

Standardization and waste reduction are both important measures in order to increase project efficiency. Both of these measures will be explained in detail in the following chapters.

4.3.1.1 Summary

Both organizations agree that poor knowledge management can cause inefficiency. As the engineering phase in large part make use of knowledge, it is important to have clear procedures on how to best store, transfer and reuse knowledge in order to be more efficient. Organization 1 solves this problem through rigorous KM, using several knowledge systems and channels, while organization 2 use their continuous improvement initiative. Both organizations use experience and knowledge to update and standardize products, processes, procedures and tools in order to increase efficiency.

4.3.2 Standardization

Managing knowledge can be very complex and time consuming. It is therefore important to be able to standardize how to handle knowledge in order for a project to run smoothly. The focus of standardizing processes regarding knowledge work is constantly increasing in both firms.

It is evident to us that how both organizations manage knowledge is fairly standardized by using knowledge systems, standard documents, standard processes, standard procedures etc., with the intention of making it easier to retrieve and apply knowledge. Organization 2 has increased their focus on how to store and transfer knowledge in order to make it more applicable through their continuous improvement initiative. However, it seems that KM is more standardized in organization 1.

«On the technical side so, if we go into the formal systems, the formal processes that, that describes where technical information shall be established and stored, and these processes do also describe how that information formally shall flow between the various steps of the process."

Informant 1.6

Informants in organization 2 stated that it is difficult giving the same information to all engineers at the same time worldwide. This makes it important to synchronize processes and procedures, making it possible for everyone to store and retrieve necessary knowledge at the same place.

Informants in organization 1 are of the opinion that the need for standardization increase in line with project activities. This is due to the fact that increased project activity normally leads to increased knowledge creation, which then have to be transferred and stored properly in order to easily be reapplied. Standardizing the way this knowledge is transferred and stored is important in order to achieve this.

Further, we found that both organizations standardize products, processes, documents, and tools by utilizing knowledge. Organization 2 mainly handle this through the continuous improvement initiative.

Both organizations have a focus on knowledge transfer across projects through sharing lessons learned at the end of each project. Lessons learned is also used to update and improve existing standards regarding products, processes, and procedures across projects. This is exemplified in the following citation.

"Knowledge transfer from project to project is a huge focus, and it comprises two elements, as we say lessons learned, that is a very, it is a relatively detailed process on how to conduct a lessons learned. And then there's links to risk analysis, or risk management. It's evident that you have to use this lessons learned, and it, and use it as a basis for a risk-analysis, is, is, is an appropriate way of doing it."

Informant 1.7

4.3.2.1 Summary

Both organizations have an increased focus on standardization. They continually standardize products, processes, documents, and tools by utilizing knowledge. Organization 2 mainly use the continuous improvement initiative to standardize. Both organizations have also tried to

standardize how knowledge is stored in order to make it easier to retrieve and apply. However, we found that this was better managed in organization 1 than organization 2. Further, both organizations have a focus on transferring lessons learned across projects. Lessons learned is also used to update and improve existing standards regarding products, processes and procedures.

4.3.3 Waste reduction

We found that organization 2 has a stronger focus on waste reduction than organization 1 in terms of processes, procedure etc., but a lower focus on waste reduction regarding KM. However, both organizations focus on waste preventing activities.

KM can be categorized as a waste prevention initiative. As knowledge and experiences is stored and transferred in knowledge systems and channels, using this information will prevent remaking previous mistakes, and remove non-value-adding activities. Additionally, both organization focus on giving their employees sufficient training to make sure they acquire the knowledge and experience necessary to perform their work properly and efficient. This contribute to preventing mistakes and rework.

Another waste preventing initiative is in terms of communication with customers. Free flow of information between the customer and the organization, is essential to prevent rework caused by misunderstandings in terms of customer specifications. Both organizations communicate with their customers through different knowledge channels, e.g. knowledge systems, telephone, and emails. The following citation exemplifies the engineers' thoughts regarding communication with customers.

> *«…we are of the perception that the customer lacks competence, so it is very difficult to communicate with them. And it's a bit of what we talked about early, then, that we deliver very complex system and the only thing they want is the finished product. But the fight until we can provide the finished product, it can be quite difficult because they do not understand what we try to explain to them(…)"*
>
> Informant 2.4

Organization 2 has also reduced the amount of information sent to the customer regarding system specifications, down to a single page with simple explanations and illustrations. This is to make sure that the customer understands the system specifications and to prevent rework in a later

project phase or after installation. We categorize this initiative as waste reduction, as they have stopped providing information that does not bring value to the customer.

As previously mentioned, organization 2 use their continuous improvement initiative to reduce waste in processes and procedures. This is done as problems are defined and appropriate solutions eventually found by using knowledge and experience.

> *"Our continuous improvement initiative is about defining problems that we detect on a sticky note, and then work on that problem until we have found a solution, and then try to implement that solution."*
>
> Informant 2.4

Both organizations review customer specifications several times in order to prevent misunderstandings. However, some errors occasionally pass through due to misinterpreted requirements. This can be due to lack of knowledge, lack of experience, insufficient training, etc.

Informants in organization 1 claim that the enormous amount of knowledge stored in knowledge systems makes it more difficult to search and retrieve information. In order to reduce information stored in different knowledge systems, organization 1 has newly started a project which focuses removing outdated non-value-adding information. This is illustrated in the following citation.

> *"That's also one aspect of, that we're struggling with. Because it's stored so much, and the way to find documents is to search, and the more waste we have the harder it is to retrieve that document."*
>
> Informant 1.2

> *"And this projects focus is to clean up, and what's going to happen first is simply to remove documents that haven't been used in x number of years. And at the same time we uh, we'll find, try to find all of the information owners so they can relate to – they must take a stand, do you still want this, or may we remove it?"*
>
> Informant 1.2

In both organization, some document types are reviewed and updated on a regular basis, while others are not, as exemplified with the following citation:

> *"We probably lack sufficient formal processes on, on some of it, in some areas we've formal processes, so with global work instructions, or work instruction*

for example we have a routine for them to be reviewed regularly to make sure they are up to date. That also applies to processes in general. But on some of the more informal arenas for knowledge exchange there's a lack of that type of, that type of formal, formalism around it. Where you might risk that information becomes obsolete for example."

Informant 1.6

4.3.3.1 Summary

We found that organization 2 has a stronger focus on waste reduction than organization 1 in terms of processes, procedure etc., but a lower focus on waste reduction regarding KM. Organization 2 focus on waste reduction through their continuous improvement initiative. They have also reduced the amount of system specific information sent to customers. Organization 1 has newly started a project in order to reduce non-value-adding information stored on the company's knowledge systems. Beyond this, both organizations focus more on waste preventing activities on a daily basis, such as making knowledge available, training, document reviews and document updates.

4.3.4 Conclusion

After conducting this analysis, it is evident that LPD and KM influence each other and that the combination of the two concepts can be interpreted in two ways: (1) how KM influence LPD in engineering, by using KM to increase efficiency, standardization, and reducing waste, and (2) how LPD influence KM in engineering by standardizing and streamlining KM-processes, as well as reducing KM waste. The findings in this analysis supports both interpretations.

(1) It is evident after conducting this analysis that standardization and waste reduction is important measures in order to increase efficiency. It is also evident that knowledge and experience is utilized when standardizing processes, procedures, products, documents, and utilities/tools, as well as when removing waste, in order to increase efficiency. In organization 2 the continuous improvement initiative is mainly used in order to achieve this. In this initiative knowledge and experience is frequently used to locate problems and find solutions regarding processes, products, procedures etc., in addition to locate and remove waste. Further, both organizations have a focus on transferring lessons learned across projects. Lessons learned is also used to update and improve existing standards regarding products, processes and procedures. We also found that organization 2 has a stronger focus on waste reduction than organization 1, as they remove waste through their continuous improvement initiative. Beyond this, both

organizations focus more on waste preventing activities on a daily basis, such as training new employees, and reviewing documents.

(2) Based on the analysis, we found that LPD influence KM in the engineering phase through standardizing knowledge storage and transfer globally, using knowledge systems in order to make it easier to retrieve and apply. This to enhance efficiency. However, we found that this was better managed in organization 1 than organization 2. Further, we found that organization 1 has a higher focus on waste reduction regarding KM, than organizations 2. Organization 1 has newly started a project in order to reduce non-value-adding information stored on the company's knowledge systems, while organization 2 has reduced the amount of system specific information sent to customers. Beyond this, both organizations focus more on waste preventing activities on a daily basis, such as making knowledge available through standardized knowledge storing and transfer, document updates to prevent obsolete information. Our key findings regarding the relationship between LPD and KM, and how they together enhance the engineering process is presented in the figure below.

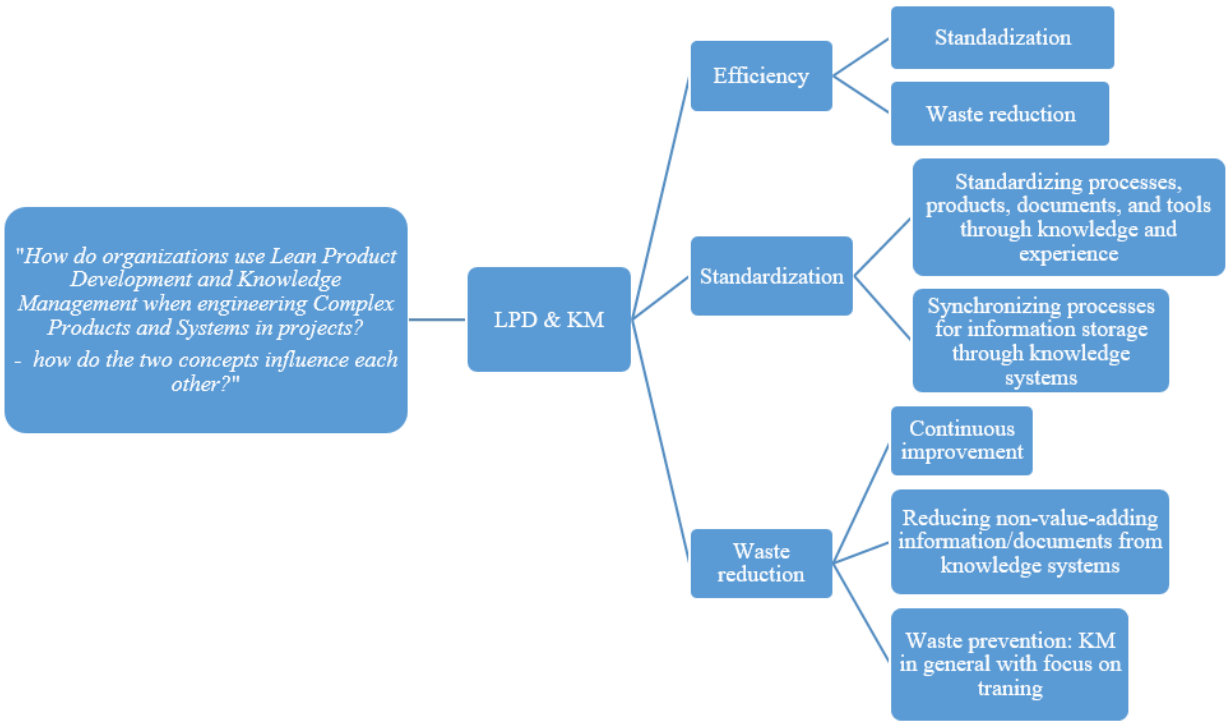

Figure 10 Summary key findings LPD & KM

4.4 Summary of the analysis

We have in this chapter summarizes our findings by answering the operationalization questions presented below. All paragraphs are marked in order to make it easy to recognize which paragraph that answers which question.

1. How differences in terms of how LPD and KM are used when engineering CoPS, can be explained?
2a. If LPD is regarded as valuable in the engineering phase in projects, or not?
2b. If KM is regarded as valuable in the engineering phase in projects, or not?
3. If it is used specific initiatives or aspects regarding LPD or if it is more in terms of having a Lean mindset?
4a. If using LPD is something employees concern themselves with on an everyday basis, or if it is just underlying elements that is controlled by the management – a top-down approach?
4b. If using KM is something employees concern themselves with on an everyday basis, or if it is just underlying elements that is controlled by the management – a top-down approach?
5. If it is specific tools or aspects regarding KM the organizations emphasize?
6. How LPD and KM influence each other in the engineering phase?

(1) We have during this analysis found that both organizations have an increased focus on LPD and KM. This is due to changes in the industries, which increases the need for higher efficiency and lower cost. As a result, it is important being able to standardize processes and products, as well as reuse knowledge. Overall, we found that organization 2 has a stronger focus on LPD than organization 1, and that organization 1 has a stronger focus on KM than organization 2. We are of the opinion that this is the reason why some aspects of our findings differs in the two organizations.

(2a) Both organizations consider the use of LPD to be valuable. The reason for this is that standardized processes and work procedures is vital for an efficient project execution, when they are applied. Further, it is also important to focus on standardizing products, as it decreases the need for extensive engineering. This in turn, increases the efficiency of the engineering phase.

(3) We have in this analysis found that the organizations under study have different interpretations and focus on Lean. However, both organizations have implemented what can be

regarded as LPD initiatives, in order to standardize processes and reducing waste, hence increase efficiency. Nevertheless, the focus on waste reduction is considered higher in organization 2 than organization 1. Organization 1 has implemented a zero defect approach, which is used to update and standardize processes in order to make them zero defect capable. Apart from this, organization 1 mostly make use of the LPD mindset. Organization 2 has implemented a continuous improvement initiative. This initiative involves all employees in defining problem areas and finding solutions, in collaboration with their department and managers. Therefore, the initiative is considered a bottom-up approach. As a means to keep this process going, the department managers host weekly mandatory whiteboard meetings with their employees. The employees do usually not associate this approach with Lean or LPD, but as a process used to improve their everyday work.

(4a) The informants consider it important to standardize and reduce waste in order to continually improve processes and tools, and hence work more efficiently. However, the engineers do not concern themselves with the LPD approach on an everyday basis, as LPD is rather an underlying element of how processes, products, procedures, etc., are created. Hence, LPD influence the way the engineers perform their work, without them being aware of it.

(2b & 4b) It is understood that KM and knowledge systems are important for an efficient project execution. Being able to find and reuse knowledge in order to work more efficiently, is considered important in both organizations. Engineers create, transfer, store, and apply knowledge every day, some unconscious and some conscious. Usually the management facilitate KM, which makes it a top-down approach. However, KM may in some cases be considered as a bottom-up approach as workers' knowledge and experience are used to improve processes, products, procedures etc.

(5) It seems evident that knowledge creation, transfer, storage, and application is intertwined, and must therefore be viewed as an interacting whole. Managing knowledge storage and transfer is complex especially in large organizations, which also increase the need for extensive KM. Knowledge creation is regarded as an important part of the engineering phase as lots of new knowledge arise in this phase, as well as in projects in general. Knowledge creation is fund to mainly be triggered by the customer, through needs and specifications. Knowledge is found to be created in the following four contexts: during breaks (socialization in the hallway, cafeteria, etc.),

individually, in teams/groups, and through knowledge tools. Further, we found that tacit and explicit knowledge creation is intertwined, and that it usually is created a lot of tacit knowledge in a project-context. Knowledge transfer is considered as an area of focus, and to share and help each other is regarded as part of the culture in both organizations. Several knowledge channels are used in order to transfer knowledge, both formal and informal. Both organizations are good at communicating and sharing knowledge within the projects in general, but also between projects, through lessons learned and project manager forums. Training is found to focus on transferring both explicit and tacit knowledge. In both organizations knowledge is stored in various knowledge systems or channels, as well as in tools, processes, products, working procedures, etc. Removing non-value-adding information lacks focus in both organizations. However, it seems to be a slightly higher focus in organization 1. Some documents are frequently updated and reviewed, while others are not. Removing non-value-added information and updating information is vital as it affects how easy it is to retrieve and apply stored information. In both organizations it varies how often stored knowledge is retrieved and applied. This is mainly due to the fact that it varies how easy it is to find needed information and how easy it is to apply the knowledge found. Out of the four KM aspects, knowledge transfer and storage seems to be the two aspects which are best managed, through various knowledge systems.

(6) Further, it is evident that LPD and KM influence each other and that the combination of the two concepts can be interpreted in two ways: (1) how KM influence LPD in engineering, by using KM to increase efficiency, by standardization and reducing waste, and (2) how LPD influence KM in engineering by standardizing and streamlining KM-processes, as well as reducing KM waste. Knowledge storage and partially transfer and application, is standardized in both organizations through knowledge systems and channels, as well as standard documents and procedures. We also found that there is a lack of focus on updating documents, as well as removing documents that can be characterized as waste. However, organization 1 has recently started a project to remove non-value-adding information that is stored in the organization's knowledge systems. We also found that KM affects LPD, as experience and knowledge is used to standardize as well as locating and removing waste in processes, products, procedures etc., in order to increase efficiency. Our key findings regarding how LPD and KM is used when engineering CoPS in projects, and how the two concepts influence each other, are illustrated in the figure below.

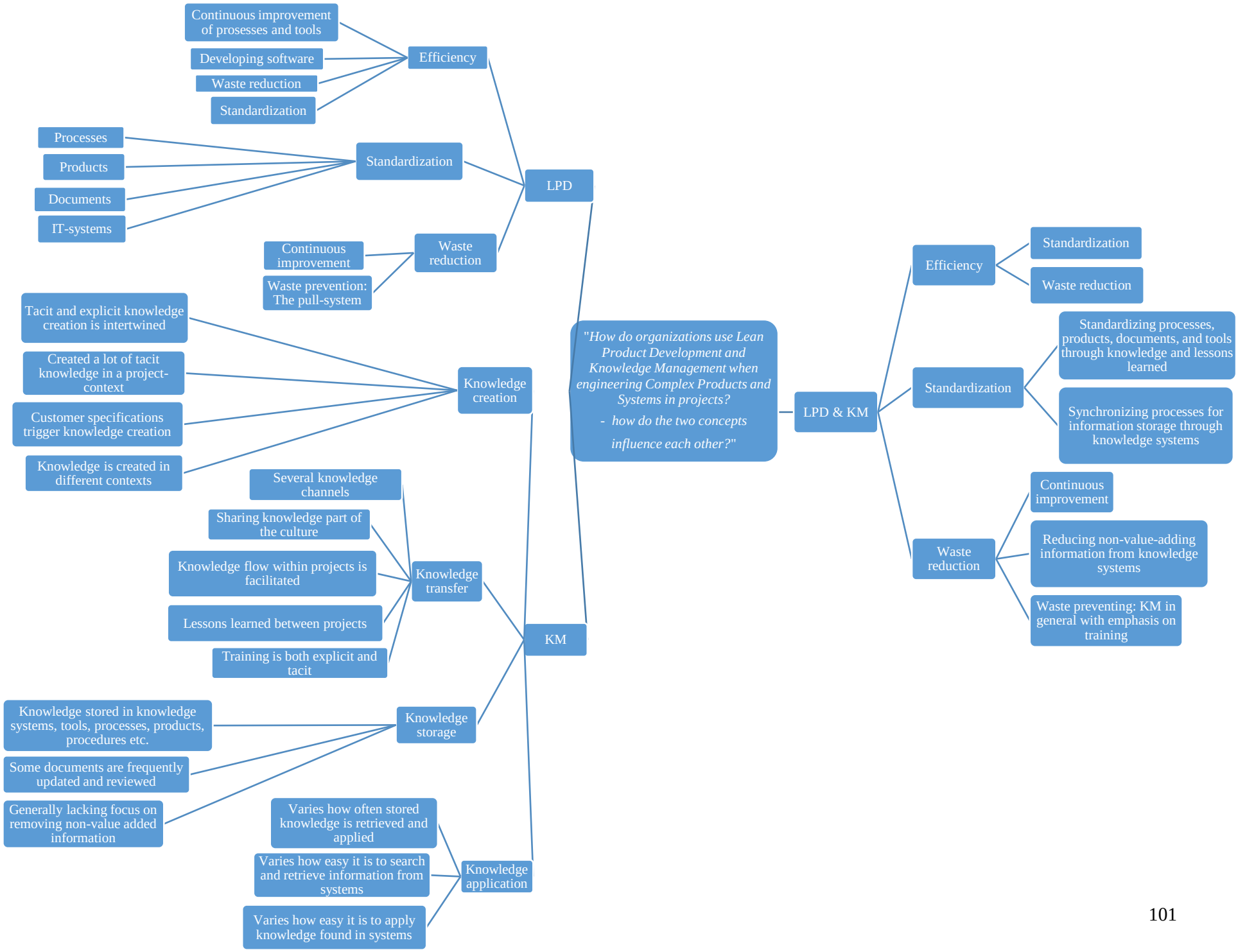
"How do organizations use Lean Product Development and Knowledge Management when engineering Complex Products and Systems in projects?
- how do the two concepts influence each other?"
LPD & KM
Efficiency
Standardization
Waste reduction
Standardization
Standardizing processes, products, documents, and tools through knowledge and lessons learned
Synchronizing processes for information storage through knowledge systems
Waste reduction
Continuous improvement
Reducing non-value-adding information from knowledge systems
Waste preventing: KM in general with emphasis on training
LPD
Efficiency
Continuous improvement of prosesses and tools
Developing software
Waste reduction
Standardization
Standardization
Processes
Products
Documents
IT-systems
Waste reduction
Continuous improvement
Waste prevention: The pull-system
KM
Knowledge creation
Tacit and explicit knowledge creation is intertwined
Created a lot of tacit knowledge in a project-context
Customer specifications trigger knowledge creation
Knowledge is created in different contexts
Knowledge transfer
Several knowledge channels
Sharing knowledge part of the culture
Knowledge flow within projects is facilitated
Lessons learned between projects
Training is both explicit and tacit
Knowledge storage
Knowledge stored in knowledge systems, tools, processes, products, procedures etc.
Some documents are frequently updated and reviewed
Generally lacking focus on removing non-value added information
Knowledge application
Varies how often stored knowledge is retrieved and applied
Varies how easy it is to search and retrieve information from systems
Varies how easy it is to apply knowledge found in systems

Figure 11 Summary of all key findings

5 Discussion

This thesis aims at examine how LPD and KM are used in practice during engineering of CoPS in projects, as well as how these concepts influence each other. We will in this chapter discuss our main findings, presented in chapter 4, in regards to the theory, presented in chapter 2, and the research question. First, we have discussed and compared the findings related to LPD, KM, and LPD and KM to their respective theories. Further, we present the conclusion, and theoretical and practical implications. Finally, our reflections regarding the study are accounted for, and suggestions for further research is provided.

5.1 Discussion Lean Product Development

The term "Lean" is not part of the everyday language in any of the organizations under study in this thesis. Nevertheless, during the analysis, we found that both organizations have implemented what can be characterized as Lean-initiatives in the engineering phase. However, one can argue if everything they categorize as "Lean" actually is part of the theory. This is due to the fact that Lean can be interpreted differently by different people. In this chapter we will present our key findings regarding efficiency, standardization, and waste reduction, as illustrated in the figure below, and compare these to the theory we have presented regarding LPD.

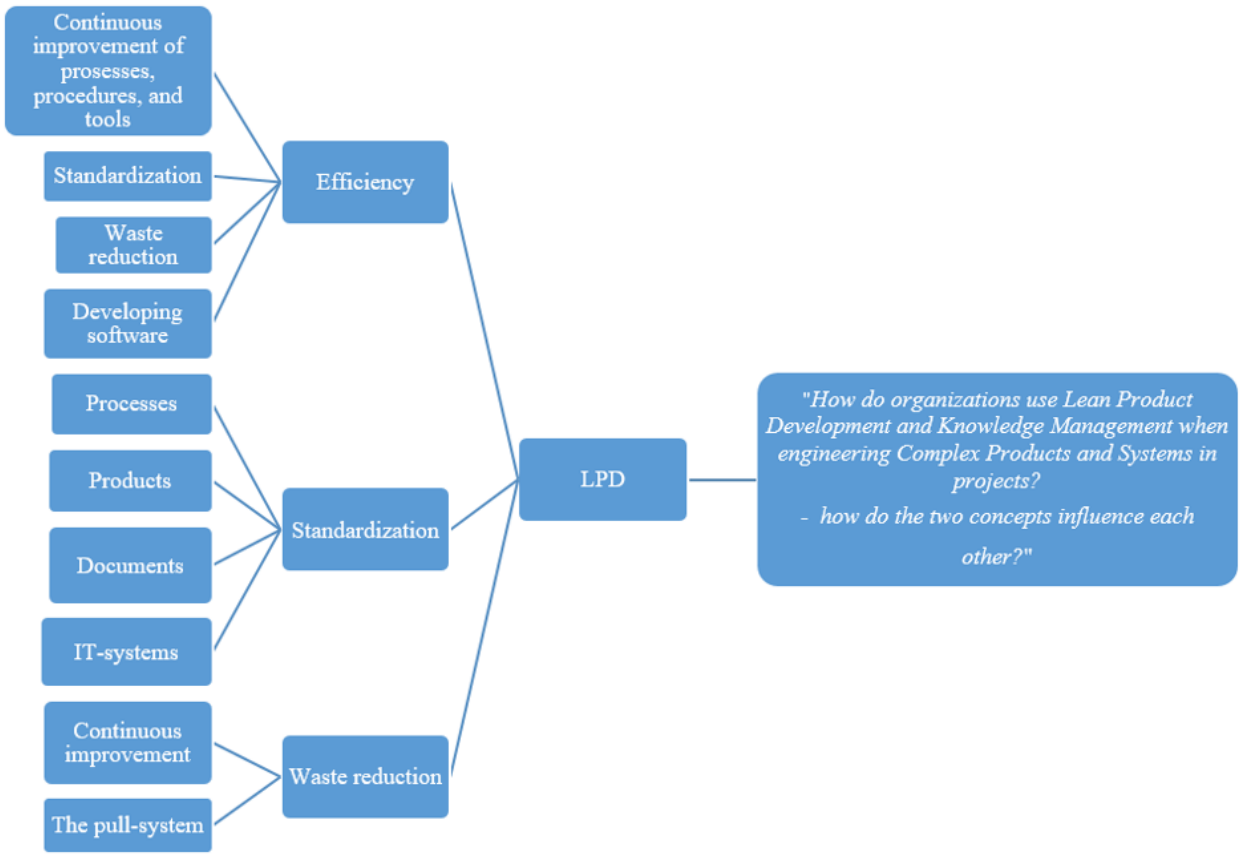

Figure 12 Summary key findings LPD

5.1.1 Efficiency

As illustrated in figure 12, the main findings regarding efficiency are:

- Continuous improvement of processes and tools
- Developing software
- Waste reduction
- Standardization

These findings are discussed in relation to the theory presented in chapter 2, in the following section.

Due to the recession period in the industries, the focus on efficiency has increased considerably in both organizations. As a means to ensure an efficient project execution they continually improve products, processes, procedures and tools. Haque and James-Moore (2004) describe continuous improvement as a key activity regarding LPD.

Organization 2 has a focus on finding better solutions to work tasks by e.g. developing software or finding other less advanced solutions in order to better support that task. We later found that

many of these solutions were shelved due to lack of time to complete them. However, the solutions that were implemented in the engineering phase were described as very beneficial in relation to efficiency. We argue that this can be related to the people principle, as well as the tool and technology principle, presented by Liker and Morgan (2006). Liker and Morgan (2006) presents six people principles, and two of them are as follows: (9) build in learning and continuous improvement, and (19) build a culture to support excellence and relentless improvement. Organization 2 support employees to use their knowledge in order to improve existing solutions through the continuous improvement initiative. We therefore argue that they have built a culture for excellence by supporting learning and continuous, relentless improvement. As the organization also developed software to support the engineering process, we argue that this can relate to Liker and Morgan's (2006) principle 11: adapt technology to fit your people and process.

Both companies also focus on standardization and waste reduction in order to become more efficient. These measures are both related to the approaches presented by Haque and James-Moore (2004) and Liker and Morgan (2006). Both will be explained in detail below.

Based on the preceding discussion, we conclude that all our findings regarding efficiency are supported by the theory.

5.1.2 Standardization

As illustrated in figure 12, the main findings regarding standardization are:

- Processes
- Products
- Documents
- IT-systems

These findings are discussed in relation to the theory presented in chapter 2, in the following section.

Due to the lack of a visual flow in the engineering process, standardization is difficult. Even so, as organizations grow and/or become global, their need for standardization increases. The reason for this is that in order to ensure that all projects have the same opportunity to be equally efficient in the engineering phase, all engineers within a company should work in more or less the same way. Both organizations in this case study focus on standardizing processes. Organization 1

asserted that they only use the Lean mindset while making their processes zero defect capable, whereas organization 2 use their continuous improvement initiative with methods like root cause analysis and value flow analysis. The standardization methods used in organization 2, are therefore directly related to Liker and Morgan's (2006) principle 13, which states: use powerful tools for standardization and organizational learning. Further, as both organizations focus on standardization of processes in general, in order to make the processes more predictable, one can argue that they both relate to Liker and Morgan's (2006) principle three and four as well: (3) create a levelled product development process flow, and (4) utilize rigorous standardization to reduce variation, and create flexibility and predictable outcomes.

In addition to processes, both organizations also standardize products, documents, and IT-systems. The theory does not specifically mention standardization of products, documents and IT-systems. Nevertheless, we do argue that standardization of all three can be related to principle four, as it will reduce variation, and hence create more predictable outcomes in the engineering process.

Based on the preceding discussion, we conclude that all our findings regarding standardization are supported by the theory.

5.1.3 Waste reduction

As illustrated in figure 12, the main findings regarding waste reduction are:

- Continuous improvement
- Waste prevention: The pull-system

These findings are discussed in relation to the theory presented in chapter 2, in the following section.

The theory is very vague in terms of waste reduction. Haque and James-Moore (2004) state that to eliminate waste is one of the key activities that constitute a LPD system. However, they do not provide any specific examples of how to eliminate waste. On the other hand, one of the principles presented by Liker and Morgan (2006) states: establish a customer-defined value to separate value added from waste. However, we do not know whether or not any of the organizations build their processes on the direct basis of customer-defined value. Nevertheless, both organizations continuously try to root out waste and standardize their processes in order to make them as efficient as possible, and as cost-effective as possible. We argue that eliminating waste and

standardizing processes in order to be able to deliver products as fast as possible is in line with Haque and James-Moore's (2004) statement.

As both organizations produce and deliver products on customer order, they both let the customer pull. As discussed in the analysis, the continuous improvement initiative solves problems which can be a source of waste. The pull-system prevents using resources and time on unnecessary activities that do not bring value to the customer, and hence not to the organization. To let the customer pull is also described as one of the key activities that constitute a LPD system, by Haque and James-Moore (2004).

Even though the theory regarding waste reduction is very vague, we conclude that all our findings regarding waste reduction are supported by the theory.

5.2 Discussion Knowledge Management

Knowledge is an important part of organizations that develop CoPS, and the organizations under study is no exception. The findings presented in chapter 5.2 emphasize the importance of managing this knowledge. In this chapter, the main findings presented in chapter 5.2 about KM are discussed in relation to the theory presented in chapter 2. The findings regarding KM are presented in the figure below. As before, each of the four different stages of KM emphasized in this study, knowledge creation, transfer, storage, and application, will be discussed separately and in that order.

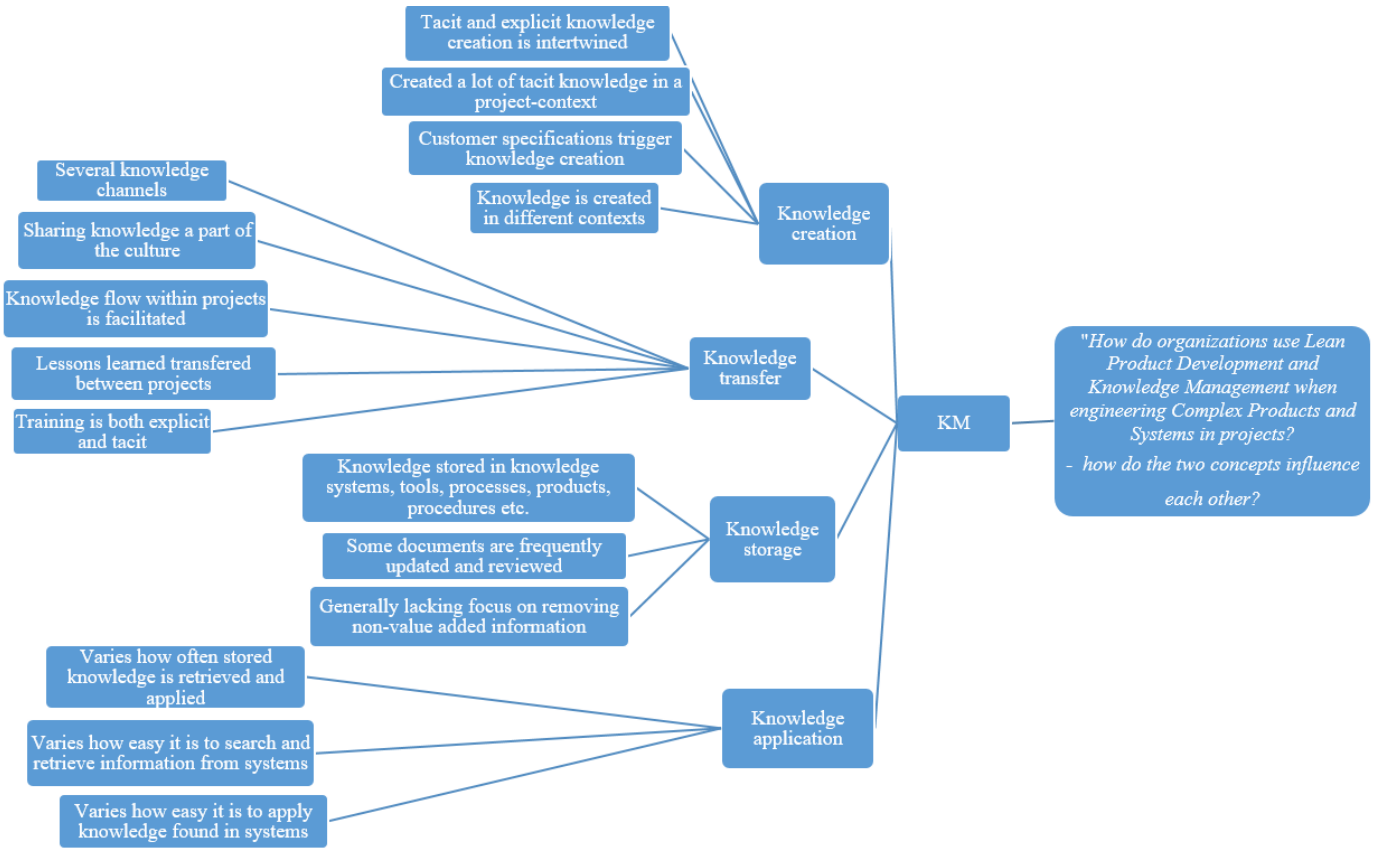

Figure 13 Summary key findings KM

5.2.1 Knowledge creation

As illustrated in figure 13, the main findings regarding knowledge creation are:

- Tacit and explicit knowledge creation is intertwined
- Created a lot of tacit knowledge in a project-context
- Customer specifications trigger knowledge creation
- Knowledge is created in different contexts

These findings are discussed in relation to the theory presented in chapter 2, in the following section.

Tacit and explicit knowledge creation is found to be intertwined, as the informants found it difficult to separate the two. This is consistent with Nonaka and Takeuchi's view on knowledge creation as a repeatedly spiral process of interaction between explicit and tacit knowledge. Informants also stated that there is created a lot of tacit knowledge in a project-context due to experience gained every day, which is consistent with existing theory. Marshall and Brady (2001) argue that there is a lot of tacit knowledge involved during development of CoPS. Further, Gann

and Salter (2000) argue that there is a need for tacit knowledge sharing between engineers. This in order to maintain technical consistency, as well as to create new knowledge and find new solutions.

Further, the amount of knowledge being created in the engineering phase in projects seems to be triggered or controlled by customer demands and specifications. However, this is not mentioned in the theory; thus it may be considered as a theoretical contribution.

We also found that knowledge basically is created in four different contexts, namely during breaks or random socialization, in teams and different types of groups, individually, and through knowledge tools. The latter was only mentioned used in organization 1. All of these stages can be related to Nonaka and Takeuchi's (1995) spiral process for organizational knowledge creation. This process comprises four modes, the socialization mode (tacit to tacit), the externalization mode (tacit to explicit), the combination mode (explicit to explicit), and the internalization mode (explicit to tacit).

Knowledge creation during socialization in different types of breaks is naturally related to the socialization mode where experiences is shared face-to-face in a common place in the organization. Knowledge creation in teams or groups may be related to the externalization mode where tacit knowledge is shared among people through dialog and collaboration in a more controlled setting, and gradually made explicit. Individual knowledge creation may be related to the internalization mode where explicit knowledge is converted to tacit through i.e. operative trial and error. In other words, when working individually with explicit knowledge one will gain tacit knowledge related to how tasks are best conducted. Using web-tools for knowledge creation, as applied for brainstorming in organization 1, may be related to the combination mode where interaction and correspondence take place in a virtual space. According to Nielsen (2005) focusing on dialog and communication in different settings is important for knowledge creation, problem correction, and the overall success when developing CoPS.

In summery, the main findings regarding knowledge creation that support existing theory are "tacit and explicit knowledge creation is intertwined", "created a lot of tacit knowledge in a project context", and "knowledge is created in different context". It is only one main finding regarding knowledge creation that is not mentioned in the theoretical review, namely "customer

specifications trigger knowledge creation". Hence, this may be considered as a theoretical contribution.

5.2.2 Knowledge transfer

As illustrated in figure 13, the main findings regarding knowledge transfer are:

- Use of several knowledge channels
- Sharing knowledge and helping each other is regarded as part of the culture
- A well-functioning knowledge flow within engineering and projects is facilitated
- Several measures for transferring lessons learned between projects
- Training is both explicit and tacit

These findings are discussed in relation to the theory presented in chapter 2, in the following section.

It is understood that the need for structuring knowledge transfer is high in the organizations under study as they are global businesses with thousands of employees. The two first findings regarding how knowledge is transferred in the organizations is further discussed in relation to element two, three, and four, of the five elements presented by Gupta and Givindarajan (2000). These three elements are, 2) Willingness to share knowledge, 3) Existence and quality of transmission channels, and 4) Willingness to acquire knowledge.

Element two regards people's willingness to share the knowledge identified within them. In general, there are a willingness to share knowledge and make each other better in both organizations. It is also regarded as part of the organizational culture to ask questions and help each other, by sharing knowledge.

Element three regards the existence and quality of knowledge transmission channels. There exist several tools and channels for knowledge transfer in both organizations. However, some argue that there exist too many channels, and that some of them are poorly managed. Among others, knowledge is transferred during coffee breaks, meetings, training, colloquia, forums, on the job training (experience), University, mentors, digitally training courses, datasheets, minutes of meetings, lessons learned, and digital forums. These knowledge channels may be divided into being informal or formal, or personal or impersonal (Alavi & Leidner, 2001). Coffee breaks can be characterized as an informal knowledge channel, while colloquia and forums may be both informal and formal knowledge channels. Formal training and meetings can be characterized as

formal knowledge channels, and on the job training (experience) and mentors is personal knowledge channels. Finally, the organizational university, digital training courses, digital forums, datasheets, lessons learned, and minutes of meetings can be characterized as impersonal knowledge channels. Both organization have several impersonal knowledge channels which makes knowledge available for everybody. This is important in these types of organizations as they are global with thousands of employees. Digital forums, as used in organization 1, will most likely contribute to extend individuals existing network by facilitating contact between those that seeks knowledge and those who possess that knowledge, as stressed by Robertsen et al. (1996).

Element four regards the individual's willingness to acquire new knowledge. Willingness to acquire have not been mentioned by the informants, but as there exist a culture where asking questions is common, it is reasonable to believe that those who ask those questions also are willing to acquire the knowledge given to them. In organization 2, the management also seem willing to acquire knowledge from all employees as the continuous improvement initiative explained in chapter 5.1 is a bottom-up process.

Findings regarding how knowledge is transferred within and between projects is further discussed in relation to different scholars. In a project team, consisting of people with individual capabilitites and skills, all actors are dependent on each other for a sucessful project execution. Ngai et al. (2008) stresses the importance of creating a tight personalization linkage among actors in order to create an effective knowledge flow. In organization 1, project members are placed in a physical place which facilitates a good oral communication flow for sharing of experiences. Knowledge is also exchanged between project members and the departments they actually belong to. According to Gann and Salter (2000), this is important in order to maintain consistency and to solve challenges. This also suggest that there exists a well-functioning knowledge sharing environment in projects. Lynn et al., (2000) stresses that a knowledge-sharing environment is necessary in order to successfully create a knowledge linkage between all actors involved in a CoPS project.

It is understood that lessons learned and project manager forums, which bring experiences from one project to another, contribute to project efficiency. Informants working in projects in organization 1 claim that lessons learned and quality databases are used as a base when configuring a new project. It is also used in risk and opportunity planning in order to avoid

making the same mistakes twice, and to make the planning process and task execution more efficient. This is consistent with the view of Radeka (2012) who stresses the importance of learning from previous mistakes. It is also consistent with an analysis conducted by Todorovića, et al. (2014), which shows that documenting aquired knowledge from previous projects contributes to a more efficient planing-process, faster task execution, improved problem solving, and a decrease in resource consumption.

Ngai, et al. (2008) stresses the importance of managing knowledge properly. It seems like organization 1 has a greater focus on KM than organization 2, mainly due to the fact that they have a KM-department. According to Hansen, et al. (1999) the organization must choose between a codification strategy or a personalization strategy. It is evident that the organizations under study use a mix of both, as knowledge is both codified and stored in knowledge systems, in addition to shared through meetings, forums, brainstorming, well-fuctioning communication flows between project team members, and knowledge sharing during coffee breaks.

Further, training is not mentioned in the theoretical review presented in this thesis. However, several scholars argue that both explicit and tacit knowledge is of use when developing CoPS (Marshall & Brady, 2001; Gann & Salter, 2000; Bresnen, et al., 2003; Todorovića, et al., 2014).

In summery, the main findings regarding knowledge transfer which are consistent with the presented theory, are: “use of several knowledge channels”, “sharing knowledge and helping each other is regarded as part of the culture”, “a well-functioning knowledge flow within engineering and projects is facilitated”, and “several measures for transferring lessons learned between projects”. It is only one main finding regarding knowledge transfer that is directly mentioned in the theoretical review, namely “training is both explicit and tacit”. However, it is argued that both explicit and tacit knowledge is of use when developing CoPS.

5.2.3 Knowledge storage

As illustrated in figure 13, the main findings regarding knowledge storage are:

- Knowledge is stored in knowledge systems, tools, processes, products, procedures etc.
- Some documents are frequently updated and reviewed, while others are not.
- Generally lack of focus on removing non-value-added information.

These findings are discussed in relation to the theory presented in chapter 2, in the following section.

Hanisch et al. (2009) stresses the importance of using IT systems and having a systematic approach towards KM, which fit the project needs and the organizational structure. Hanisch et al. (2009) also stress the fact that employees must be willing to use the organization's knowledge systems. It seems like both organizations use too many knowledge systems in order to store knowledge. This makes them difficult to deal with for employees. In organization 2, knowledge systems are not properly managed as there is a lack of clear guidelines on which knowledge system to use in different situations, who that is responsible for using them, and when to use them. This may have a negative effect on project efficiency as it is difficult to know what kind of information that is stored in which systems and where to store different types of information.

We found that a lot of knowledge and experience is stored in processes, products, working procedures etc., which according to Walsh and Ungeson (1991) is transforming experience and knowledge into organizational memory. This makes knowledge available for the organization as a whole. Both organization also continuously update their tools with new knowledge and information, which is considered important by Alavi and Leidner (2001) as this makes new information available for everyone at the same time.

Both organizations generally lack a focus on removing non-value-adding information from knowledge systems. Additionally, it varies how frequently knowledge is reviewed and updated. Alavi and Leidner (2001) argue that outdated information is more likely to be found in organizations that operate in a changing environment, in which it is a need to continuously renew knowledge. This is the case for the organizations studied in this thesis, as both operates in markets which continuously evolve.

In summery, all main findings regarding knowledge transfer are consistent with presented theory: "knowledge is stored in knowledge systems, tools, processes, products, procedures etc.", "some documents are frequently updated and reviewed, while others are not", and "generally lack of focus on removing non-value-added information".

5.2.4 Knowledge application

As illustrated in figure 13, the main findings regarding knowledge application are:

- Varies how often stored knowledge is retrieved and applied
- Varies how easy it is to search and retrieve information from systems
- Varies how easy it is to apply knowledge found in systems

These findings are discussed in relation to the theory presented in chapter 2, in the following section.

According to Alavi and Leidner (2001) knowledge itself is not the source of competitive advantage, but the application of it is. This stresses the importance of being able to reuse and apply knowledge. In both organizations knowledge-systems is used to store and transfer knowledge, which makes knowledge available for everybody at the same time - across time and space. This should enhance the speed of knowledge application. Nevertheless, it varies how often stored knowledge is retrieved and applied in both organizations, mainly because it may be difficult to search for the information needed, to find the people possessing the knowledge needed, or to interpret the information found. Walsh and Ungeson (1991) suggest that transforming knowledge and experience into standards and procedures helps reapplying knowledge, which is continuously done in both organizations.

As stated under knowledge storage Hanisch et al. (2009) stress the fact that employees must be willing to use the organization's knowledge systems. In organization 2 it is pointed out that systems are not always used as the information found is not adjusted to projects, but contain information regarding several departments. This makes it time consuming, as employees have to filter out the information needed.

Alavi and Leidner (2001) further argue that having a large number of routines and procedures may make it problematic for the employees to choose which one to use in different settings. This is relevant for the organizations under study in this thesis. As mentioned under knowledge storage, some information is frequently updated and reviewed, while some is not. This may result in application of knowledge that is outdated. The same information may also be stored in several knowledge systems, in which some are updated and others are not. This creates a risk of someone using information that is no longer relevant.

In summery, all main findings regarding knowledge transfer are consistent with presented theory: "varies how often stored knowledge is retrieved and applied", "varies how easy it is to search and retrieve information from systems", and "varies how easy it is to apply knowledge found in systems".

5.3 Discussion Lean Product Development and Knowledge Management

As illustrated in the theory chapter, knowledge has gradually become an important part of the LPD theory. We find this both logical and natural, as knowledge plays a central role in product development and engineering. We found that the combination of the two concepts can be interpreted in two ways: (1) how KM influence LPD in engineering, by using KM to increase efficiency, through standardization and waste reduction, and (2) how LPD influence KM in engineering by standardizing and streamlining KM-processes, as well as reducing KM waste. We will in this chapter present how our key findings regarding how LPD and KM, as illustrated in the figure below, influence each other in terms of efficiency, standardization, and waste reduction, aligns with the theory.

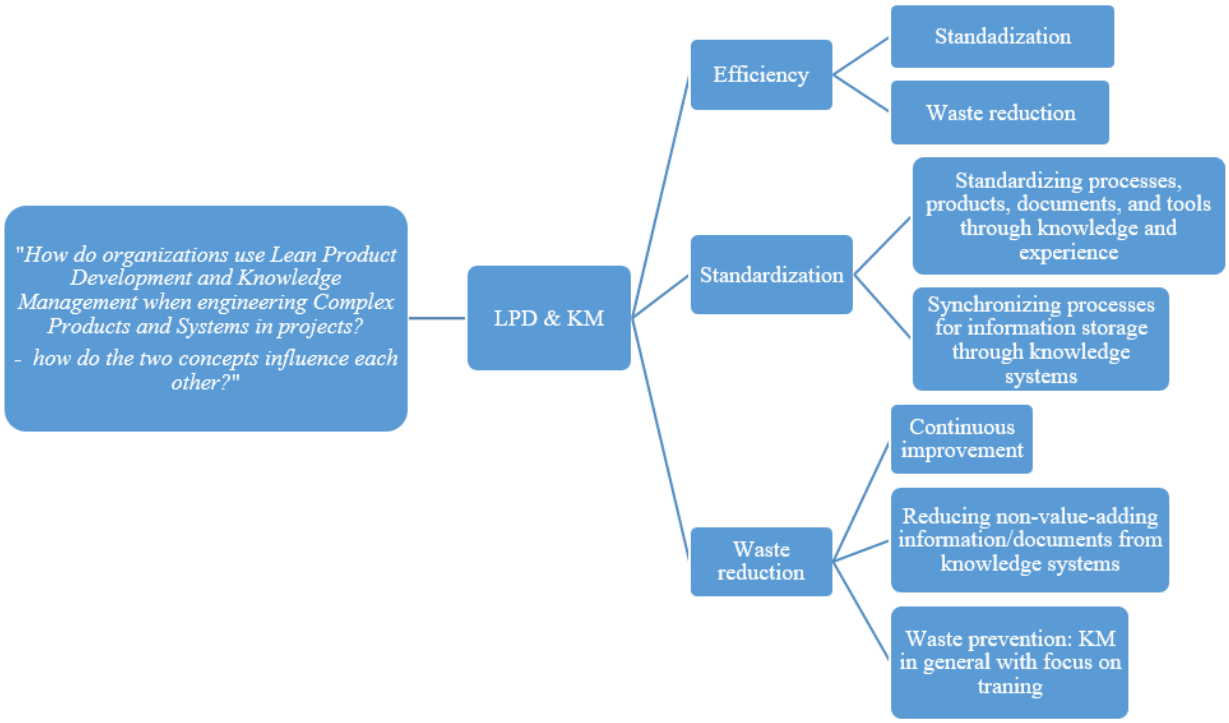

Figure 14 Summary key findings LPD & KM

5.3.1 Efficiency

As illustrated in figure 14, the main findings regarding efficiency are:

- Standardization
- Waste reduction

These findings are discussed in relation to the theory presented in chapter 2, in the following section.

Radeka (2012) describes LPD as the process of maximizing value and minimizing waste in order to deliver the right product to the market at the right time and the right price. She also states that by being able to create, capture, share, and use valuable company knowledge, a company is able to spend more time on generating innovative products with high value and low risk, through a fast, predictable, reliable, and innovative product development process. This illustrates that efficient KM is important in order to enhance the project efficiency.

We found that knowledge storage and partially transfer and application, is standardized in both organizations through knowledge systems and channels, as well as standard documents and procedures. We also found that there is a lack of focus on updating documents, as well as removing documents that can be characterized as waste. We can argue that this is related to Radeka's (2012) description of LPD. Organization 2 handles standardization and waste reduction through their continuous improvement initiative, where whiteboard meetings are included. Once a week every department host a whiteborad meeting for their employees where information is visualized and shared. Lindlöf et al. (2013) states that visualization has proven to be a powerful method where knowledge work is concerned. As a result, visualization of information can be used to sort, add, combine, and categorise explicit knowledge, and be a tool for helping employees to communicate and acquire the information more easily. Organization 1 did also state that they through their KM initiative focus on transferring the right information to the right person at the right time. This is directly related to how Radeka (2012) describes the LPD process.

Based on the preceding discussion, we conclude that both our findings regarding efficiency are supported by the theory.

How the organizations work in order to standardize and reduce waste is discussed in detail in the upcoming chapters.

5.3.2 Standardization

As illustrated in figure 14, the main findings regarding standardization are:

- Standardizing processes, products, documents, and tools through knowledge and lessons learned
- Synchronizing processes for information storage through knowledge systems

These findings are discussed in relation to the theory presented in chapter 2, in the following section.

The more projects that run in parallel, the more knowledge is created within a firm. It is therefore important to be able to standardize how to transfer, store, and reapply this knowledge in order for a project to run smoothly.

Both organization uses knowledge and experience to standardize processes, products, documents, and tools. They do this by implementing new knowledge in order to improve these aspects. Among others, this is done through lessons learned and organization 2's continuous improvement initiative. We characterize lessons learned and the previously explained methods used in the continuous improvement initiative, as tools to gather, store, share, and reuse knowledge. This because these initiatives motivate the employees to share their knowledge and experience, which again will be stored in order to use it as a source for process improvements, etc. As a result, we relate these initiatives to Liker and Morgan's (2006) principle 13: use powerful tools for standardization and organizational learning. Further, Radeka (2012) states that a failure in early product development is a valuable learning experience. We therefore argue that these lessons learned and continuous improvements initiatives are important in order to be able to capture valuable knowledge and experience.

We found that knowledge storage and partially transfer and application, is standardized and synchronized in both organizations through knowledge systems and channels. This is done in order to make it easier for the engineers to find necessary knowledge in the same systems globally. Haque and James-Moore (2004) states that information flow and the IT-systems used to transfer information is an important part of LPD. We can therefore conclude that the organizations work regarding standardizing and synchronizing knowledge storage processes globally, is aligned with the LPD theory.

Based on the preceding discussion, we argue that both our findings regarding standardizations are supported by the theory.

5.3.3 Waste Reduction

As illustrated in figure 14, the main findings regarding waste reduction are:

- Continuous improvement

- Reducing non-value-adding information from knowledge systems
- Waste preventing: KM in general with emphasis on training

These findings are discussed in relation to the theory presented in chapter 2, in the following section.

We found that organization 2 has a stronger focus on waste reduction than organization 1 in terms of processes, procedure etc., but a lower focus on waste reduction regarding KM. Even so, organization 2 use their continuous improvement initiative to reduce waste in processes and procedures by using knowledge and experience to define problems and finding appropriate solutions. This initiative is in line with Haque and James-Moore's (2004) approach regarding waste reduction. Additionally, we also argue that the initiative can be related to Radeka's (2012) description of the LPD process, which is to maximizing value and minimizing waste in order to deliver the right product to the market at the right time and the right price.

Organization 1 has newly started a project which focuses on reducing non-value-adding information which is stored in their knowledge systems. Organization 1's initiative is clearly in line with Haque and James-Moore's (2004) approach which includes waste reduction in general. We also argue that the project is aligned with their approach regarding information flow and the IT-systems used for such. The reason for this is that removing non-value-adding information will make it easier for the employees to find and reapply information. This is important as it is the application of knowledge that brings value to an organization (Alavi & Leidner, 2001).

Further, we included KM in general, with emphasis on training, as a key finding regarding waste prevention. The reason for this is that sufficient training should ensure that the engineers are competent, and hence make less mistakes. Both organizations mentioned that they use mentors in order to train new employees. Lindlöf et al. (2013) identify mentorship as one key method to support the transfer of knowledge in a product development setting. They further describe the mentor as the most experienced in their department, and that he or she should act as a supporting teacher enabling the employees to learn by doing. Organization 2 has initiated a certification program, which means that all mentors has gone through sufficient training before being certified. We argue that this initiative prevents unexperienced engineers from becoming mentors, and that the certification ensures that all mentors are qualified. One of the principles in Liker and

Morgan's (2006) LPD approach is to develop towering technical competence in all engineers. We argue that this principle is covered through the organizations focus on training employees.

Based on the preceding discussion, we conclude that all our findings regarding waste reduction are supported by the theory.

5.4 Conclusion

In this thesis, we have examined how organizations use LPD and KM when engineering CoPS in projects. We have also examined how these two concepts influence each other. A summary of our findings is illustrated in figure 11.

It is evident that both LPD and KM is extensive concepts that is interpreted differently by individuals, and hence used differently in organizations. We found that organization 1 has a stronger focus on KM, while organization 2 has a stronger focus on LPD, which influence the organizations approaches regarding the two concepts. However, both organizations are of the opinion that KM and LPD is valuable concepts that may enhance project engineering.

Both organizations have implemented what can be categorized as LPD initiatives. Organization 1 has implemented a zero defect approach globally, but during every day work in project engineering LPD function more as a mindset. Organization 2 uses a continuous improvement approach with weekly compulsory whiteboard meetings. Mainly, both initiatives regard standardizing processes, procedures, documents, tools, and products (as far as possible) in order to increase efficiency. Even though both organization have implemented what can be characterized as LPD initiatives, LPD is not something employees think about in their everyday work. Further, organization 2 has a stronger focus on waste reduction than organization 1. Even so, both organizations have implemented some measures in order to reduce waste. Organization 2 handles this actively as part of their continuous improvement initiative, while organization 1 mainly makes us of the Lean mindset in order to reduce waste during project execution.

It seems evident that knowledge creation, transfer, storage, and application is intertwined, and must therefore be viewed as an interacting whole. If one of them are poorly managed it will affect the others. Several initiatives regarding KM is implemented in both organizations. However, KM is not something the engineers focus on during their everyday work, but rather something they unconsciously make us of. Knowledge transfer and storage are considered essential in KM, by

both organizations, as it makes it possible to reuse knowledge, hence save time and resources. Knowledge is transferred face to face and through several knowledge channels. Lessons learned and project manager forums are used to transfer knowledge between projects. Knowledge is stored in various knowledge systems or channels in addition to tools, processes, products, working procedures etc. Knowledge creation is regarded important, but do not seem to be clearly facilitated within any of the organizations. Sharing knowledge and helping each other is regarded as part of the organizational culture. Knowledge creation is fund to mainly be triggered by the customer, through specifications, and is basically created in four different contexts: during breaks (socialization in the hallway, cafeteria, etc.), individually, in teams/groups, and through knowledge tools. Tacit and explicit knowledge creation is found to be intertwined. Knowledge application is of fluctuating focus. Where and how information is stored affect how easy it is to retrieve and apply this information.

Both LPD and KM are found to influence each other. We found that KM is advantageous in LPD regarding standardizing, waste reduction, and efficiency. As knowledge, information and experience is made available through KM, it contributes to standardizing products, processes, procedures etc., as well as locating, removing and/or prevent waste. Both standardizing and waste reduction may increase efficiency. We found that LPD-thinking is advantageous in KM as it may be used to standardize how knowledge is transferred, stored, and applied. Additionally, it may be used to increase the focus on removing non-value-adding information.

It can be concluded that both organizations have implemented different LPD-initiatives with the purpose of reducing waste and standardizing processes, products, procedures, tools etc. in order to improve efficiency at a lower cost. The methods and tools used to manage knowledge in the organizations are quite similar, but overall better managed in organization 1. In both organizations the purpose of focusing on KM is to increase efficiency and lower cost, by reusing knowledge and avoiding making the same mistakes twice. As knowledge is important in order to standardize processes, products, procedures and tools, and Lean-thinking may enhance the quality of KM, the two concepts seem to influence each other.

5.4.1 Theoretical implications

In the discussion chapters, we compared our key findings with the theory presented in chapter 2. The discussion illustrates that more or less all our findings regarding how the organizations use

LPD and KM in practice during the engineering phase in projects confirm the existing theory. Thus, we have in this thesis supported existing theory, by providing findings on how LPD and KM are used in practice during engineering of CoPS.

As stated in the theoretical review, there is a lack of both theoretical and empirical research regarding how LPD can be exploited in organizations that develop CoPS. On the other hand, there exist some theoretical research regarding how KM can be exploited in organizations that develop CoPS. However, there is a lack of empirical research. In this regard, our thesis contributes with examples of how organizations makes us of LPD and KM separately, in practice when engineering CoPS. Thus, our thesis contributes with an increase the understanding of how organizations make us of LPD and KM when engineering CoPS in projects

Further, the theoretical review illustrates that knowledge has become an important part of LPD. However, specific examples of how the two concepts influence each other, is lacking. This thesis has provided practical examples of how KM influence and enhance LPD (standardization, waste reduction, and thus efficiency) in the engineering phase, as well as how LPD influence and enhance KM (knowledge transfer, storage, and application) in the engineering phase. Our findings regarding this is illustrated in figure 10.

Overall, our theoretical contribution is an increased understanding of how organizations make us of LPD and KM separately when engineering CoPS in projects, as well as how the two influence each other.

5.4.2 Practical implications

This thesis illustrates how organizations make us of LPD and KM when engineering CoPS, and how these two concepts influence each other. How organizations make use of LPD varies between implementing specific LPD initiatives, to only make use of the LPD mindset. Implementation of specific LPD initiatives has proven to advantageous for project efficiency. Knowledge creation, transfer, storage, and application, are found to be intertwined, and organizations must therefore treat it as a coherent whole. If one of them is poorly managed, it will affect the others. Further, there is created a lot of knowledge in the engineering phase, and in projects in general, and especially when CoPS are concerned. As a result, it is crucial for organizations to have clear guidelines regarding how knowledge should be transferred and where

it should be stored, in order to make it easier for the employees to retrieve this knowledge. If knowledge is not sufficiently managed, it will negatively affect project efficiency. It is also important for organizations to focus on removing non-value added information, as well as updating stored information. This in order to make it easier and efficient for the employees to retrieve and apply stored knowledge. Organizations can increase their awareness and focus on KM by establishing a KM department. Further, involving all employees in both LPD and KM initiatives will increase employees' motivation to contribute to improve the organization, as well as increase awareness and focus on the subjects.

Another practical implication is in regards to how knowledge and information can be preserved by updating and standardizing processes, products, documents, and tools across projects. However, it is important not to over-specify these aspects, as it may affect the employee's ability to make individual adjustments when necessary. Nevertheless, if organizations are able to manage knowledge sufficiently, they will be better prepared to make us of LPD initiatives in a satisfactory manner. This is due to the fact that initiatives to enhance efficiency, better standardize, as well as reduce waste, necessarily must culminate from new information or past experience.

5.5 Reflections regarding the study

The aim of this thesis was to examine how LPD and KM are used in practice during CoPS engineering, as well as how these two concepts influence each other. We are aware that this is an extensive research question. By narrowing down the area of research, we would have been able to enhance the depth of the study even further.

This thesis is built on the basis of 11 informants individual experience, knowledge, and perception of how LPD and KM are used when engineering CoPS in projects. We have during the execution of this thesis made choices to limit the scope in order to make it fit into a thesis framework in terms of time and resources. This has necessarily affected the study's range. One of this study's weaknesses is the number of case study organizations that are represented. As we only had time and resources to gain insight and understanding of how two comparable project-based organizations in two different industries use LPD and KM in practice, we are aware that this limits our ability to generalize our findings. To enhance the results further, we could have gathered data from numerous comparable companies in several industries in order to see whether

the results would still be coincided. The number of informants in this study can also be considered a weakness. In order to enhance our results, we could also have included more informants from each organization in order to get more viewpoints on the phenomena under study. We did, however, consider this redundant as the informants interviewed had sufficient knowledge that covered all the aspects of the topics we were interested in. We are also of the opinion that we collected data until the point of saturation was met. However, we are aware that our study could have benefited from more informants in order to strengthen our research findings, especially as this is large organizations.

Further, if the timeframe would have allowed it, we could have enhanced our thesis' validity further by using more of the strategies that Johnson (1997) suggests. For example, we could have enhanced the theoretical validity by conducting extended fieldwork, negative case sampling, and pattern matching. We could also have enhanced the internal validity through method triangulation, e.g. observation and surveys. This could potentially have added more width to our study. Nevertheless, we do believe that our data covers a wide range of opinions, and that our thesis provides useful and interesting information with practical relevance.

5.6 Further research

This thesis focuses on how organizations that develops CoPS use LPD and KM in practice during the engineering phase in projects, as well as how LPD and KM influence each other. Due to our thesis' limited resource- and timeframe, we have only been able to conduct the study in two organizations. In order to increase the generalizability, we suggest to conduct similar studies and compare the findings. As this thesis is based on two organizations in different industries, another suggestion for further research is to examine how KM and LPD is used when engineering CoPS in projects in organizations in different industries, and within the same industry. Yet another suggestion for further research is to conduct a similar study in organizations that develop less complex products and system, and compare the findings to the findings in this thesis. This would have been interesting in order to detect if there actually is a difference. Further, as there exists limited empirical research regarding how LPD and KM influence each other in practice, there should be conducted several studies regarding this.

The literature review revealed that there exists limited research, both empirical and theoretical, regarding how LPD and KM separately is compatible in organizations that develop CoPS. Nor

did we detect any research regarding how LPD or KM are used when developing or engineering CoPS, compared to the development or engineering of less complex products and systems. As a result, we believe there exists a basis for further research regarding these topics.

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Appendix

Appendix 1 – Rating of publication channels

Publication channel	Rating of publication channels (2016)	Title	Number of citations on Google Scholar
Academy of Management Perspectives	1	The Toyota way in services: The case of Lean Product Development (Liker & Morgan, 2006)	261
Academy of Management Review	2	Building Theories from Case Study Research (Eisenhardt, 1989)	35133
		Organizational memory (Walsh & Ungson, 1991)	3312
Accounting, Management and Information Technologies	-	Information systems and organizational learning: the social epistemology of organizational knowledge systems (Pentland, 1995)	476
AMCIS 1998 Proceedings	-	Developing a preliminary framework for knowledge management in organizations (Tan, et al., 1998).	52
Basic Books	1	The Coming of Post-Industrial Society: A Venture in Social Forecasting (Bell, 1973)	69
California Management Review	1	Paradox in project-based enterprises: the case of filmmaking (DeFillippi & Arthur, 1998)	710
Cappelen Damm Akademisk	1	Hvordan kan du vite om noe er sant?: veiviser i forsknings-og utredningsarbeid for studenter, ledere, konsulenter og journalister (Grenness, 2012)	4
Computers in Human Behavior	1	Enterprise knowledge management model based on China's practice and case study (Zhao, Ordóñez de Pablos, & Qi, 2012)	38
Education	-	Examining the validity structure of qualitative research (Johnson, 1997)	1088
Engineering Management Journal	1	A Multilevel Framework for Lean Product Development System Design (Letens, et al., 2011)	31
European Journal of Information Systems	2	Knowledge management and the politics of knowledge: illustrations from complex products and systems (Marshall & Brady, 2001)	89
Expert systems with applications	1	Knowledge Management: Where Did It Come From and Where Will It Go? (Wiig, 1997)	1090
Fagbokforlaget Vigmostad & Bjørke AS	1	Det kvalitative intervjuet, fra vitenskapsteori til feltarbeid (Ryen, 2002)	160
GBR: Productivity Press	-	Mastery of Innovation: A Field Guide to Lean Product Development (Radeka, 2012)	8
HarperCollins Publishers	1	The machine that changed the world (Womach, et al., 1990)	13667
Harvard business press	-	Working Knowledge: How Organizations Manage what They Know (Davenport & Prusak, 1998)	17340
Harvard business review	2	Lean Knowledge Work (Staats & Upton, 2011)	49
		The knowledge-creating company (Nonaka, 1991)	8969
		What's your strategy for managing knowledge (Hansen, Nohria, & Tierney, 1999)	42

IEEE Transactions on Engineering Management	1	Component sharing in complex product and systems: challenges, solutions, and practical implications (Oshri & Newell, 2005)	47
		Knowledge management in new product teams: practices and outcomes (Lynn, et al., 2000)	235
Innovation Management. Technovation	2	Hotspots in Complex Product Systems: Emerging Issues (Hansen & Rush, 1998)	140
International Journal of Computer Integrated Manufacturing	1	Practices supporting knowledge transfer – an analysis of lean product development (Lindlof, et al., 2013)	14
International Journal of Operations & Production Management	1	Assessing changes towards lean production (Karlsson & Aahstrom, 1996)	515
		Learning to evolve: A review of contemporary lean thinking (Hines, et al., 2004)	1043
International Journal of Production Research	2	A new value stream mapping approach for complex production systems (Braglia, et al., 2006)	170
		Structural Equation Modelling of lean manufacturing practices	40
International Journal of Project Management	1	Project success analysis framework: A knowledge-based approach in project management (Todorovića, et al., 2014)	15
		Social practices and the management of knowledge in project environments (Bresnen, et al., 2003)	420
Journal of Accounting, Organizations and Society	2	Management accounting and control practices in a lean manufacturing environment	48
Journal of Business Research	2	Systematic combining: an abductive approach to case research (Dubois & Gadde, 2002)	2002
		The role of knowledge embeddedness in the creation of synergies in the strategies alliances (Nielsen, 2005)	175
Journal of Curriculum Studies	2	Three good reasons for not doing case studies in curriculum research (Walker, 1983)	57
Journal of Engineering Design	2	Applying lean thinking to new product introduction (Haque & James-Moore, 2004)	173
Journal of Knowledge Management	1	Knowledge communication and translation-a knowledge transfer model (Liyanage, Elhag, Ballal, & Li, 2009)	154
		Knowledge, Management, and Knowledge Management in Business Operations (Gao, Li, & Clarke, 2008)	119
		Knowledge management in project environments (Hanisch, et al., 2009)	95
Journal of Management Studies	2	The Role of Networks in the Diffusion of Technological Innovation (Robertson, et al., 1996)	284
Journal of Manufacturing Technology Management	1	Towards Lean Product Lifecycle Management: a Framework for New Product Development (Hines, et al., 2006)	91
	2	Defining and developing measures of lean production (Shah & Ward, 2007)	1005

Journal of Operations Management		Lean manufacturing: Context, practice bundles, and performance (Shah & Ward, 2003)	1472
		The genealogy of lean production (Holweg, 2007)	864
Knowledge management research & practice	1	Knowledge-based development research: a comprehensive literature review 2000–2010. (Ergazakis, Metaxiotis, & Askounis, 2013)	6
Long Range Planning	1	Knowledge management: A strategic agenda (Quintas, Lefrere, & Jones, 1997)	781
Management accounting quarterly	-	Are ABC and RCA accounting systems compatible with lean management? (Grasso, 2005)	52
Management Decision	1	The role of communication and management support in a lean manufacturing implementation (Worley & Doolen, 2006)	248
Management Science	2	Product development decisions: A review of the literature (Krishnan & Ulrich, 2001)	1479
MIS Quarterly	1?	Review: Knowledge Management and Knowledge Management Systems: Conceptual Foundations and Research Issues (Alavi & Leidner, 2001)	8172
NKS Forlaget	-	Slik skapes kunnskap: Hvordan frigjøre taus kunnskap og inspirere til nytenkning i organisasjoner (Sandvik, 2001)	17
Organization science	2	Prospering in Dynamically-Competitive Environments: Organizational Capability as Knowledge Integration (Grant, 1996)	5645
Operations Management	1	Six Myths of Product Development (Thomke & Reinertsen, 2012)	28
Oxford University Press	2	Knowledge Asset: Securing a Competitive Advantage in the Information Economy (Boisot, 1998)	1504
		The Knowledge-creating Company: How Japanese Companies Create the Dynamics of Innovation (Nonaka & Takeuchi, 1995)	32764
Qualitative inquiry	2	Five Misunderstandings About Case-Study Research (Flyvbjerg, 2006)	5539
R&D Management	-	A qualitative study of inter-organizational knowledge management in complex products and systems development (Ngai, et al., 2008)	
Research policy	2	Innovation in project-based, service-enhanced firms: the construction of complex products and systems (Gann & Salter, 2000)	1027
		The project-based organisation: an ideal form for managing (Hobday, 2000)	1049
Routledge	2	Qualitative Research: The esseantial guide to theory and practice (Savin-Baden & Major, 2013)	212
		What's wrong with ethnography?: Methodological explorations (Hammersley, 1992)	3266
Sage Publications	2	Case Study Research: Design and Methods (Yin, 2014)	109226
Strategic Management Journal	2	Knowledge flows within multinational corporations (Gupta & Govindarajan, 2000)	3666
Studies in Educational Evaluation	1	Situational context as influence on evaluation design and use (Stake, 1990)	24
Systems Engineering	2	On Customer Value and Improvement in Product Development Processes (Browning, 2003)	112

Appendix 2 – Knowledge definitions

Definitions	Scholars
"justified true belief"	Plato (Gao, et al., 2008)
"{that} which is objectively known, an intellectual property, attached to a name and a group of names and certified by copyright or some other form of social recognition" "a set of organized statements of facts or ideas, presenting a reasoned judgment or an experimental result, which is transmitted to others through some communication medium in some systematic form"	(Bell, 1973)
"a dynamic human process of justifying personal belief toward the truth"	(Nonaka & Takeuchi, 1995)
"a capacity that builds on information extracted from data or the set of expectations that an observer hold with respect to an event"	(Boisot, 1998)
"a fluid mix of framed experiences, values, contextual information and expert insight"	(Davenport & Prusak, 1998)
“knowledge is information that "changes something or somebody either by becoming grounds for action, or by making an individual or an institution capable of different and more effective action"	Drucker (Gao, et al., 2008)

Appendix 3 – Interview protocol

Short introduction of the study

- Date:
- Time:

Personal information:

- Name:
- Gender:
- Age:
- Organization:
- Job description:
- Years in the organization:

Introductory and general questions:

- What kind of products do this organization develop?
- Would you categorize these products as complex?
    - Why?
- What is the purpose of having projects?
    - What are the main tasks in a project?
- Can you explain the processes included in the product development phase in projects?

Lean:

- What do you associate with the term lean?

- Do you have any associations to the term and/or the theory lean product development? What perception do you have of the term?
- Is lean used as a tool in projects? If so, which lean aspects are emphasized?
    - Why are preciously these tools/aspects used?
    - How long has lean been used as a tool in projects?
    - What is your role in relation to lean in this organization?
    - How long have you worked with lean?
- Can you explain how lean is used in practice in the projects in this organization?
    - Do the organization focus on securing effectivity in the project processes? How?
    - Do the organization focus on non-value-added activities or processes in projects?
        - Do you have methods to detect non-value-added activities and eliminate such activities?
- Does there exist processes that previously was not standardized, but that are today, du to use of lean in projects?
- Are lean aspects/tools useful for an effective project execution?

KM:

- Do you have any associations to the term and/or the theory Knowledge Management? What perception do you have of the term?
- Is KM given attention in projects? Which aspects of KM are emphasized in projects?
    - How long has KM been used as a tool in projects?
- What is your role in relation to KM in this organization?
- How long have you worked with KM?
- How is the communication in projects? What types of communication tools are used?
    - How is the communication flow in relation to suppliers and the customers?
    - Do delays occur from poor information sharing internally and externally in projects? How do you avoid this?
- Do you distinguish tacit and explicit knowledge in the organization?

We are interested in how explicit and tacit knowledge is created, shared/transferred, stored, and applied in projects, and what kind of IT-systems is used in this regard?

- How does knew knowledge arises in projects? I what contexts?
    - Is there a difference between how explicit and tacit knowledge occur?
- How is knowledge being transferred to other members of the projects?
    - Is there a difference between how explicit and tacit knowledge is transferred?
    - Do the organization have IT-systems used in relation to knowledge sharing
    - Is there knowledge sharing across projects? How is it done?
- How is explicit knowledge stored?
    - How much is stored? Too much or too little?
- Do you have a method to convert tacit knowledge to explicit knowledge, in order to make it possible to store? How?
    - How much is stored? Too much or too little?
- How is knowledge made available for later use?
    - How often is stored knowledge used later on?
    - Are knowledge from previous projects made available and used in new projects?

- Does the organizational structure and culture support KM in the organization? In what way?
- Do the organization focus on reducing non-value-added information? How?
- Does there exist processes that previously was not standardized, but that are today, du to use of KM in projects?
- Is KM useful for an effective project execution?
- Is knowledge systems useful for an effective project execution?

Closing questions:

- Is there anything else you would like to add regarding the topics covered in this interview?
- Is there other people in this organization you believe we should interview about this theme?

Appendix 4 – Declaration of consent

Samtykkerklæring

Vi er to masterstudenter ved Høgskolen i Sør-Øst Norge, avdeling Hønefoss, der vi studerer økonomi og ledelse med fordypning i industriell økonomi. Vi er i gang med vår masteravhandling som omfatter bruken av Lean Product Developement og Knowledge Management ved utviklingen av komplekse produkter og systemer. Problemstillingen vi ønsker å besvare i denne studien er:

"How do organizations use Lean Product Development and Knowledge Management when engineering Complex Products and Systems in projects?

- *how do the two concepts influence each other?"*

For å svare på denne problemstillingen har vi valgt å benytte oss av kvalitativ metodetilnærming. Det er dermed naturlig at intervju og observasjon benyttes som datainnsamlingsteknikker. Da vår avhandling søker å undersøke temaet Lean Product Developement og Knowledge Management ved utviklingen av komplekse produkter og systemer, er det ønskelig at du som informant har kunnskap om hvordan din virksomhet forholder seg til dette.

Intervjuet er estimert til å vare i omlag 1 time, og vi ønsker å benytte oss av lydopptak i intervjuprosessen, da dette vil være med på å styrke vår troverdighet i studien. I tillegg vil det også tas notater underveis.

Din deltakelse er selvfølgelig frivillig, og du har muligheten til å trekke deg underveis uten videre begrunnelse. Alle data og opplysninger om deg vil da bli slettet. Videre vil alle opplysninger og

intervju bli anonymisert, og behandles konfidensielt. Dette gjør at det ikke vil være mulig å gjenkjenne enkeltindivider i avhandlingen. Når avhandlingen er ferdigstilt og vurdert vil alle lydopptak slettes. Dette vil skje senest ved utgangen av mai 2016. I tillegg vil alle personlige opplysninger bli behandlet på en forskningsetisk og ansvarlig måte.

Dersom du har spørsmål eller innspill vedrørende studien og intervjuet kan du ta kontakt med oss.

Studien er meldt inn til personvernombudet for forskning, Norsk Samfunnsvitenskapelig Datatjeneste (NSD).

Denne masteravhandlingen blir skrevet av:

Carina Røren Husmoen | +47 45222915 | carina.r.husmoen@student.hbv.no

Anja Linnerud Hansen | +47 99432588 | anja.l.hansen@student.hbv.no

Samtykke til deltakelse i studien

Jeg har mottatt informasjon om avhandlingen og intervjuprosedyren, og sier meg villig til å delta i studien.

Sted, dato:……..

Signatur:…….

Telefon:…….

Appendix 5 – LPD-findings

Lean Product Development	Organization 1	Organization 2
Focus	- Do not use «Lean» as a term - Different perceptions of the extent to which LPD is implemented or not - Focuses on making processes zero defect capable	- Do not use «Lean» as a term - Implemented a Continuous improvement initiative that all employees participate in - The initiative includes: - Whiteboard meetings

	- Use the Lean mindset in projects - Increased focus on efficiency	- 5 why - Root cause analysis - Value flow analysis - A3 - Focus on process improvements outside the project, which is being implemented in projects. - Increased focus on efficiency
Efficiency	- All informants believe that Lean contributes to an effective project execution - Focus on efficiency, more important now than before - Continuously improves processes and tools - Focus on waste reduction - Standardizing processes - Focus on putting together effective project teams - Measure KPIs	- All informants believe that Lean contributes to an effective project execution - The engineers do not focus on efficiency, rather on following processes - Continuously improve processes and tools in parallel to projects - Focus on waste reduction - Standardizing processes - Develops software to enhance efficiency - Measure KPIs
Standardization	What has been standardized: - Documents - Processes - Procedures - Products - Different perspectives on to which extent products are standardized - Globalization and standardization of processes - The need for standardizing processes increase in line with the size of the organization - Focus on making processes standardized and zero defect capable - Uses IT-systems to structure document storage	- What has been standardized: - Documents - Processes - Procedures - Products - Different perspectives on to which extent products are standardized - Globalization and standardization of processes - The need for standardizing processes increase in line with the size of the organization - Continuous improvement initiative is used to standardize processes - Uses IT-systems to structure document storage
Waste reduction	- Measures PONC to detect waste-inducing processes and activities - Use Lean mindset to reduce waste during project execution - Document reviews - Pull-organization	- Continuous improvement initiative - Up to the engineers themselves to avoid wasting time - Develop software - Document reviews - Pull-organization

Appendix 6 – KM-findings

Knowledge Management	**Organization 1**	**Organization 2**
Focus	- KM is extensive and people have different association regarding KM - KM-department - Knowledge organization - It is understood that KM and knowledge systems are important for an efficient project execution	- KM is extensive and people have different association regarding KM - Knowledge organization - It is understood that KM and knowledge systems are important for an efficient project execution - KM is a complex and continuous process
Creation	- Knowledge is created due to customer specification - Occurs both individually and in teams - Depends on the environment - Experience from conducting tasks - Created more tacit than explicit knowledge - Brainstorming tool for knowledge creation	- Knowledge is created due to customer specification - Occurs both individually and in teams - Trial and error - Experience from conducting tasks

Transfer	- The need for structuring knowledge transfer, increases with the size of the organization.
	- Processes synchronized globally
	- Several tools and knowledge systems/channels
	- Specialists transfer knowledge and experience through systems/tools, training etc.
	- Sharing knowledge and helping each other is regarded as part of the culture
	- Formalized better within projects than between them
	- Project team:
	  - Placed in the same physical place making communication flow freely
	  - Share experiences
	  - Continuously transfer knowledge from the departments they belong
	- Experiences shared weekly in project manager forums
	- Lessons learned is transferred between projects
	  - Also used to update products, processes etc.
	- Training:
	  - Combination of tacit and explicit
	  - Often assigned mentor during training
		- The need for structuring knowledge transfer, increases with the size of the organization.
		- Processes synchronized globally
		- Several tools and knowledge systems/channels
		- Lead-engineers' knowledge and experience by improving existing processes, through training etc.
		- Knowledge transfer while drinking coffee regarded as important and a part of the culture
		- Sharing knowledge and helping each other is regarded as part of the culture
		- Norwegians are sent abroad to transfer knowledge
		- More knowledge transfer within departments than between them
		- Lessons learned is transferred between projects
		  - Also used to update products, processes etc.
		- Knowledge is transferred to all projects by the continuous improvement initiative
		- Training:
		  - Combination of tacit and explicit
		  - Mentoring program
		- Transfer of tacit knowledge is important in projects, including the engineering phase

	- Focus on formal training - Transfer of tacit knowledge is important in projects, including the engineering phase - Difficult as you might not be aware of it, or that other people do not have the same knowledge as you - Have reached the saturation point in terms of knowledge transferred through meetings, mail and documentation	
Storage	- Lot of knowledge stored - Well-functioning knowledge systems important for an effective project execution - Knowledge and experience is stored in various knowledge systems/channels and in tools, processes, products, working procedures etc. - Exist better ways to store knowledge - Difficult and costly transforming tacit knowledge to explicit - Lack of focus on reducing non-value adding information – recently increased - Some documents are frequently updated and reviewed, others are not. - The same information may be stored in several knowledge systems	- Lot of knowledge stored - Knowledge systems important for an effective project execution - Knowledge and experience is stored in various knowledge systems/channels and in tools, processes, products, working procedures etc. - Lack of clear guidelines on which knowledge system to use in different situations - Management view the usefulness of storing knowledge in systems and channels in a different way that those who actually (should) use them. - Lack of focus on reducing non-value adding information - Some documents are frequently updated and reviewed, others are not - The same information may be stored in several knowledge systems
Application	- Reusing knowledge is important for an efficient project execution - Varies how often stored knowledge is retrieved and applied - Lessons learned frequently applied - Knowledge is made available through different knowledge systems - Varies how easy it is to search and retrieve information from systems or find the people possessing the knowledge needed - Have search systems for finding people with specific knowledge - Have started to tag documents	- Varies how often stored knowledge is retrieved and applied - Knowledge is made available through different knowledge systems - Varies how easy it is to search and retrieve information from systems or find the people possessing the knowledge needed - Varies how easy it is to apply knowledge found in systems. - Contains too much information.

Appendix 7 – LPD & KM-findings

LPD & KM	Organization 1	Organization 2
Efficiency	**LPD in KM:** - Poor knowledge management can cause inefficiency - Standardizing - Waste reduction - Customer-specific adaptions affect the efficiency	**LPD in KM:** - Poor knowledge management can cause inefficiency - Continuous improvement initiative - Standardization - Waste reduction - Customer-specific adaptions affect the efficiency
	KM in LPD: - Knowledge systems/channels - Reusing knowledge - Use experience rather than procedures - Use knowledge and experience to update product, processes, and utilities to increase efficiency	**KM in LPD:** - Knowledge systems/channels - Reusing knowledge - Use knowledge and experience to update product, processes, and utilities to increase efficiency
Standardization	**LPD in KM:** - Increased focus on standardizing knowledge storage, transfer and application	**LPD in KM:** - Increased focus on standardizing knowledge storage, transfer and application - Continuous improvement initiative
	KM in LPD: - Knowledge and experiences continually baked in to processes, products, working procedures	**KM in LPD:** - Knowledge and experiences continually baked in to processes, products, working procedures
Waste reduction	**LPD in KM:** - Newly started project to reduce non-value-adding information - Document updates	**LPD in KM:** - Continuous improvement - Document updates
	KM in LPD: - Document reviews - Training	**KM in LPD:** - Document reviews - Training

Appendix 8 – NSD Approval

Roland Hellberg
Institutt for industriell økonomi (Kongsberg) Høgskolen i Buskerud og Vestfold
Postboks 235
3603 KONGSBERG

NSD
Harald Hårfagres gate 29
N-5007 Bergen
Norway
Tel: +47 55 58 21 17
Fax: +47 55 58 96 50
nsd@nsd.uib.no
www.nsd.uib.no
Org.nr: 985 321 884

Vår dato: 14.04.2016 Vår ref: 48293 / 3 / STM Deres dato: Deres ref:

TILBAKEMELDING PÅ MELDING OM BEHANDLING AV PERSONOPPLYSNINGER

Vi viser til melding om behandling av personopplysninger, mottatt 13.04.2016. Meldingen gjelder prosjektet:

48293	*Lean og Knowledge Management i komplekse systemer*
Behandlingsansvarlig	*Høgskolen i Sørøst-Norge, ved institusjonens øverste leder*
Daglig ansvarlig	*Roland Hellberg*
Student	*Anja Linnerud Hansen*

Personvernombudet har vurdert prosjektet og finner at behandlingen av personopplysninger er meldepliktig i henhold til personopplysningsloven § 31. Behandlingen tilfredsstiller kravene i personopplysningsloven.

Personvernombudets vurdering forutsetter at prosjektet gjennomføres i tråd med opplysningene gitt i meldeskjemaet, korrespondanse med ombudet, ombudets kommentarer samt personopplysningsloven og helseregisterloven med forskrifter. Behandlingen av personopplysninger kan settes i gang.

Det gjøres oppmerksom på at det skal gis ny melding dersom behandlingen endres i forhold til de opplysninger som ligger til grunn for personvernombudets vurdering. Endringsmeldinger gis via et eget skjema, http://www.nsd.uib.no/personvern/meldeplikt/skjema.html. Det skal også gis melding etter tre år dersom prosjektet fortsatt pågår. Meldinger skal skje skriftlig til ombudet.

Personvernombudet har lagt ut opplysninger om prosjektet i en offentlig database, http://pvo.nsd.no/prosjekt.

Personvernombudet vil ved prosjektets avslutning, 01.05.2016, rette en henvendelse angående status for behandlingen av personopplysninger.

Vennlig hilsen

Kjersti Haugstvedt

Siri Tenden Myklebust

Kontaktperson: Siri Tenden Myklebust tlf: 55 58 22 68
Vedlegg: Prosjektvurdering

Dokumentet er elektronisk produsert og godkjent ved NSDs rutiner for elektronisk godkjenning.

Personvernombudet for forskning

Prosjektvurdering - Kommentar

Prosjektnr: 48293

Prosjektet gjennomføres av studentene Anja Linnerud Hansen og Carina Røren Husmoen.

Utvalget informeres skriftlig og muntlig om prosjektet og samtykker til deltakelse. Informasjonsskrivet er i all hovedsak godt utformet, men vi ber om at veileders kontaktinformasjon påføres informasjonsskrivet før utvalget kontaktes.

I meldeskjemaet er det krysset av for at det skal publiseres personopplysninger i oppgaven. Personvernombudet legger til grunn at dette er feil og har endret dette punktet. Vi gjør oppmerksom på at dersom personopplysninger skal publiseres må det innhentes et eksplisitt samtykke til dette. Det framgår ikke av informasjonsskrivet at personopplysninger skal publiseres.

Dere oppgir i meldeskjemaet og i informasjonsskrivet at data skal innhentes ved personlig intervju, gruppeintervju, observasjon og blogg/sosiale medier/internett. Det går ikke frem av meldeskjemaet hvilke opplysninger som innhentes gjennom andre metoder enn intervju. Vi legger derfor til grunn at det kun er i intervjuene det registreres personopplysninger, og at innhenting av data i de øvrige metodene gjøres anonymt. Hvis det blir aktuelt å samle inn personopplysninger via andre metoder, må utfyllende informasjon sendes til personvernombudet@nsd.no.

Personvernombudet legger til grunn at studentene etterfølger Høgskolen i Sørøst-Norge sine interne rutiner for datasikkerhet. Dersom personopplysninger skal lagres på privat pc/mobile enheter, bør opplysningene krypteres tilstrekkelig.

Forventet prosjektslutt er 01.05.2016. Ifølge prosjektmeldingen skal innsamlede opplysninger da anonymiseres. Anonymisering innebærer å bearbeide datamaterialet slik at ingen enkeltpersoner kan gjenkjennes. Det gjøres ved å:
- slette direkte personopplysninger (som navn/koblingsnøkkel)
- slette/omskrive indirekte personopplysninger (identifiserende sammenstilling av bakgrunnsopplysninger som f.eks. arbeidssted, stilling, alder og kjønn)
- slette digitale lydopptak