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Leaning on Knowledge

Managing Knowledge with Lean Product Development Tools and Methods

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Master of Science Thesis in Quality and Operations Management

Department of Technology Management and Economics
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CHALMERS UNIVERSITY OF TECHNOLOGY
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Abstract

Increased globalization and competitiveness puts higher demands on companies to manage and create knowledge in the company. More specifically is Product Development an area where knowledge handling is of great importance due to e.g. increasing demands on shorter development cycles and the large costs of unplanned loop-backs. The purpose of this master thesis was to investigate tools and methods in the Lean Product Development concept to manage knowledge. The purpose was fulfilled by answering the following research questions:

- *What role does Knowledge Management have in Lean PD?*
- *What tools and methods from Lean PD are companies using to manage knowledge?*
- *What are the benefits of the tools and methods?*

This was carried out with a literature study, a broad survey to 47 Swedish based industry companies, case studies at Swedish Lean PD companies and interviews with Swedish Lean PD experts in the area.

In literature, KM has a large role in Lean PD and is described as the core of a successful Lean PD initiative. Furthermore, to manage knowledge is a significant part of Lean PD tools and methods. Of the more Lean PD specific tools and methods, the most commonly used, are according to the survey; Checksheets (59%), Set-based design (56%), Obeya (53%) and A3s (47%). The tool that is used significantly less frequent is Trade-off curves that only one of the companies have implemented fully. It is important to clarify that coherency was found between literature, survey, case study companies and experts that tools and methods are only one part of Lean PD and that a culture needs to be in place to support the Lean PD effort to succeed. It is found that the benefits gained from using Lean PD tools and methods are completely dependent on how the company is using them.

The tools and methods are according this research helping to manage knowledge but to a much smaller extent than were found in the literature, probably due to how they are used in companies. Moreover, companies need to select and adapt the tools and methods to suit their organization. If this is successful, and the tools and methods are used at its' fully potential, a better knowledge sharing and knowledge creating organization will occur. However the largest separate benefits found at the survey companies from using A3s, Set-based design and Checksheets are better basis for decision making. Finally it can be argued that the facilitation of making decisions is due to increased knowledge and knowledge sharing.

Keywords: Lean Product Development, LPD, Knowledge Management, Organizational learning, Checksheets, A3, Set-based design.

Sammanfattning

Ökad globalisering och konkurrens ställer högre krav på företag att skapa och hantera kunskap. Mer specifikt är produktutveckling ett område där kunskapshantering är av stor vikt på grund av hårdare krav på kortare produktutvecklingscykler och höga kostnader för oförutsedda loop-backs. Syftet med uppsatsen var att undersöka verktyg och metoder i managementkonceptet Lean produktutveckling för att hantera kunskap (Knowledge Management). Syftet var uppfyllt genom att besvara följande frågor:

- *Vilken roll har Knowledge Management i Lean produktutveckling?*
- *Vilka verktyg och metoder från Lean produktutveckling använder företag för att hantera kunskap?*
- *Vilka är fördelarna med verktygen och metoderna?*

Basen i studien var en litteraturstudie, en enkät till 47 svenska industriföretag, intervjuer och studiebesök på svenska företag som arbetar med Lean produktutveckling samt intervjuer med experter inom området.

Inom litteraturen har kunskap en stor roll och beskrivs som kärnan för en lyckad Lean produktutveckling. Vidare är kunskapshantering en viktig del av de verktyg och metoder som finns inom Lean produktutveckling. Av de verktyg och metoder som är specifika för Lean produktutveckling är de mest använda enligt enkäten: Checksheets (59%), Set-based design (56%), Obeya (53%) och A3s (47%). Det verktyg som används mest sällan hos företag är Trade-off kurvor som endast ett företag i studien har implementerat fullt ut. Det är viktigt att påpeka att konsenus till stor del råder mellan litteratur, besökta företag, enkät och experterna att verktyg och metoder endast är en del av Lean produktutveckling och att kulturen har en viktig uppgift att stötta ett Lean produktutvecklingsinitiativ. Fördelar från att arbeta med verktyg och metoder inom Lean produktutveckling beror till största del på hur företagen använder dem.

Resultatet visar att verktygen och metoderna underlättar kunskapshantering men till en mindre grad än vad som beskrivs i litteraturen, antagligen på grund av hur de används i företagen. Vidare behöver företagen välja och anpassa verktygen och metoderna för att passa organisationen. Om detta är gjort framgångsrikt, och verktygen och metoderna är använda på rätt sätt kommer bättre kunskapshantering och skapande av kunskap ske. Den största separata fördelen från att använda antingen A3, Checksheets och Set-based design är, enligt resultatet från enkäten, bättre beslutsunderlag. Slutligen är det värt att notera att bättre beslutsunderlag beror på ökad kunskap och ökad kunskapsdelning.

Keywords: Lean produktutveckling, kunskap, organisatoriskt lärande, Checksheets, A3, Set-based design.

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Hennie Jensen & Linnea van Lokhorst

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1 Introduction

The following chapter will give an introduction to the studied area. Furthermore, the purpose and research questions will be presented and finally limitations to the research.

1.1 Background

In a rapidly changing environment and competitive markets, product cycles are becoming increasingly shorter (Chesbrough, 2007; Wheelwright & Clark, 1992), and hence companies need to develop products faster and more effectively to stay competitive. Therefore, managing knowledge is an increasingly important factor for companies on existing markets. Lean Product Development (Lean PD) is originally developed at Toyota and its core is to focus on knowledge (Morgan & Liker, 2006).

Many authors describe Knowledge Management (KM) as an area worth paying attention to. Nonaka (2007) describes that due to uncertainty and changing environments, managing knowledge is the one definite source of lasting competitive advantage. In line with Nonaka (2007), both Dalkir (2011) and Lucas (2005) describe knowledge as an increasingly important factor to stay competitive. The area of KM is wide and contains many different subareas. Managing knowledge may include creating, sharing and applying knowledge (Dalkir, 2011), and could also include terms such as retaining (Morgan & Liker, 2006), transferring and capturing knowledge (Nonaka, 2007). However, we argue that all are important for companies and often are very connected. Hence, in this thesis, the word managing knowledge will be used to represent all these expressions.

Toyota Production System, also referred to as Lean Production, has been investigated and implemented to a large extent, though Lean PD has not been studied at the same extent (Martinez León & Farris, 2011). Lean PD is described as the next area to be developed with huge opportunities for competitive advantage (Morgan & Liker, 2006).

Companies tend to focus on short-term profits by putting efforts on bringing products fast to the market and thereby neglecting the organizational learning (Swan & Furuhjelm, 2010). Hence, there is an opportunity to deeper investigate the combination of KM and Lean PD and specifically to study tools and methods which will facilitate companies to bring products fast to the market, meanwhile focusing on KM.

1.2 Company background

Triathlon is a management consultancy firm mainly working within technology intensive industries with large to medium size companies. Triathlon offer its

clients consultancy services in four areas of practice; Product & Innovation, Sales & Aftermarket, Supply Chain and Finance & IT, which all includes strategy, operations and finance. This master thesis is in the area of Product & Innovation.

Triathlon is experiencing an increasing demand from companies for Lean PD and KM. Moreover, Triathlon considers the development of an understanding on the subject of Lean PD and KM through this master thesis as valuable in order to develop sustainable value for clients. More specifically Triathlon wants to investigate how companies, clients and potential clients are working with these arising subjects.

1.3 Purpose

The purpose of this thesis is to investigate tools and methods of Knowledge Management in Lean Product Development.

The investigation will consist of outlining how tools and methods are described in literature and which of them that are most frequently used in companies. The investigation will further consist of a description of the experienced benefits from the tools and methods.

1.3.1 Problem Analysis and Research Questions

The area of Lean PD is highly associated with how to manage knowledge within and between projects (Kennedy, Harmon, & Minnock, 2008; Morgan & Liker, 2006). To gain knowledge about the tools and methods and about KM, it is important to create an understanding of how KM is used in Lean PD. Kennedy et al. (2008) describe knowledge as an essential part of Lean PD. The first question aims to outline these two areas and how they are related and connected theoretically. The studied area is illustrated in Figure 1.

1. What role does Knowledge Management have in Lean Product Development?

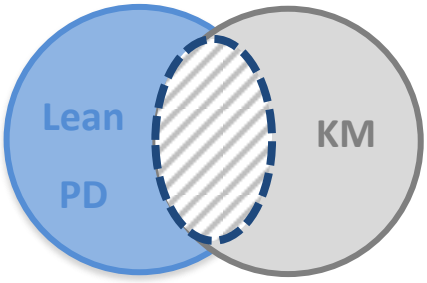

Figure 1. Illustrated are the studied area and the link between Lean PD and KM.

The focus of the question above is organizations and which tools and methods that are used in companies. The relationship will be described by analyzing the

area of KM and Lean PD, both separately and together. Furthermore, the importance and necessity of KM in Lean PD and will be described.

One part in transferring knowledge effectively and efficiently is the use of tools and methods. Many different tools exist in Lean literature that support managing knowledge such as A3s (for documentation and communication) (Sobek & Smalley, 2008), LAMDA (a learning cycle) and Trade-off curves (that generalize knowledge for reuse) (Kennedy et al., 2008). The aim of the next question is to investigate tools and methods presented in literature, but primarily to outline which tools and methods that are implemented and used in large and medium sized Swedish industry companies.

2a. What tools and methods from Lean Product Development are companies using to manage knowledge?

Highly related to the question above are the benefits of the researched tools and methods. Knowledge regarding benefits of tools and methods can enhance the process of deciding appropriate tools for a company. Hence, benefits of each tool and method both according to literature and according to companies that use them are of interest to this research. This will in turn create a better result from the chosen tools and methods. The last research question is hence:

2b. What are the benefits of the tools and methods?

1.4 Delimitations

The purpose is not to give a complete description of neither Lean PD nor KM, but to provide the reader a necessary background for this thesis. Both KM and Lean PD are broad areas that include many subareas. In this thesis, mainly information about the connection of these areas will be presented. Furthermore, all tools and methods in Lean PD and KM cannot be covered and therefore this thesis is limited to those that are relevant for both Lean PD and KM.

Even though the survey is conducted on a large sample of companies, findings from the study cannot be claimed to be valid outside the studied population. Finally, the project is limited to 20 weeks, and the limited amount of time will affect numbers of interviews and the extent of the literature study.

2 Methodology

The following section will present the method and research approach that has been used throughout the study. This will hence provide the opportunity to replicate the research and thus increase the reliability.

2.1 Research design

In order to answer the proposed research questions of this master thesis, both qualitative- and quantitative methods have been used in order to provide a wide data collection but also to gain a deeper understanding of the study. An on-going literature study was conducted during the project. Further, triangulation was used throughout the research by conducting expert interviews, a survey as well as case study interviews as sources for data and analysis. Triangulation will with a higher confidence secure the credibility of the study. Aspects that were taken under consideration in the planning and decision of which method to choose were e.g. trustworthiness and ethical standpoints. It was furthermore stressed that the method chosen should be as objective as possible in order to secure the validity of the result. (Bryman & Bell, 2011)

2.2 Decision of Research Area

After an initial contact with Triathlon, we had the possibility to quite freely decide upon a suitable subject for the thesis. A discussion was further held with supervisors at Chalmers to establish that the chosen area was appropriate with regard to existing literature and previous research. The bases for narrowing down the scope and to decide research questions were discussions with supervisors at Chalmers and Triathlon together with an initial literature review. The goal was to find a subject that were of interest to all stakeholders i.e. Chalmers, Triathlon, industry companies and for our self.

In the early literature review it was encountered that several researches e.g. Kennedy et al. (2008) and Morgan & Liker (2006) are presenting concepts of KM as an important part of Lean PD. However, there are different views on KM and Lean PD and also the link between them. This was a challenge for the project, but it also implied that there was a need for more research on the subject.

2.3 Literature Review

An on-going literature study was carried out continuously in the subject of KM in Lean PD, with a focus on tools and methods. The literature study and search for literature were predominantly done on work by Kennedy et al., Morgan and Liker and other recommended work from supervisors at Chalmers and Triathlon. Then, the "snowball effect" was used on references to find more literature in the area. Consultants at Triathlon who had collected and structured

relevant articles in the area also gave advices on literature that were included in the study. Additionally, articles and recommendations for further reading in the area were also provided by supervisor at Chalmers and during the expert interviews. Finally, the theory also provided a foundation for the development of relevant hypotheses for the research findings and as a base for the interviews and survey.

2.4 Case Study Interviews

Company visits and interviews were used as a qualitative compliment to the survey and to gain a deeper understanding of how the companies are working with Lean PD and KM. This qualitative part of the study gave important insights of how the tools and methods are used and integrated in the daily work. Interviews were held at four companies who have implemented and are working with Lean PD and KM tools relatively extensively.

Interviews were carried out using a semi-structured approach, which promoted standardization of both asking and recording answers but with the flexibility to ask follow up questions (Lantz, 2007). The interviews were well planned in advanced to save time. Guidelines and aids, such as in which order questions should be put, according to Bryman & Bell (2011), were taken into account and were used to plan and conduct the interviews. The main ways to find interview objects were by recommendations by supervisor at Chalmers but also through the supervisor at Triathlon and by personal contact made at CHARM (Chalmers career fair). Kongsberg Automotive, Atlet, Autoliv and Scania were chosen due to their experiences of using Lean PD and KM tools and methods. Two interviews were held prior to the survey which also gave the opportunity to gain important input to the survey. From the interviews conducted after the survey, input for analyzing the survey was collected.

The generation of questions was mostly based on literature study findings and expert interviews but was also altered according to findings in the survey. Furthermore, a brainstorming session was conducted to ease a creation of framework for the interviews. Interviews were documented with a sound recorder and notes were taken during the interviews. The types of notes taken were “jotted notes” which are very brief notes to facilitate the interviewers’ memory afterwards (Bryman & Bell, 2011). The notes together with the recording provided a possibility to go back to the sources of the findings afterwards.

Triangulation was used during the interviews by having two interviewers, and two analyzers of the data and possible documentation provided from companies. Additionally, objectivism from interviewers was stressed by analyzing and comparing findings from the interviews with each other (Bryman & Bell, 2011).

Finally, the findings were crosschecked and compared to the findings in the literature study, expert interviews and findings from the survey.

2.5 Survey

To collect data for the quantitative part of the project, it was necessary to sample (Bryman & Bell, 2011). A web-based survey was conducted on 47 Swedish based industry companies. 65 companies were approached and the respondent rate was 71%. The size of the sample was limited by time and the amount of interested companies. A survey was found as an appropriate method due to the possibility to reach many companies and since the area of interest entailed the possibility to ask questions suitable for a survey. Furthermore, the survey gave us a possibility to measure fine differences among the companies (Bryman & Bell, 2011). The advantages of a self-completion questionnaire compared with a structured interview are e.g. the cheaper and quicker administration and absence of interviewer effects (Bryman & Bell, 2011). The disadvantages such as the inability to probe and prompt (Bryman & Bell, 2011) were of minor concern due to that qualitative methods are used as well. The aim of the survey was to gain a wide understanding of what tools companies are using, how far they have reached in their Lean PD efforts and what benefits they have experienced.

In order to reduce the administration and amount of data, a list of approximately 50 large Swedish industry companies, provided by Triathlon of their customer segment, was used as a convenient research sample. Additionally, large companies with PD in Sweden and registered on Nasdaq OMX Stockholm were added to enlarge the sample. A convenient sample is often used in business and management research and could in these cases be more beneficial than probability sampling due to easier access to respondents and lower costs. (Bryman & Bell, 2011). In one case, more than one employee from the same company answered the survey. These answers were however regarded separately since it concerned different business units within the company group.

2.5.1 Distribution of Survey

The companies were approached by phone in order to establish a first contact. If interested, the respondents had the possibility to choose between answering the survey on the phone or online. By giving the respondents the possibility to answer the questionnaire by phone and establish a first contact by phone, the drawback of low response rate with web-based questionnaires (Bryman & Bell, 2011; Czaja & Blair, 2005) was decreased. The benefits with web-based questionnaires are that it is easily distributed, possible to use visual aids and that it gives the respondent the possibility to look up information in records (Bryman & Bell, 2011; Czaja & Blair, 2005). Furthermore, advantages with web-based questionnaires compared with post are higher response rate, faster response speed and cheaper administration (Bryman & Bell, 2011). Ethical standpoints

were taken, such as providing the information that the thesis was done at Triathlon and giving the respondents an honest opportunity to decline answering the survey. The aim was to have respondents that are development managers or equal in PD.

2.5.2 Generation of Survey Questions

Generally, the generation of questions was made from findings in the literature study and during the expert interviews. For narrowing down the amount of questions, a continuously focus were a coherence between survey questions and the research questions.

The survey (see Appendix A) consisted of three parts in order to make a logical flow for the respondent. The first part included questions about settings of the respondent company such as size of PD department and types of products. Furthermore it included questions about the work at the PD department such as to which extent knowledge is shared between projects. The questions in the first part were included in order to be able to segment the responded companies and facilitating the analysis. The questions of the first part of the survey were generated at a brainstorming session together with discussions with supervisor at Triathlon. The second part included questions regarding if, and to which extent the tools and methods are used. Which tools and methods to include in this part were based on frequency in literature together with discussions during the expert and company interviews. The third and last part of the survey was exclusively for companies that either sporadically or fully is using either of the four selected tools and methods. The selection was done according to literature and interviews findings of most frequently used tools and methods. The questions concerned how the tools are used and which benefits companies are experiencing. Questions about experienced benefits were generated mostly with help of findings from literature but were also deducted from discussions with supervisors and during the expert interviews.

An important aspect of the survey was to consider how to measure the result of the survey and also to identify other factors that may affect the result. When the questions were constructed emphasis was put on a clear presentation of the questions (Bryman & Bell, 2011) and to ask appropriate questions to achieve the research objectives (Czaja & Blair, 2005). Moreover, one aspect when designing the survey was to sharpen the questions to make them clear and to secure a useful result to the research.

2.5.3 Improving the Survey

The survey layout and the questions were tested with help of our supervisor at Chalmers as well as by consultants and our supervisor at Triathlon. Also, to get a better general understanding of how to construct a survey, and to improve

ours, a meeting was also held with Assistant Professor Oskar Rexfelt, Chalmers University of Technology, who teaches about research methods. Rexfelt was recommended by lecturers at Chalmers for improving our survey. Furthermore, pilot studies on the survey were done during the interviews at Autoliv and Scania to secure that the questions were logical and understandable, and hence secure the result of the survey. Further, after receiving approximately 10 answers a minor web-format related error was detected and corrected.

2.6 Other Sources of Information

As a compliment to the described methods above, opportunities for additionally sources of information that occurred during the project are described below.

2.6.1 Senior Industry Advisers

In order to get input from persons with great industrial experience, a 2-hour long meeting with Senior Industry Advisors and consultants at Triathlon was held. The research objectives of the master thesis were discussed and analyzed. This gave input to the subject of Lean PD and KM, and where the scope of this master thesis should be. Explicitly, input regarding *how* companies are working with the tools and methods was given as an important area to study. This area was hence included in the survey.

2.6.2 Expert Interviews

Two interviews each were held with two experts on the area of Lean PD and KM who are currently educating and have a thorough background in the area. The two experts; Håkan Swan and Stefan Bükk, were recommended by Triathlon and supervisor at Chalmers respectively. Interviews were carried out using a semi-structured approach, using an interview guide but with the flexibility to ask follow up questions and where the interviewee also had the possibility to talk freely on the topics (Bryman & Bell, 2011; Lantz, 2007). The interviews held could be seen as a light version of the Delphi-method, which is when a panel of experts is used as sources of information (Linestone & Turoff, 2002). The interviews gave important insight of how companies are working with Lean PD and especially which tools and methods that is commonly used in companies, and were hence an important basis for the survey. Two interviews were held in the beginning of the project and the last two interviews were held during the analysis phase and gave thereby important opportunities for discussing the result of the survey.

2.6.3 Lean PD Course

By Stefan Bükk we got the opportunity to participate in a 3-days long Lean PD education. Participating in the course were PD managers and project leaders.

The education concerned areas such as A3, visual planning and implementation of Lean PD. Included in the course was also a company visit at RUAG.

2.7 **Analyzing the Data**

The method used for analyzing the data could be described to be systematic combining which base lies within the abductive approach. The process is non-linear and gives an opportunity to go back and forth between the different activities with the goal to match theory and reality, see Figure 2. (Dubois & Gadde, 2002)

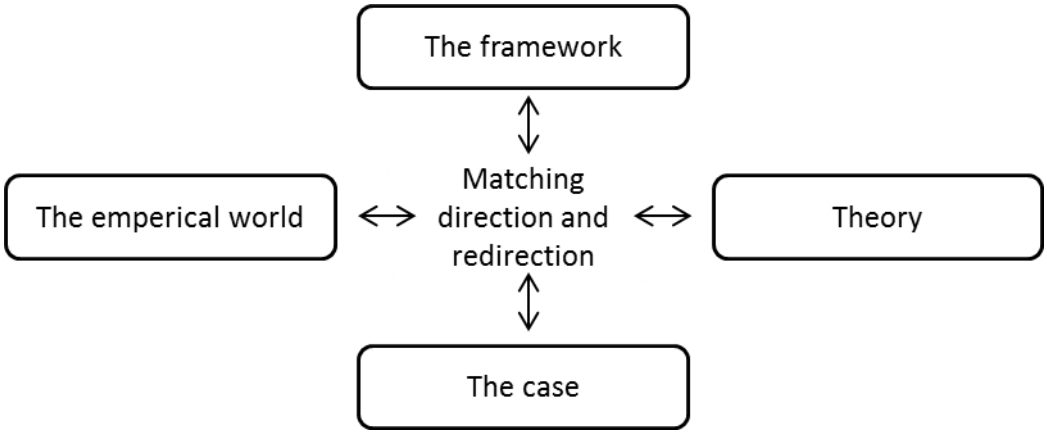

Figure 2. Systematic combining. (Dubois & Gadde, 2002)

The practical approach was to first do an initial analyze on a high level, which was carried out through the summery of the answers, provided by the web survey system. Next, interesting data were visualized using tables and graphs in Excel. To make sure no interesting results were ignored, a brainstorming session was held with consultants at Triathlon. Overall during the analysis, an emphasis was to work with hypothesis and check if the hypothesis were right or wrong.

3 Theoretical framework

The theoretical framework will start with a presentation of KM and Lean PD and the section will end with a description of used tools and methods to facilitate KM in Lean PD. The following theoretical sections will provide a basis to support the research and analysis in this master's thesis.

3.1 Knowledge Management

KM focuses on the creation and distribution of knowledge in organizations through technical solutions e.g. databases, but also through social relations and interaction (Alvesson & Kärreman, 2001). The area of managing knowledge has been around for hundreds of years. However, the concept and consciousness practice of KM have gained more attention in organizations over the last decades (Alvesson & Kärreman, 2001; Hansen, Nohria, & Tierney, 1999). The numbers of disciplines within the area of KM are many and include e.g. database technologies, document and information management, technical writing and cognitive science. Due to this diversity, there exist challenges regarding the boundaries (Dalkir, 2011). Focus in this thesis has not been to deal with these challenges, neither to describe these disciplines. The goal is rather to gain knowledge in the area of KM to facilitate the understanding of KM in Lean PD.

KM is strongly related to the term knowledge. Hence, this chapter will start with a description of knowledge. As stated, KM include many subareas. Creating and transfering knowledge is of great importance for companies and are therefore further introduced in more detail in the next section. KM comes close to organizational learning (Mehra & Dhawan, 2003) and organizational culture (Alvesson & Kärreman, 2001) and hence, lastly, these areas are presented.

3.1.1 What is knowledge?

Bollinger & Smith (2001) defines knowledge as the understanding and awareness, acquired through study, investigation, observation, or experience over the course of time. They further suggest that knowledge is an individual's interpretation of information based on personal experiences, skills, and competencies. Both data and information are expressions strongly related to, but not interchangeable to the word knowledge (Davenport & Prusak, 2000). The authors describe data as objective facts about events and the importance of data is the use of it as the raw material for information. Information is described as a message with a sender and a receiver, which moves around an organization by hard and soft networks. A hard network is described to be visible and has a clear infrastructure. On the other hand, a soft network is described as less formal such as if someone gives you a small paper note with information. A common view is that by e.g. experience, people may transform information into knowledge. Knowledge is consequently derived from information, which in turn is derived

from data, see Figure 3 (Davenport & Prusak, 2000). However, Tuomi (1999) argues that the hierarchy could be the reverse, where information is created from knowledge and by adding value to the information data is created.

Figure 3. Knowledge is built on information that in turn is based on data (Davenport & Prusak, 2000).

Knowledge is often divided into tacit and explicit, where tacit is described as "hard-to-pin-down skills" which often are hard to articulate (Nonaka, 2007). Dyer and Nobeoka (1998) in Morgan & Liker (2006) suggest that tacit knowledge is difficult to learn but that it holds most competitive potential for companies. A common description of tacit knowledge is to know how the perfect dough feels when baking (Nonaka, 2007) or how to ride a bike (Nonaka, 1994). Even if you perfectly know how to ride a bike, it is hard or almost impossible to explain how to ride a bike for another person so that this person can ride the bike. Explicit knowledge is described as formal, which easily can be communicated and shared (Nonaka, 2007), such as simple software code (Hansen, Nohria, & Tierney, 1999).

3.1.2 Individual and Organizational Learning

One way to defining learning is to divide it into two purposes. The first purpose is to gain know-how to be able to do physical actions. The second purpose is know-why which means being able to articulate an experience. The field of learning can be approached from different angels such as psychodynamic theory, cognitive development processes and Gestalt theory. Although is the area of learning and the human mind not clearly understood. The process of learning for individuals can be visualized with different models. One of the models is the experimental learning model. When learning occurs, the individual cycles through experiences, reflections regarding these experiences, forming generalizations from the experiences and finally testing these generalizations, and a new experience thereby occurs. The PDCA-cycle is described to be a different setting of the experimental learning model. (Strakey, Tempest, & McKinley, 2004)

However, handling knowledge and the creation of knowledge is strongly related to organizational learning (Mehra & Dhawan, 2003) and organizational learning exists in all organizations, deliberately of not. It is therefore wise to construct these processes so they will be as efficient as possible (Mehra & Dhawan, 2003).

The concept of organizational learning and learning organizations became popular during the 1990s (Loh, 1997), there is however not an agreement of the

meaning of the concept. One interpretation of the concept is "..a place where people continually expand their capacity to create results… and where people are continually learning how to learn together" (Loh, 1997, p. 14). Organizations are furthermore seen as learning when experiences from the past are embedded into routines that will guide the individuals' behavior (Loh, 1997).

From Individual to Organizational Learning

There is a difference between organizational and individual learning (Fiol & Lyles, 1985). Organizational learning is not the cumulative result of individuals learning, but individual learning is an important part of the organizational learning and could be viewed as the building block of organizational learning (Mehra & Dhawan, 2003). Over time individuals develop personalities and personal habits but organizations develop worldviews and ideologies (Fiol & Lyles, 1985). With help of specialization individuals learn about knowledge structures, which the organization thereafter learns by adapting to the individuals' understanding and interpretations (Mehra & Dhawan, 2003). Crossan and Inkpen (1992) in Mehra & Dhawan (2003) claim that there are three ways to transform individual learning to organizational learning: personal facilitation (a leader facilitates to create a shared understanding), shared facilitation (individuals develop a common understanding by extensive discussions) and artificial facilitation (the structure of the organization e.g. regular meetings and rotation of managers is the integrating mechanism).

Von Zedwitz (2002) has a slightly different view, and reasons that there are three levels of learning; individual, team/group learning and organizational learning. Team/group learning has the role of distributing, processing and interpreting individual learning and experience to the organization. The team/group learning is hence viewed as a step towards organizational learning (von Zedwitz, 2002).

Double and Single Loop Learning

Argyris (1977) has a different view on organizational learning and states that it occurs when errors are detected and corrected. When an organization detects and corrects an error this is according to the author called single-loop learning. On the contradictory, when learning involves questioning and evaluating the organization's goals and strategies, double-loop learning occur (Argyris, 1977). In line with the reasoning above, Fiol & Lyles (1985) distinguish between lower- and higher-level learning. Lower-level learning is described as short term, which is repetition of past behavior. The higher-level learning develops complex rules and is non-routine and will develop a new culture (Fiol & Lyles, 1985).

3.1.3 Knowledge Creation and Knowledge Transfer

For a company to sustain competitive, knowledge creation and knowledge transfer is becoming increasingly important (Argote, Ingram, Levine, & Moreland, 2000). In an organization, knowledge transfer occurs when one unit, such as an individual or department is affected by another unit's experience (Argote et al., 2000). Transfer of knowledge within an organization can only occur if employees are willing to share what they already know and if other employees know that the knowledge exists. Furthermore, knowledge can only be transferred if employees have the trust and willingness to use the existing knowledge. Access to information does not guarantee its use. (Lucas, 2005) Knowledge creation on the other hand describes the process of how new knowledge emerge (Nonaka, 2007).

SECI-model

With help of the distinction between tacit and explicit knowledge, Nonaka & Takeuchi (1995) describes four possible ways to transfer knowledge within an organization, known as the SECI-model (Socialization, Externalization, Combination and Internalization), see Figure 4. Socialization is described as the process of sharing experiences and thereby transferring tacit knowledge from one person to another. Externalization is described as articulating tacit knowledge into explicit. Furthermore is combination the process when knowledge is transferred explicit to explicit, which is done by systematizing concepts into a knowledge system. Internalization is when explicit knowledge is embodied to tacit knowledge. (Nonaka & Takeuchi, 1995)

New knowledge always starts at an individual level and then spreads to an organizational level. The creation of knowledge in an organization is described as a "continuous dynamic interaction between tacit and explicit knowledge" (Nonaka & Takeuchi, 1995, p.70). The creation is also described as shifts between the different modes i.e. Socialization, Externalization, Combination and Internalization. A spiral, often starting with Socialization, describes the creation of knowledge in the organization, see Figure 4. Socialization is in turn triggering Externalization and so forth creates knowledge. (Nonaka & Takeuchi, 1995)

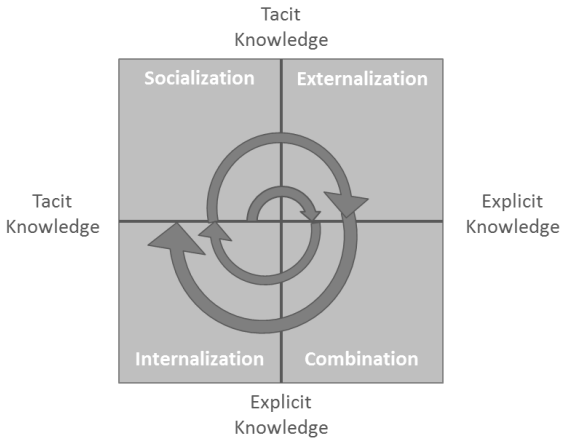

Figure 4. The spiral of knowledge creation within an organization (SECI-model) (Nonaka & Takeuchi, 1995).

This view of knowledge creation can be exemplified with a product developer that will develop a bakery machine. The transfer from tacit to tacit knowledge is done when the developer learns the secrets to the perfect dough by observing an expert baker, imitating him and by practicing (Socialization). The developer then transfer this knowledge into explicit by communicating what he learned with his PD team (Externalization). Next, this explicit knowledge is transferred into new explicit knowledge when a team member writes it down in a report (Combination). The last step occurs when the team members enrich their explicit knowledge with new tacit knowledge by the R&D process of the bakery machine (Internalization). The spiral starts thereafter all over again, but this time at a higher level; the knowledge base in the organization has grown. (Nonaka, 2007) The example moreover visualizes how knowledge moves from an individual to an organizational level.

Nonaka, Toyama & Konno (2000) describes that in order to create knowledge with the SECI-model, the model must be supported by what is called knowledge assets and *Ba*. Ba is described as the context or place where knowledge is shared, created and utilized. However, Ba doesn't have to be a physical place but a common time and space e.g. e-mail or mental space. Moreover, he authors stress the importance of commitment and interacting in the Ba. As compared with the four types of knowledge sharing presented in the SECI-model, four types of Ba exists, see Figure 5. Originating Ba is described as a place for face-to-face interactions which is manly applicable for Socialization. Dialoguing Ba is where collective face-to-face interactions take place, where the key for success is to select individuals with the right mix of knowledge to facilitate Externalization. Systemizing Ba is furthermore described by collective and virtual interactions such as mailing lists for sharing knowledge explicit to explicit. Exercising Ba is when individuals and interactions are working together to create a context for internationalization. (Nonaka, Toyama, & Noboru, 2000; Nonaka & Toyama, 2005)

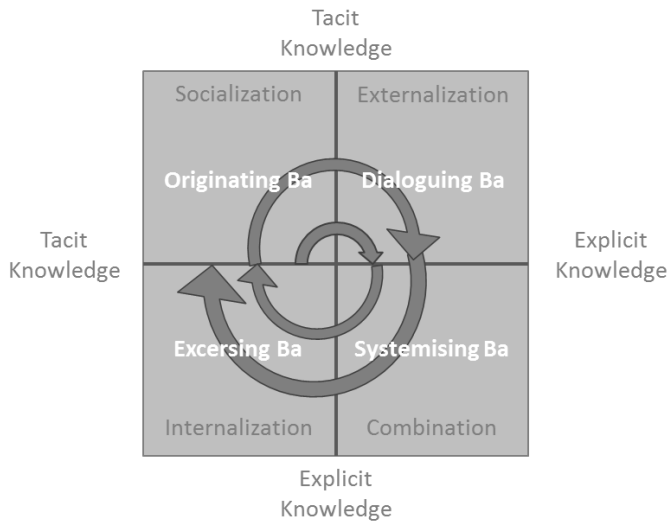

Figure 5. The concept of Ba (Nonaka et al., 2000)

In the literature review some critique to the SECI-model was encountered. Gourlay (2006) argued that the SECI-model is supported by evidence that have alternative explanations and that the evidence could be explained more simple, e.g. could internalization be explained by ambiguous notions. Further, he suggests that different kinds of knowledge are created by different kinds of behavior. Also, Cook & Brown (1999) argue that it is not possible for explicit knowledge to become tacit, or vice versa. Together with others e.g. Polanyi (2002), he criticizes the whole concept of transferring tacit knowledge, due to its nature of being tacit. Finally, Snowden (2002) points out that the SECI-model has certain limitations. The criticism regards that the model views knowledge as only a thing. To overcome this limitation a model called Cynefin which views knowledge as both a thing and a flow is presented that includes four spaces; *known*, *knowable*, *complex* and *chaotic.* The core of the model is that we are strongly influenced by past experiences (Snowden, 2002). However, according to e.g. Gourlay (2006) and Dalkir (2011), Nonaka & Takeuchis' SECI-model is highly respected and influential model in the KM literature and is therefore used in this master thesis.

Other Knowledge Transfer Approaches

One recognised theory on knowledge transfer in organizations is presented in Hansen, Nohria, & Tierney (1999), known as the Codification and the Personalization approach. Codification is when knowledge is codified and stored in databases. As a result, the information is easy accessible for others and possible to use concurrently by different persons. Furthermore, this approach makes it possible to access the knowledge without physically meet a person, or know who that has given the input to the information. The Personalization strategy is, as the name implies, when knowledge is closely linked to persons. Knowledge is transferred person-to-person and the main use of computers is not

to store knowledge but to help people communicate knowledge. Companies that follow the Codification approach are relying on "economics of reuse"; once a knowledge asset is established, it can be used many times with a very low cost. On the contradictory, the Personalization approach is relying on "expert economics", since it is involving deeper tacit knowledge. (Hansen, Nohria, & Tierney, 1999)

According to Hansen, Nohria, & Tierney (1999) an organization should choose one of the two approaches, either Codification or Personalization, and use this to 80% to successfully transfer knowledge. The other approach should be used to support the primary approach. Finally, the authors emphasize the importance for a company to choose a strategy that is in line with the company's overall strategy. To facilitate the decision of which approach to choose, questions to consider are e.g.; *Is the company offering standardized or customized products?, Is it mature and innovative products?* and *Do people in the company rely on tacit or explicit knowledge to solve problems?*. (Hansen, Nohria, & Tierney, 1999)

3.1.4 **Knowledge Management Culture**

According to Popper & Lipshitz (1998) effective organizational learning is contingent on establishing a culture that promotes inquiry, openness and trust. An organization´s underlying values, beliefs, mental models, and unspoken rules, are its culture (Dalkir, 2011). Bollinger & Smith (2001), states that organizational culture is critical to promote learning and development, and the sharing of skills and knowledge. Therefore to succeed, KM efforts almost always require a culture change from "knowledge is power" to "sharing knowledge in more powerful" (Dalkir, 2011). Furthermore, Dalkir (2011) also stresses that organizational culture is a key component of ensuring that critical knowledge and information flow in an organization and that it needs to reward both vertical and horizontal knowledge flow. Similarly, Bollinger & Smith (2001) conclude that organizational culture plays a primary role in effecting employee's willingness to work together and share their knowledge. Correspondingly, a knowledge culture is one where sharing is the norm and where it is encouraged to collaborate and share. Hence, leadership in the knowledge creating firm should be based on a more flexible distributed leadership, rather than a control mechanism (Nonaka & Toyama, 2005). Likewise, management needs to ensure a supportive culture that will encourage and facilitate the sharing of tacit knowledge (Bollinger & Smith, 2001). Moreover, Dalkir (2011) also points out the importance of absorptive capacity in an organization, referred to the individual or organizational openness to change and innovation capability to integrate it, as critical to succeed with KM efforts.

3.2 **Lean Product Development**

Lean PD is of great interest by companies today, and could be discussed if it should be seen as a management fashion or not (Abrahamsson, 1996). However, Lean PD originates from Toyota and is hence related to Lean Production. One of the cornerstones in Lean Production is waste and how to reduce waste. Waste is described as a non-value adding activity, which is an activity that not contributes with any value for the customer. In other words Lean could be described as always having a customer focus. (Liker, 2004)

When comparing Lean Production and Lean PD it is noticed that in production, loopbacks are negative and related with waste but in PD, loopbacks could rather be related with gaining important knowledge. It is hence not obvious that the principles from Lean production can be translated to Lean PD (Radeka, 2008 in Holmdahl, 2010). Morgan & Liker (2006) compare Lean Production and Lean PD. They state that in Lean Production, pull production eliminates overproduction by using signals of demand from downstream activities to upstream activities, to produce value for the end-customer. However in Lean PD, knowledge and information are pulled through the PD system to get the right information to the right engineer at the right time. Additionally, PD is seen as a creative process characterized by uncertainty and large variations and where many activities carried out are not possible to evaluate strictly from an end-customer perspective (Swan & Furuhjelm, 2010).

Benefits from using Lean PD are e.g. found in Oosterwal, 2010, who describes Harley Davidsson's Lean PD efforts. After implementing Lean in their PD, the development time was reduced by half, and the PD throughput increased with four times. Furthermore the author describes the traditional number of new products as 0.74 models/year, compared with 4.6 models/year after the implementation of Lean PD. Shorter development time are also descibed by Morgan & Liker (2006) and Kennedy et al. (2008).

Martinez León & Farris (2011) argue based on a litterature review, in the area of Lean PD that seven different perspectives can be taken towards the subject. The perspectives are Performance Based, Decision Based, Process-Modeling, Strategy, Supplier/Partnership, Knowledge-Based Networks and the Lean Manufacturing Domain. In the area of Knowledge-Based Networks, the authors summarize that the existing research with this perspective emphasize the importance of organizational learning for achieving competitive advantage. Furthermore, organizational learning is described as the primary goal for Lean PD. (Martinez León & Farris, 2011)

3.2.1 A Knowledge View on Lean Product Development

Even though Lean Production and Lean PD have similarities it should not be mistaken for the same. Lean PD is also called "Learning–first product development" by Kennedy et al. (2008) who stress the importance of knowledge in Lean PD. Toyota focus on the two value streams of PD; the product value stream and the knowledge value stream, see Figure 6 (Kennedy et al., 2008). They refer to the product value stream as the flow of tasks, people and equipment for the product desired by the customer through the Set-Based phase, Product Design phase, Prove Out phase and the Launch Phase. The set-based phase focuses on using all existing knowledge to narrow down targets. The product value stream is specific for each project. In the Set-Based phase, Trade-off curves that are showing feasible design solutions are used to generalize the knowledge in the knowledge value stream and define sets of possible design solutions. Knowledge-Briefs (A3s) are used to capture everything that is learned. Moreover, the knowledge is made available for all decision-making via Checksheets (Kennedy et al., 2008). The tools and methods will be further described in section 2.3.

The knowledge value stream is referred to as the capture and reuse of knowledge about markets, customers, technologies, products and manufacturing capabilities that is generalized for visual flow across projects (Kennedy et al., 2008). Trade-off curves are a part of the knowledge value stream as well, and are used to generalize the knowledge to be applied for multiple situations. Figure 6 illustrates the two value streams. The two value streams are developed concurrently where knowledge flows across projects and is integrated into the design decisions for specific products. Knowledge, which is gained from each project, accumulates and is visualized by a rising arrow (Kennedy et al., 2008).

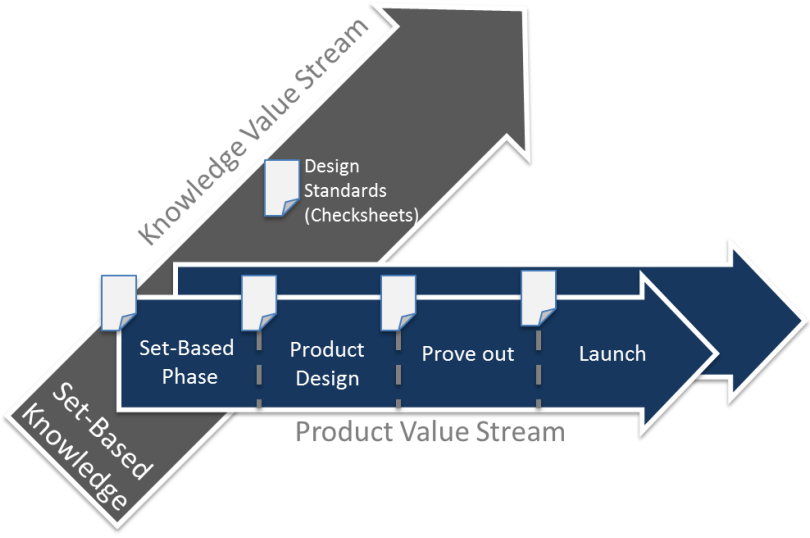

Figure 6. Learning-First PD, concurrent development of both product and knowledge (Kennedy et al., 2008)

3.2.2 Lean Product Development Culture

As declared, an organization´s culture is its underlying values, beliefs, mental models, and unspoken rules (Dalkir, 2011). According to Morgan & Liker (2006) culture and customer focus is the core of Toyota and no company can develop Lean PD without a strong culture. Toyota adapts new tools and methods that work and fit into their cultural framework (Morgan & Liker, 2006). Further, it is stressed that "a tool is not the solution" (Morgan & Liker, 2006) and that Lean PD is not achieved by simply implementing some techniques (Karlsson & Åhlström, 1996), but that a Lean culture is needed to sustain the tools and methods and make them effective (Morgan & Liker, 2006). Toyota has a learning culture, where mistakes are not punished (Morgan & Liker, 2006) and where "why" is the question, not "who" (Holmdahl, 2010). Another important aspect of the culture at Toyota is the spirit of continuous improvements (Kaizen) throughout all levels of Toyota (Morgan & Liker, 2006). Further, they point out that Toyota leaders are one key in sustaining the culture and exemplify it every day by their behavior.

3.2.3 A System View on Lean PD

Lean is often described as a system with subsystems that are related and connected (Modig & Åhlström, 2011; Liker, 2004). Likewise is Lean PD by many authors described as a system (Morgan & Liker, 2006; Ballé & Ballé). Morgan & Liker (2006) views Lean PD as a system consisting of three primary subsystems: Processes, People and Tools and Technology, see Figure 7.

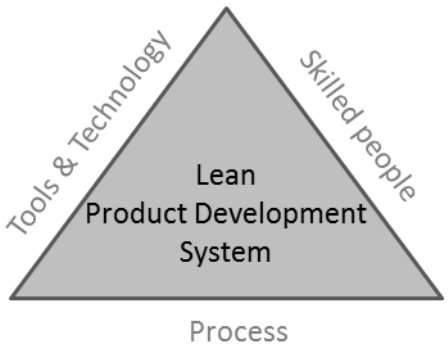

Figure 7. Lean PD viewed as a system (Morgan & Liker, 2006).

The system view is further described as: "What makes the Lean Product Development truly powerful is the whole system of mutually supportive tools, processes, and human systems working in harmony" (Morgan & Liker, 2006, p. 17). The idea to see Lean PD as a system is shared by (Ballé & Ballé), who divides the Lean PD system into four subsystems; the PD Process, Platform Centre, Lean Manufacturing and Knowledge. If these four subsystems are

working together an efficient Lean PD is in place where customer satisfaction, time to market and costs are improved (Ballé & Ballé).

According to Morgan & Liker (2006) the subsystem of Processes includes all tasks that are necessary to bring a concept to a product. Furthermore, focus in the Processes are also what in Lean terms are described as "mapping the value stream", which is described as customers are only willing to pay for processes that adds value to the end product, other processes should be removed as waste. One principle included in this subsystem is to front-load the PD, to explore the alternatives thoroughly and make rigorous planning to prevent decisions to be made too quickly. Further, the subsystem includes principles such as utilizing standardization to reduce variation. (Morgan & Liker, 2006)

The Subsystem People is related to areas such as recruitment, leadership and the organizational culture. Important principles in the subsystem are to organize in order to balance functional expertise and cross-functional integration, and to build a culture to support excellence and improvement. The authors argue that the core of Toyotas Lean PD is strong beliefs and values that are shared between generations of managers and engineers. (Morgan & Liker, 2006)

Tools and Technology is the focus of this master thesis, and is the subsystem that includes e.g. machines, but also what Morgan & Liker (2006) describe as "soft" factors that supports the people in the projects. Technology should not be added without assuring that the new technology fit the people and existing processes. Furthermore, the importance to use tools for standardization and organizational learning is emphasized. Continuous improvement, one important part in Lean PD, cannot be successful without *kaizen*, which is built on standardization. Finally, Morgan & Liker (2006) emphasize the importance of considering the concept of Lean PD as system, which is not working successfully with only one subsystem in place. (Morgan & Liker, 2006)

3.3 Tools and Methods for Managing Knowledge Management in Lean PD

There exist several powerful tools and methods for standardization, learning, visual communication etc. that are used to assist the Lean PD system (Morgan & Liker, 2006). It is furthermore stressed the importance that companies need to adapt tools and methods to fit the people and their specific processes (Morgan & Liker, 2006). Many of the Lean PD tools and methods found during the literature study of this master thesis include or focus on knowledge. However, all KM tools and methods used in PD are not Lean PD tools. The tools and methods to manage knowledge that are described in the literature (e.g. Kennedy et al., 2008; Morgan & Liker, 2006) are introduced next. Moreover, the main reason why companies fail to implement Lean is a focus to only implement the

"easy" explicit parts of the tools (Morgan & Liker, 2006). It is hence worth to stress the importance of the tacit aspects of these tools.

3.3.1 LAMDA and PDSA

LAMDA, which is an abbreviation of Look-Ask-Model-Discuss-Act, is the learning process that Toyota uses for building deep understanding and reusable knowledge and further documenting the learning and the results (Kennedy et al., 2008). LAMDA is said to be either similar or different to PDCA depending on whom you ask. The process of LAMDA is continuous and follows the steps in cycles (Holmdahl, 2010; Kennedy et al., 2008):

Look: Going physically to the source. Seeing for yourself and learn from practical experience.

Ask: Get to the root cause of the problem. E.g. asking "why" until the source is found.

Model: Finding models for new alternatives for solving the root cause. Use pictures, graphs and trade-off curves to visualize and avoid misunderstandings.

Discuss: Involve all concerned in a discussion. Try to understand and evaluate the models and if needed looking for more alternatives and plan for implementation.

Act: Implement and verify that the results are right. Standardize and decide how to act.

Another way of visualizing an improvement process is with the PDSA-cycle. The cycle consists of four phases, Plan, Do, Study and Act (also referred to as PDCA-cycle, Plan, Do, Check and Act). Plan is when data are collected and e.g. larger problems are broken down into minor. During the Do-phase an improvement team is assigned to the problem and testing of solutions to the problem is done. Thereafter actions are taken to make sure that the Do-phase was successful. This step is hence the Study-phase. The last step of the cycle is Act and during this phase decisions are taken whether the suggestions should be implemented or not. If the suggestion is not ready to be implemented, the cycle starts all over again. (Bergman & Klefsjö, 2010)

3.3.2 Checksheets

Toyota standardize the knowledge into knowledge checklists, referred to as Checksheets that are used to review all design decisions (Kennedy et al., 2008). Checksheets are reminders of things that should not be forgotten and are at Toyota visual and should be regularly updated and used (Morgan & Liker, 2006). Checksheets can include e.g. design practices, performance requirements, critical design interfaces, critical to quality characteristics and manufacturing requirements (Morgan & Liker, 2006). The Checksheets are the resulting

standards used at defined project review points for validating the designs and are updated after each project (Kennedy et al., 2008). Hence, based on Kennedy et al., (2008) and Morgan & Liker (2006) the benefits from using Checksheets can be many, e.g. improved design decisions and review, and knowledge reuse through knowledge documentation and visualization.

3.3.3 **A3**

A3 originally refers to Toyotas standardized communication format of explaining complex thoughts accurately on a single sheet of paper (Morgan & Liker, 2006). A3s, also referred to as Knowledge-briefs (Kennedy et al., 2008), are a way to generalize and document knowledge for reuse. Moreover A3 thinking is not only the usage of A3 size paper but also a part of the knowledge flow to communicate and control the knowledge. LAMDA is the learning process in Lean PD while A3 is the documentation of the learning (Kennedy et al., 2008). Furthermore, A3s can have many different purposes depending how they are used. Sobek & Smalley (2008) views A3 as a way of thinking and a way to cultivate intellectual development, and present three types of A3: Problem Solving, Proposal and Status. In comparison, Holmdahl (2010) sees A3s both as e.g. a problem solving tool and a documentation tool. Furthermore benefits, based on Holmdahl (2010), Kennedy et al. (2008) and Morgan & Liker (2006), from using A3 are e.g. improved documentation and problem solving. Further, benefits seen are also improved visualization and hence easier access to information and more knowledge sharing. Moreover, Sobek & Smalley (2008) argues that the main way to improve performance in a company is by problem solving which in turn could be achieved by A3s.

3.3.4 **Set-based Design**

Set-based design-, decision making or concurrent engineering can be described as a convergent flow where multiple concepts of each subsystem is generated in parallel and separated. The concepts are then evaluated against threats and each other in order to systematically, narrow and combine to tighter targets and eliminate the weak concepts and delay certain decisions longer, see Figure 8. (Kennedy et al., 2008; Sobek, Ward, & Liker, 1999; Ward, 2002). Finally, Set-based design helps capture knowledge from engineers, promotes faster learning and add knowledge through the evaluation and systematic elimination of the development process (Ward, 2007). By delaying decisions as long possible it is possible to gain better basis for decision (Holmdahl, 2010). The goal with set-based design is to only eliminate the weakest concept and only if it is proven and documented not to be working feasible (Kennedy et al., 2008). Set-based design is used during the first part of the product value stream, see Figure 6. According to Ward (2002) this saves money by learning early in the development and thereby minimizing costly late learning. Further he states that Set-based design saves money by doing right the first time.

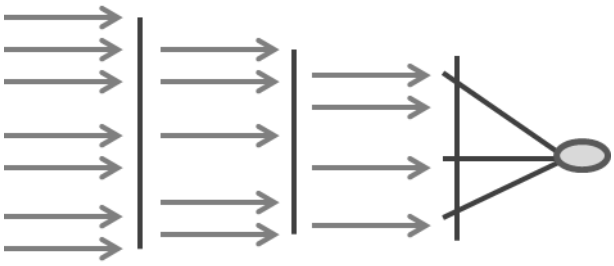

Figure 8. Set-based concurrent engineering (Kennedy, 2003).

Traditional engineering, or point-based engineering, is on the other hand when multiple design solutions are generated to a problem. The most promising design is chosen and is modified until it meets stated requirements. In this way, a single solution is chosen early. (Liker, Sobek II, Ward, & Cristiano, 1996)

3.3.5 Trade-off Curves

The Trade-off curve is simplified a curve showing, according to the companies' best practices, feasible design regarding two parameters, see Figure 9. In the design process a trade-off between two parameters might be necessary and the designer have the opportunity to easy see, with a given level of parameter X, the possible level for parameter Y and vice versa. The essence of the Trade-off curve is that the curve is changed accordingly to the companies best-known design solutions, and the Trade-off curve is hence a way to store reusable knowledge for future project. (Kennedy et al., 2008)

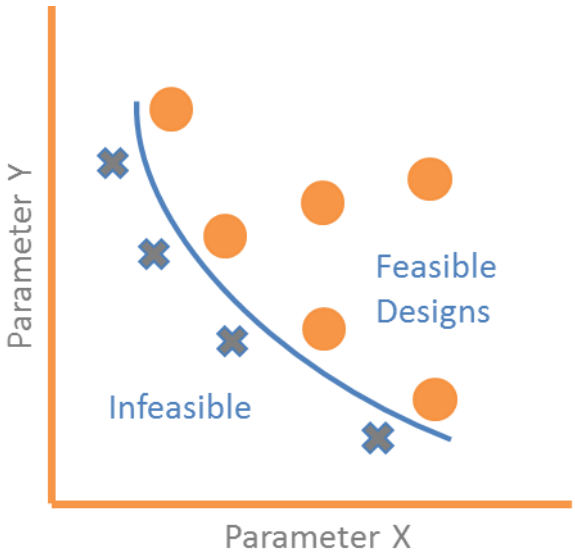

Figure 9. Trade-off curves (Kennedy et al., 2008)

3.3.6 Kaizen

Kaizen is an important part of Lean PD and can simplified be translated to continuous improvements. The word is a combination of the two Japanese words Kai and Zen that mean, "Change for the better" (Alukal & Manos, 2006).

To build in learning and continuous improvements may be the most important principle of Lean PD (Morgan & Liker, 2006). The improvements can be of both small and big nature (Bergman & Klefsjö, 2010). According to Morgan & Liker (2006) continuous improvement cannot succeed without standardization. Several tools, e.g. Checksheets and A3, used at macro- and micro level within the company, are developed in order to standardize learning (Morgan & Liker, 2006).

3.3.7 **Hansei**

Hansei, or reflection, is a meeting or event for reflection and discussions about failures and how to prevent those failures to reoccur. According to Morgan & liker (2006) a Hansei event is therefore necessary for continuous improvements. Westerns might see the event too negative since it only focuses on the negative aspects and not on the positive. However, Hansei has roots in the Japanese culture where children are asked by their parents to reflect over their behavior, and is therefore a natural way of working for Japanese. The event is designed to facilitate organizational learning, and there are three types of events (Morgan & Liker, 2006):

Personal reflection. This type of Hansei event focus on a specific skill or capability and the engineer is asked by a supervisor to reflect on his or her performance. A written plan for improvement is a part of the event. (Morgan & Liker, 2006)

Real-time reflection. The event is performed at group level and could be both intra-and cross-functional. The event is taken place as soon after major events as possible and could be carried out both on specific issues as well as on a holistic level. Questions included in the event are for example "what were our goals and objectives?" and "how did we actually perform to our goals?". This type of Hansei event often leads to an update of a standard or a new A3. (Morgan & Liker, 2006)

Postmortem reflection. This event is described as "what went right, what went wrong" and included in the meeting are representatives from the functional groups and program managers. The result of the event is a summary document, written by the program manager. (Morgan & Liker, 2006)

3.3.8 **Other Tools and Methods**

Lean PD and KM include numerous tools and methods and all cannot be covered in this thesis. Below follows a short introduction to some of these tools and methods and a summary is presented in Table 1.

Root Cause Analysis is an important step in LAMDA that Toyota uses to get to the root cause of problems (Kennedy et al., 2008). This is a systematic tool that

finds causes to a specific problem by repeatedly asking "why" until the root cause is finally found (Bergman & Klefsjö, 2010). However, Root Cause Analysis are used in PD in general, and is thereby not a lean specific tool (Bergman & Klefsjö, 2010).

Brainstorming camps are informal meetings of discussion held to solve difficult problems (Nonaka & Takeuchi, 1995). In this way participants learn with and from each other. Further they state that the meetings are held outside the workplace and are open to any employee. Moreover, criticism without constructive suggestions is taboo. Brainstorming is a method that is used not only in Lean PD (Toubia, 2006).

Visual Planning in Lean PD has a focus on resources and not activities as in more traditional methods (such as GANTT-charts). The plans are visual on e.g. large white boards on the walls that are easily accessed for the employees. Example of resources could e.g. be groups, or individuals, and each resource are dedicated to certain tasks written on sticky-notes and placed on the board. The plans could be done on different organizational levels and it is beneficial if the plans are linked to each other. Benefits described from using Visual Planning are e.g. an efficient use of resources, less delays, increased flexibility and increased communication. (Holmdahl, 2010; Lindlöf & Söderberg, 2011)

Obeya or "big room" is where participants from the functional groups are gathered, approximately every second day to discuss the project. To fulfill the rooms two main purposes; information gathering and information management, visual management tools are placed on the walls. Visual Planning boards are often visualized in Obeyas (Morgan & Liker, 2006).

Chief Engineer at Toyota is comparable to a heavyweight project manager and overseas the design projects and making sure they are on time and on budget. However, the Chief Engineer also is responsible for e.g. voice of the customer and customer value and also is also a teacher and motivator. (Morgan & Liker, 2006)

Mentors are used frequently at Toyota and leaders are described to use mentoring to coach their employees. This is done by asking questions about the situation but not providing the answers even if they are known. Liker (2004) describes the leaders as "builders of learning organizations". Furthermore the leaders are described to have deep specific knowledge of the area they are responsible for. (Liker, 2004)

Hetakuso-sekke is a booklet where experiences and specifically failures from the past are written down. Knowledge from the past is then easy made available for others. (Morgan & Liker, 2006)

Ijiwaru is when subsystems are test to failure. By pushing the design to failure, designers gain deep product knowledge and further e.g. knowledge about how materials behave close to failure. (Morgan & Liker, 2006)

Databases are used to store and make knowledge available. Toyota has implemented many databases including a know-how database for Checksheets (Morgan & Liker, 2006). However, the databases have not replaced the deep knowledge of functional experts (Morgan & Liker, 2006). Since databases are not specific for Lean PD, they will not be discussed any further in this theory framework.

Table 1. A summary of presented Lean PD tools and methods and their knowledge aspects.

Tools & methods	**Summery**	**Main knowledge aspects**	**Incl. in survey?**
LAMDA /PDCA	The process of Look, Ask, Model, Discuss, Act, and Plan, Do, Check, Act.	Is a learning process to e.g. gain more knowledge.	Yes
Checksheets	Review design decisions and update it.	Standardize knowledge.	Yes
A3s	Document, visualize and communicate on a single sheet of paper.	Documentation of learning and a problem solving method.	Yes
Set-based design	Multiple concepts are generated in parallel and systematic elimination of the weakest concepts.	Capture knowledge and learnings early in the process.	Yes
Trade-off Curves	A curve showing, according to the companies' best practices, feasible design regarding two parameters.	Store best-known solutions and thereby reuse knowledge for future project.	Yes
Kaizen	A strive for continuous improvements.	Making sure more knowledge in the organization is gained.	No
Hansei	Meeting or event for reflection and discussions about failures and how to prevent those failures to reoccur.	Learn from "what went right" and "what went wrong" and Facilitate organizational learning.	Yes
Root Cause Analysis	Systematic tools to get to the root cause of problems.	Learn the root cause and thereby get a deeper insight to the real problem.	Yes
Brainstorming camps	Informal meetings of discussion held to solve difficult problems.	Learn with and from each other.	Yes
Visual Planning	Visual planning, often of resources with help of sticky notes on large visual boards.	Visualize and share knowledge about each other's daily activities.	No
Obeya	A room for information gathering, information management and visual management placed on the walls	Facilitating for employees to access to information and knowledge.	Yes

Tools & methods	Summery	Main knowledge aspects	Incl. in survey?
Chief Engineer	Overseas the design projects and making sure they are on time and on budget at as well as being a teacher and motivator.	Is a knowledgeable person.	No
Mentors	Leaders are working as mentors while coaching the employees	The leaders have deep knowledge in the specific areas. Facilitates transfer of tacit knowledge.	Yes
Hetakuso-sekke	A booklet where experiences and failures are written down.	Knowledge from the past is easy made available for others.	No
Ijiwaru	Pushing the design to failure.	Gain deeper product and material knowledge.	No
Databases	Can be a system for documenting and storing knowledge e.g. in A3s or Checksheets.	Document and make knowledge available.	No

To summarize, Toyota's most stressed tools and methods are LAMDA which is the learning and knowledge development process, A3 (Knowledge-briefs) documents that spreads the learning, Trade-off curves that generalize the knowledge for reuse and Checksheets to standardize the knowledge and review it (Kennedy et al., 2008). These tools and methods, together with Root Cause Analysis, Brainstorming camps, Mentors, Obeya and Hansei was selected to be included in the survey due to what we found them to be most stressed in the literature and by experts but also to include the since they focus on knowledge which is line with the aim of this thesis.

4 Findings

This chapter presents the result from the study, and is divided into three areas; case study interviews, survey and expert interviews. The result presented is the basis for the analysis.

4.1 Case Study Interviews

The following findings were gathered during case studies where four companies were visited. One interview was held at each company, and the result creates the basis of the analysis.

4.1.1 Case Study Interview at Autoliv Vårgårda

An interview was held with Anders Svantesson, Quality Development Director at Autoliv in Vårgårda. Autoliv is a global company developing and producing automotive safety such as seatbelts and airbags etc. In total Autoliv (Sverige AB) in Vårgårda have about 700 employees of which 240 are in the PD department. Autoliv PD process is built on 5 phases with tollgates between the phases. Prior to the process with the phases there exists profound research where the bases for future projects are made.

Lean PD Initiatives

Svantesson describes that projects deliver to a very large extent on time and their products meet quality requirements. Furthermore, after the implementation of Lean PD tools and methods have the PD costs reduced to a large extent and the product quality increased as well.

Svantesson describes Q5 as the Lean initiative at Autoliv that is communicated to the employees, or as it is described to the employees, "*Q5 is the journey to culture at Autoliv where we have zero errors and the best customer value*". The five subparts are described as customer, growth, behavior, supplier and product. Overall Svantesson emphasizes that Autoliv are focusing a lot on the cultural part of Lean, and describes that a goal could be to have a culture where the employees feel a need for a specific tool rather than a tool is implemented first and then the employees should adapt to that tool.

Autoliv use visual planning for the projects on a board where it is possible to easily get an overview of when the projects should be ready and sub goals with the projects. A big conference room (Obeya) is used to visualize how the company is performing on Cost, Management, Safety, Delivery and Quality etc. Meetings are held regularly in the room with managers. Svantesson describes and visualizes continuous improvements and shows small pieces of paper where the employee can write a problem and solution to the problem are accessible for everyone. The basis of the note is the PDCA-cycle. The target is that each employee should do one improvement suggestion every month.

Tools and Methods
Autoliv are using A3s but are referring to it as 8D or "one pager". The tool is used for many different applications and it could include parts such as PDCA and is mainly used for problem solving, but also show status or describe a project proposal or a knowledge captured. Svantesson explains further that A3s promote a structured thinking and presentation, and that it further reduces confusions, and decisions are therefore reached faster. Furthermore, Autoliv are using Checksheets to a large extent and they are constantly a part of the PD process. The aim with the Checksheets is e.g. to front-load the input of data before tests. Trade-off curves are used, but mostly within specific projects as a part of a report or investigation in the project. However, they are not currently being used for standardization nor actively making the knowledge reusable for other projects. Set-based design are used sporadically and mostly to create greater product knowledge. Other tools for problem solving used, according are value steam mapping, 5S, lessons learnt/reflection, 5Why and Ishikawa.

4.1.2 Case Study Interview at Scania Södertälje

An interview was held with Peter Palmér, Senior Manager and Head Process Development, at Scania. Scania is a global company with more than 35 000 employees and it develops heavy trucks and busses.

Lean PD Initiatives
Scania's work with Lean PD starts with a model of value, principles, methods and results, where the values of the company is a good start of their initiatives. Therefore, Scania do not implement everything, but selects the parts of Lean PD that are coherent with their principles. Hence, Scania also tries to look at the needs of the company and what situation they are in and find methods that can help them. Palmér states that when change is needed, Scania tries to let people join that journey. Scania started their Lean PD initiatives approximately 10 years ago and have since then evolved their PD. Further, Palmér points out that sometimes revolution is not the best option and rather that evolution may be a good alternative. Everything comes back to the values and principles and what needs Scania have in their efforts towards improved PD. Here, the culture is of great importance and Scania have tried, and say they have succeeded in creating a culture where it is all right to make mistakes and where people do not point fingers.

Lean PD Tools and Methods
According to Palmér you should start where you have a problem and not where things are working well. Ask if e.g. A3s are really needed in your company. When discussing the tools and methods that Scania use, Palmér highlights the paradox of, what is a tool and what is a prerequisite for a company. Palmér states that everything that is Toyota does not work at other companies and therefore it can be a good idea for companies to look for other methods that may fit more to

their Nordic conditions. Further when implementing new tools and methods it is important to adjust them to the situation of the company and get the co-workers to collaborate. It is also important how things are implemented and not only what.

Scania use its own version of A3s that are used for everything from reports to problem solving. One example is that they try to summarize books on a single page in order to better understand it and help other understand it. Further, at Scania, an A3 can describe a goal, the present situation and how to get there. However according to Palmér, to use an A3 is not critical as long as things are presented in a good way.

Further *Train the Trainer* is something that Scania puts big focus on, where the goal is for people to pull change where they are and also train the people they are managing. This needs to be rolled out through the whole organization and not only at the top management. Further, leadership is important and the concept of *The Leader is a Teacher* is also used at Scania, where supervision and sharing knowledge is necessary to climb in the organization. This way of knowledge sharing is similar to having a mentor.

Scania also use *Set-based design* and have several concepts that they evaluate, sometimes with accelerated testing that often is a little bit over the limit.

4.1.3 Case Study Interview at Atlet in Mölnlycke

An interview was held with Dan Ulmestrand, PD Manager, at Atlet. Atlet develops trucks for warehouse and industry. It is a global company with approximately 1000 employees and has their headquarters in Mölnlycke.

Lean PD Initiatives

The Lean initiatives at Atlet started around year 2003 with both Lean in production and in PD, together with external consultants. According to Ulmestrand Lean PD at Atlet is based on continuous improvements and reflection. Everything should not, and can not be done at the same time. There is still a change toward a more Lean organization going on at Atlet and the culture is a part of that, where e.g. management from Japan is being employed. It is important to have the right mind-set in the organization and the tools and methods help to support this. Many of the Lean PD initiatives get more powerful with time, when the first obstacles are overcome. However some initiatives may also slowly dissolve when not working well.

Lean PD Tools and Methods

According to Ulmestrand, Atlet selected the tools and methods on management level and in regard to the needs that they had and what they thought would suit them. Some of the tools and methods have been harder to implement and use, due to its complexity or time pressure. Also he states that it is generally hard to

change the way of working and that none of the tools and methods are really easy. E.g. Trade-off curves are supposed to be used at Atlet, but few have managed to utilize it. Other tools e.g. Visual Planning is on the other hand working well and is used widely. Further, Ulmestrand discuss that it is important to gain an appropriate level of the tools and methods, and then improve and alter the use as time goes. He stresses the importance of reflection and improvements. During the Lean initiatives at Atlet, Ulmestrand has noticed that the tools that are used by everyone often and regularly have been the easiest to get to stick to the organization.

The largest focus at Atlet is on the Visual planning, where employees can see what everybody is doing, that they are doing the right thing and have the opportunity to reflect on it. Atlet are not using Obeyas but have the visual boards in hallways and open spaces where people may pass or can easily meet up. Checksheets are used in close relation their stage gate process, at checkpoints, design reviews and for follow-ups and decision making. Also A3s are used at gates. The A3s are mostly digital and used for decision makers. When it comes to Set-based design, Atlet do develop parallel concepts at times and would like to do it more often but they believe it comes with a too high cost. Also, they develop very mature products with specific customer requirements that limit their benefits from concept generation. Finally, In order to manage knowledge, Atlet uses a "lead engineer" as a mentor. This person needs both the technical knowledge and being able to communicate and engage others.

4.1.4 Case Study Interview at Kongsberg Automotive in Mullsjö

The interview was held with Jimmy Östman, PD manager at Kongsberg Automotive in Mullsjö. Kongsberg Automotive is a supplier to the vehicle industry and is e.g. developing and producing driveline components such as gearshifts and interior systems like seating control. In the office in Mullsjö work 140 employees within R&D and the average time for each development project is 1 year.

Lean PD Initiative

2009 Kongsberg Automotive started a Lean initiative together with Michael Kennedy, and have since then implemented several Lean tools and methods in their PD department. The overall apprehension is that Kongsberg Automotive have come far within Lean PD. The initiative started from top management, and that has according to Östman, been a key for success for the implementation. For example, to see benefits from the implementation took longer than thought, e.g. K-briefs (similar as A3s) took 3-4 years, and without management support there might have been a risk that the initiative would have been stopped before the benefits were seen. Overall, the aim of the Lean PD initiative is to reduce the number of documents and to cut costs. Since more of the development projects

now are invoiced in-house, an efficient way of storing and reuse knowledge is necessary to cut costs. However, in October 2012, a new method for working with Lean PD will be implemented that to a larger extent will be based on knowledge and will also be highly associated to Michael Kennedy's model of a product- and knowledge value stream.

Tools and Methods

The tool that Kongsberg Automotive are using to the largest extent is Knowledge Briefs (also referred to as A3s or K-briefs). Five different types of K-briefs exist which have the same format. The types of K-briefs are 1) Problem, 2) Relation, 3) Proposal, 4) Customer interest and, 5) Information. The K-briefs are created and used by all employees and are stored digital in their SAP-system. Moreover, Kongsberg Automotive use knowledge owners that are responsible for an area e.g. plastics. The knowledge owner is the person in the company that has the largest knowledge within the specific area, or at least knows who has that knowledge. The knowledge owner is making a knowledge standard with the company's best practice. The knowledge standard is hence updated when new knowledge is gained. Information on the knowledge standard is traceable to specific K-briefs if additional information is necessary.

Moreover, Kongsberg Automotive have Chief Engineers that are responsible for the technical part of the product towards the customer, time plan for the project and for the construction of the product. The Chief Engineer has no responsible for employees nor making sure that there are enough resources dedicated to the project. Kongsberg Automotive has been working with Visual Planning with very good results. But during the last years there has not, according to Östman, been a need for Visual Planning since the employees now speak to each other naturally. The initiative with Visual Planning has therefore been taken away at most PD departments. However, Östman emphasizes that it might be implemented again if necessary. Trade-off curves are not used to a large extent since it is perceived to be very difficult. The reason is that the decision often might depend on 3 or 4 parameters, which makes it more complex to do a Trade-off curve. Finally, Set-based design is used to some extent and Östman argues that the reason that it is not used more is because of the specific requirements from their customers which obstruct generating multiple concepts.

4.2 Survey

The following chapter shows the results from the survey. Focus is on research questions 2a and 2b, hence which tools and methods companies are using and which benefits they experience. Moreover, the answers presented in this section are the companies' direct answers from the survey, and could hence be seen as their subjective opinion about their operations.

4.2.1 Companies Participating in the Survey

The survey was distributed to a range of PD industries where answers were received from companies that are developing e.g. paper products, tools, chemicals and electrical products. The companies that are using Lean PD are from varying industries and the product range includes e.g. cutting tools, medical devices, chemicals, telecom products and automotive suppliers. Hence, no evident pattern was found that companies that are using Lean PD are from a specific industry.

4.2.2 Tools and Methods Used to Manage Knowledge in Lean PD

The tools and methods that were found most commonly used, fully or sporadically, in the surveyed companies were Root Cause Analysis, Brainstorming and Mentors, see Figure 10. It is furthermore clear that one or more of the tools and methods: Root Cause Analyses, Checksheets, Mentors, Brainstorming camps, Set-based design and Obeya are used by more than 50% of the 47 participating companies in the survey. The tool that is less used is Trade-off curves (16%). The distinction between using sporadically and fully implemented are the companies own opinion and the result shows that few companies are experiencing that they have fully implemented the tools and methods. Next, in Figure 11, a graph over how long time the tools and methods have been used either fully implemented or sporadically, is presented. Further visualizations of for how long the tools and methods have been used in companies are shown in Appendix B.

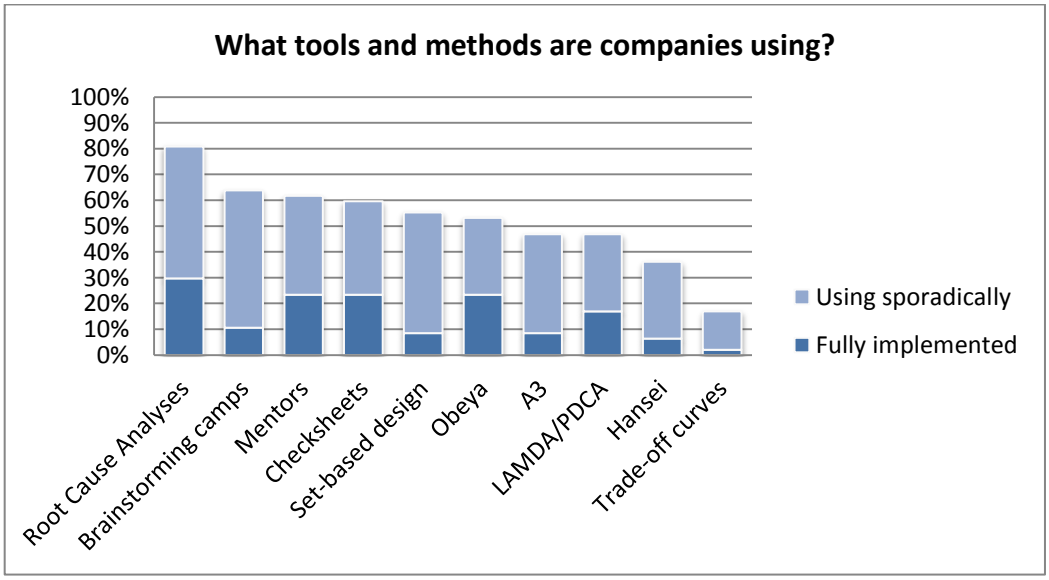

Figure 10. Companies that either have implemented the tools and methods or use them sporadically.

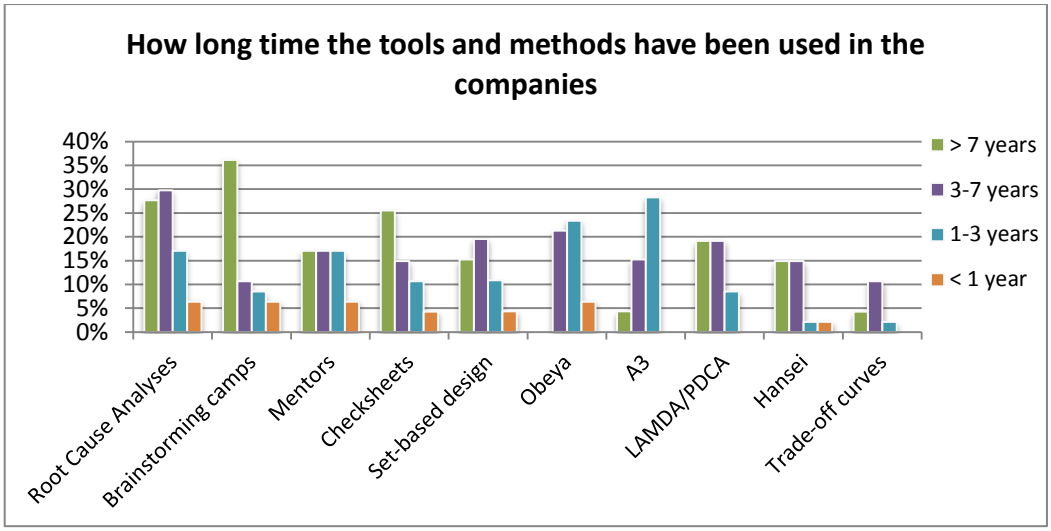

Figure 11. How long time the tools and methods have been used, either fully implemented or sporadically.

4.2.3 Company Settings for Lean Product Development

The companies were segmented in regard to their different settings e.g. types of customers and organizational settings. This was compared with what tools and methods these different segments use. The result indicated that a higher percentage of the companies with higher complexity of its products have a tendency to be using the different tools and methods compared with those with lower complexity. This is visualized in Figure 12. Especially the more Lean specific tools and methods, such as Obeya, A3s and LAMDA/PDCA are used to a larger extent by high complexity product companies, see Figure 13.

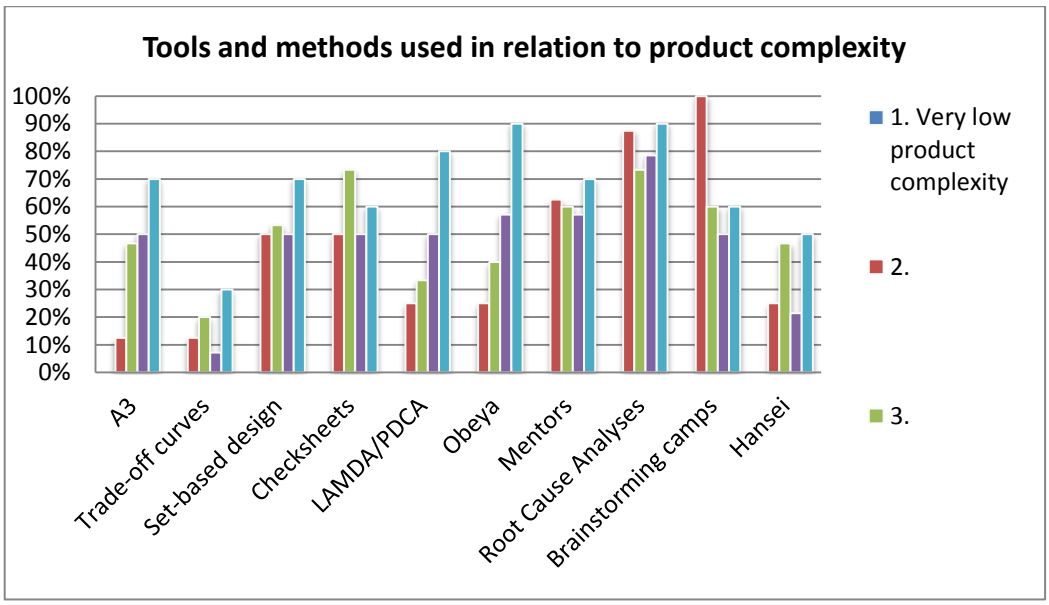

Figure 12. The diagram shows how many in each segment (product complexity) that uses the different tools and methods.

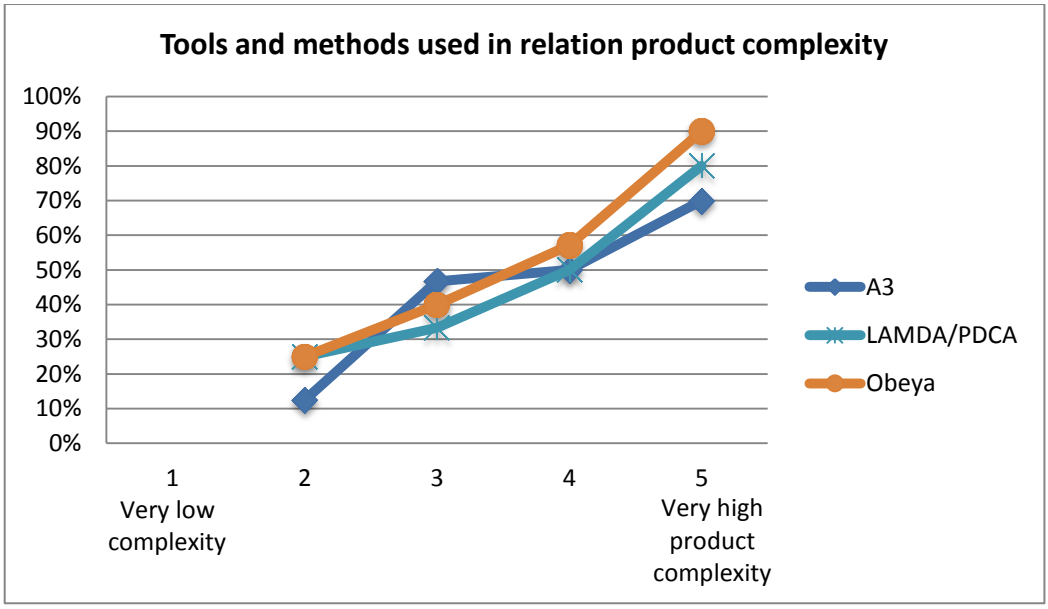

Figure 13. The diagram visualize that companies with higher complexity more often tend to use A3s, LAMDA/PDCA and Obeya.

The result clearly indicated that the PD time (defined by time to develop a new product from decision to market launch, not including pre-research) has an effect on the usage of the tools and methods, see Figure 14. A higher percentage of companies with a longer PD time than 1.5 years use the different tools and a method compared with those with a shorter PD time, this trend is further visualized in Figure 15.

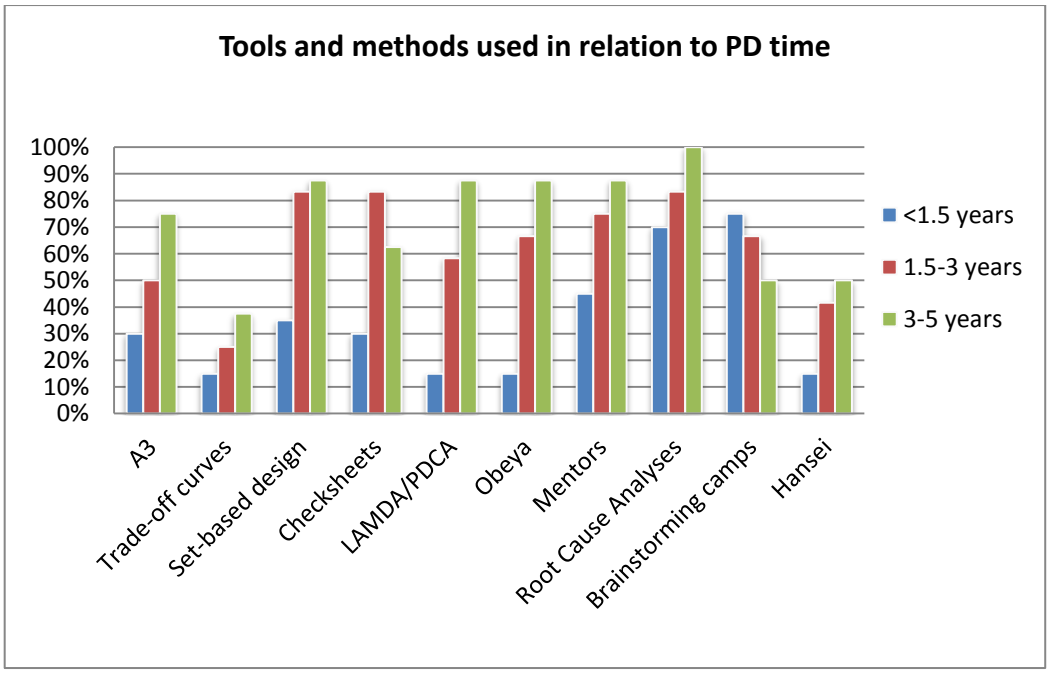

Figure 14. The diagram shows how many in each segment (PD time) that uses the different tools and methods.

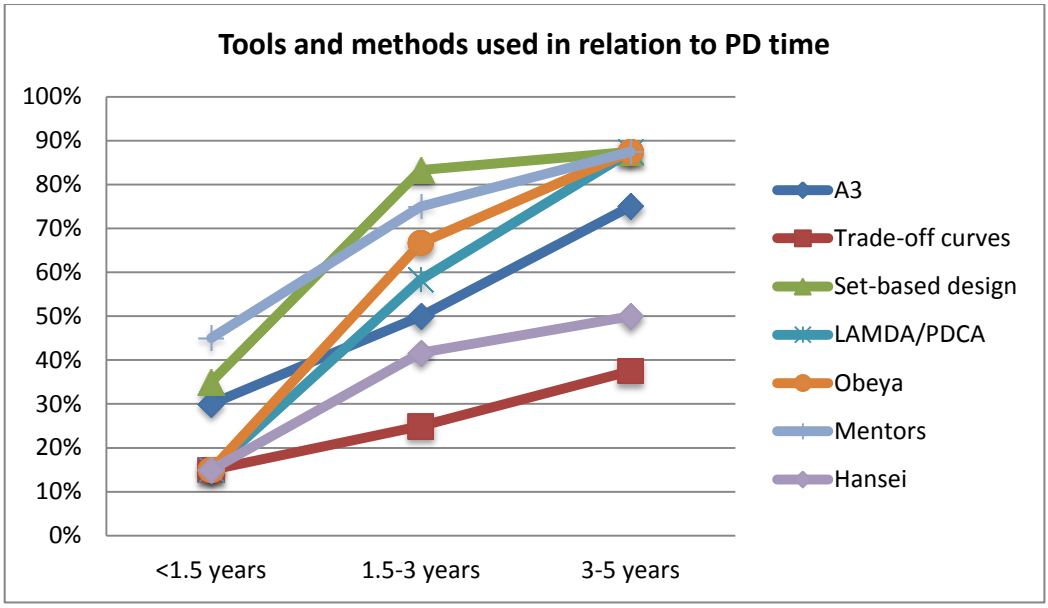

Figure 15. The diagram visualize that companies with longer PD time more often tend to use several of the Lean PD tools and methods.

Finally it is worth emphasizing that no relation was found between number of tools and methods implemented, and settings such as types of customer, number of components in products and co-location of employees in the project, see Appendix C.

4.2.4 **A3**

The survey shows that, *how* A3s are used varies between companies. Many companies use it in more than one way and with different purposes. Some use A3s for design principles in cross-functional project, for standardization and in startup or update of projects. It is also used for documentation and reuse of knowledge that is not project specific. However, most companies use A3s as a part of LAMDA/PDSA, for project planning and as a summery or documentation tool. 44% of the 47 participating companies are using A3s either as fully implemented or sporadically. Of the 11 companies that answered about A3s in the survey, 59% have used it during 1-3 years, see Figure 16.

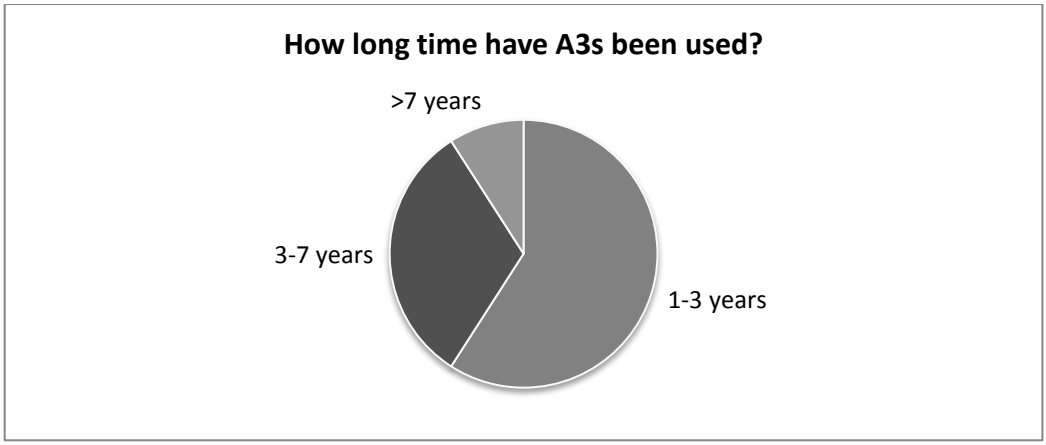

Figure 16. How long time A3s have been used in companies.

Companies are using A3s for problem solving and more than 60% of the companies use A3s for this, see Figure 17.

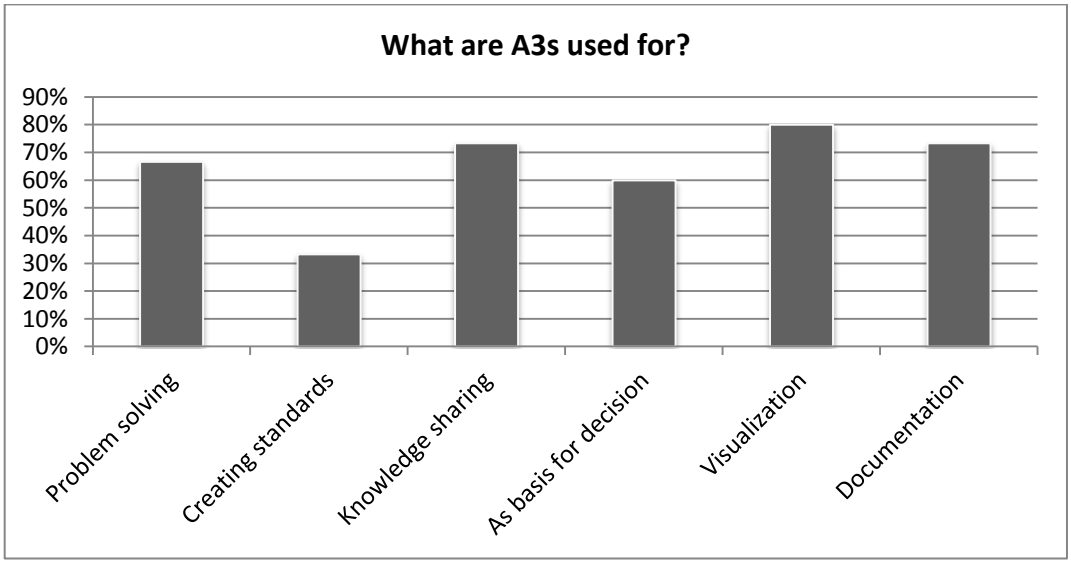

Figure 17. What A3s are used for in companies.

In general, companies are experiencing large benefits with the method. The two most common positive effects companies are experiencing are better basis for decision and increased shared understanding of projects. Better documentation of information and knowledge is also seen as an effect from using A3s, see Figure 18. Furthermore, it is found that A3s promotes a structured and standardized way to summarize and hence reduce documentation time. This standardized way also provides an easy and summarized format to faster overview and grasp the information.

When the users of the tools are segmented to regard to how long time A3s have been used, there is a slightly difference was found regarding experienced benefits. In order to see the difference between short-time and long-time users the companies were segmented depending on if they have used the tools more or

less than 3 years. The average apprehension of the benefits for the long-time users (3 years or more) is 3.7 compared with 3.2 for those that use the tool or method for less than 3 years. The answer is on a scale from 1-5 of how much the companies experience the benefits, where 1 is not at all and 5 is to a large extent, see Figure 19. Depending on how long time a company has used A3s, there is a difference of how large benefits they experience. All benefits, except increased knowledge sharing between employees and better solutions for problems are found, are experienced to a larger extent by the long-time users. The experienced benefit that has the largest difference between the two user-groups is increased shared understanding between projects.

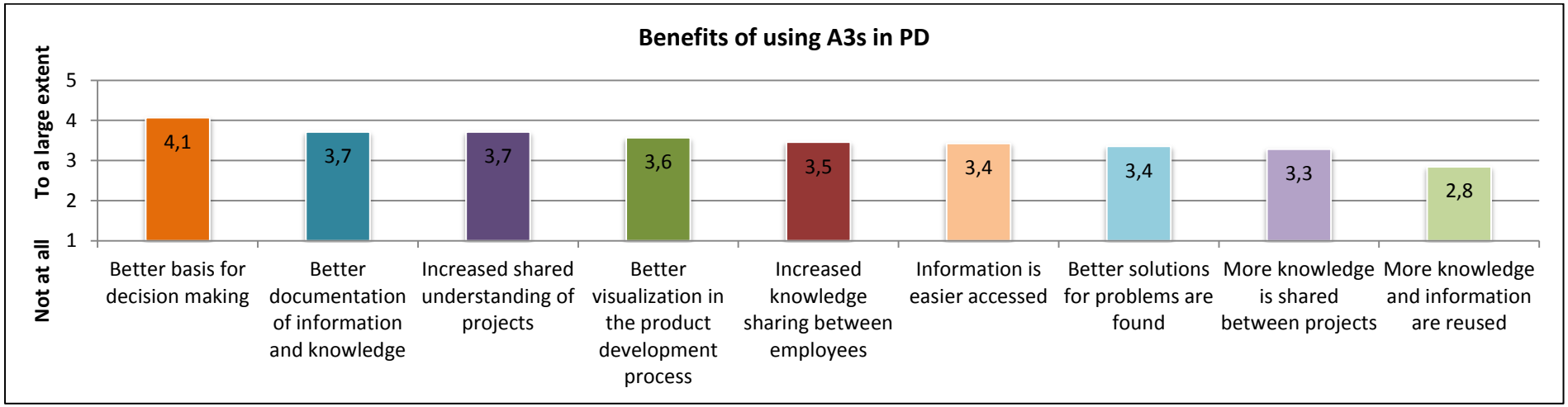

Figure 18. The diagram shows the specific benefits that companies have experienced from using A3s.

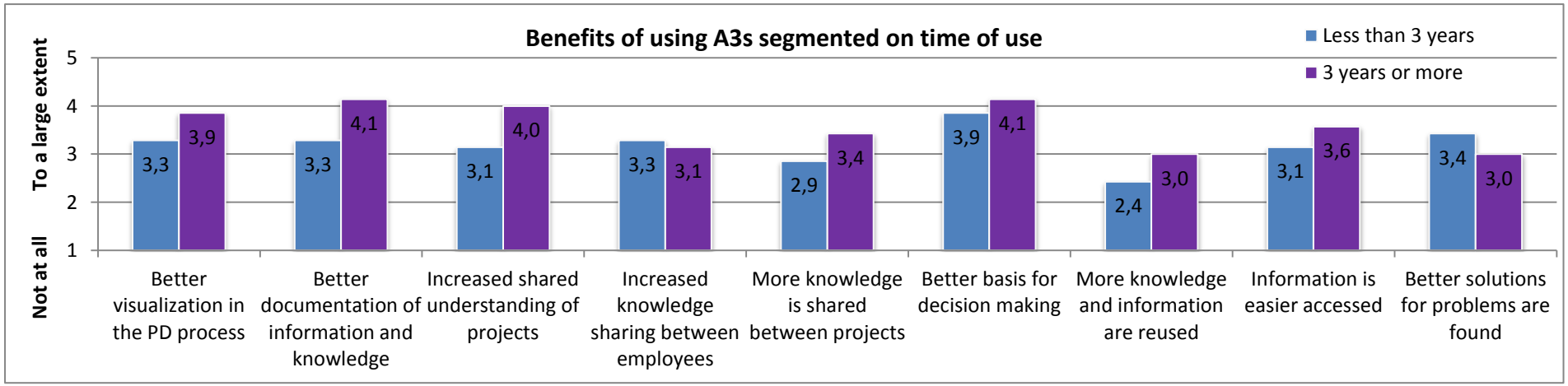

Figure 19. The diagram shows the benefit effects in relation to the time of A3s use in the companies.

4.2.5 **Checksheets**

The majority of the companies that use Checksheets use it at process gates and for making sure that things are done and to secure deliverables. However, a few companies are using Checksheets actively to document knowledge, at decision points and in project management. 59% of the 47 participating companies are using Checksheets. Of the 18 companies that answered about Checksheets in the survey, most have used Checksheets for more than 3 years, see Figure 20. Companies are using Checksheets to create standards, as basis for decision and for problem solving, see Figure 21. It is further more clear form the survey that companies are often using Checksheets at tollgates and as design guidelines and standards.

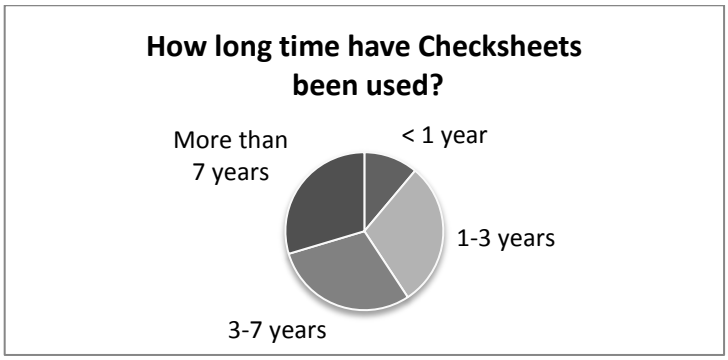

Figure 20. For how long time companies have used Checksheets

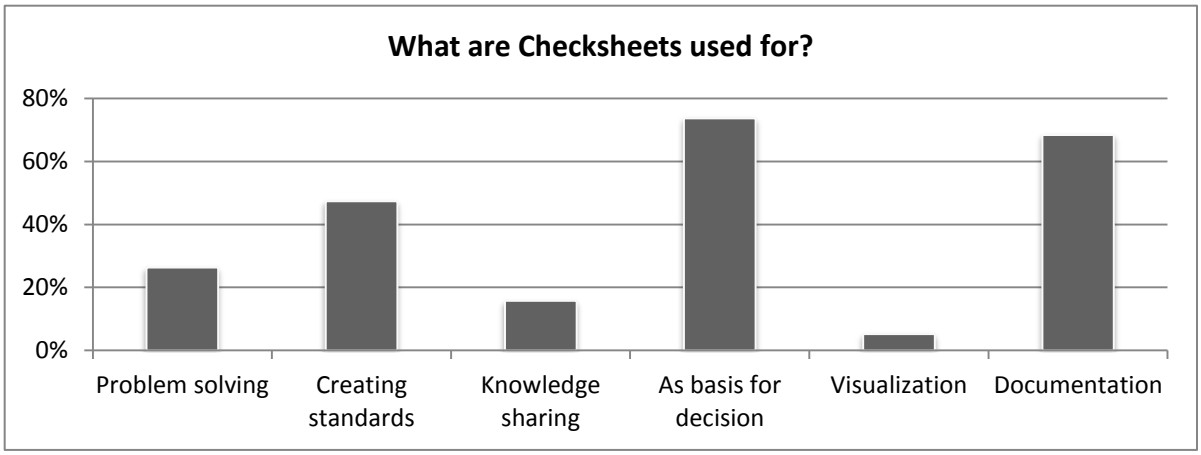

Figure 21. What Checksheets are used for in companies.

The experienced benefits are visualized in Figure 22 and the most experienced benefits are better basis for decisions and fewer changes late in processes. The effect that is experienced less frequent when working with Checksheets is more knowledge for employees. When the result is segmented in regard of how long time the company have worked with the Checksheets, it shows that the average experienced benefits for the long-time users are 3.1 compared to 2.3 for the companies that have implemented it recently, see Figure 23. The specific benefit that has greatest difference between the two user-groups is more knowledge is shared between projects.

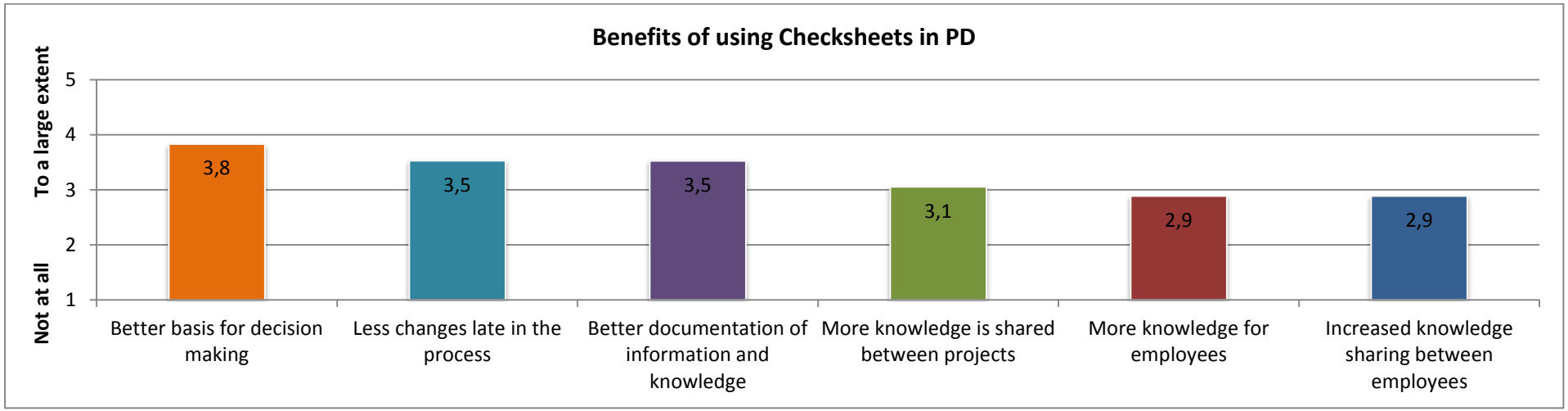

Figure 22. The diagram shows the average specific benefits that companies have experienced from using Checksheets.

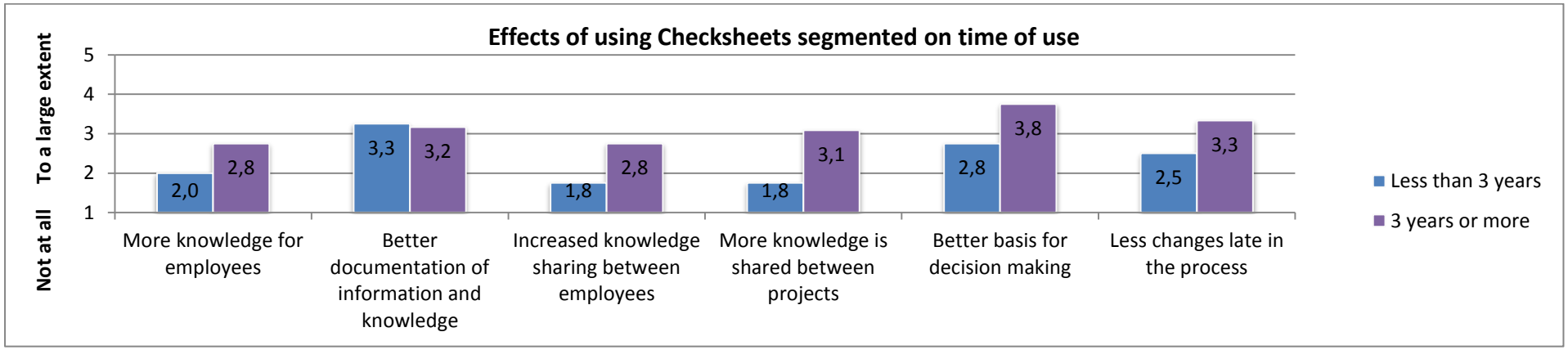

Figure 23. The diagram shows the benefit effects in relation to the time of Checksheets use in the companies.

4.2.6 **Set-based Design**

The goal with Set-based design is, for most companies, to work in parallel with different concepts. Few companies are using it fully, but mention that they are trying to make it work. 13 companies answered that they use Set-based design, but only 4 of these that they have fully implemented it. It was found that companies generally have been using Set-based design for more than 3 years, see Figure 24. Further that they are using Set-based design mainly fore problem solving and as for basis for decision, see Figure 25. Moreover it was seen in the survey that some companies are using Set-based design in early stages of the PD process. Many of the companies mention that they use parallel concept or "plan Bs" but none of them mention that they eliminate concepts instead of selecting concepts.

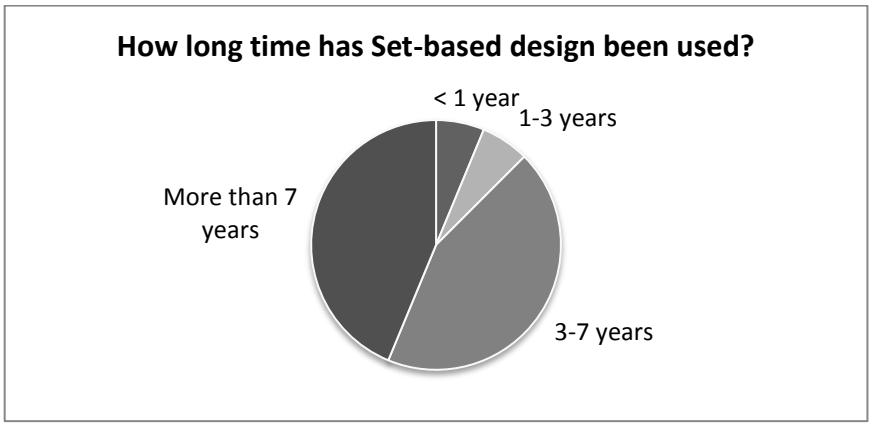

Figure 24. The figure shows how long time Set-based design has been used in companies.

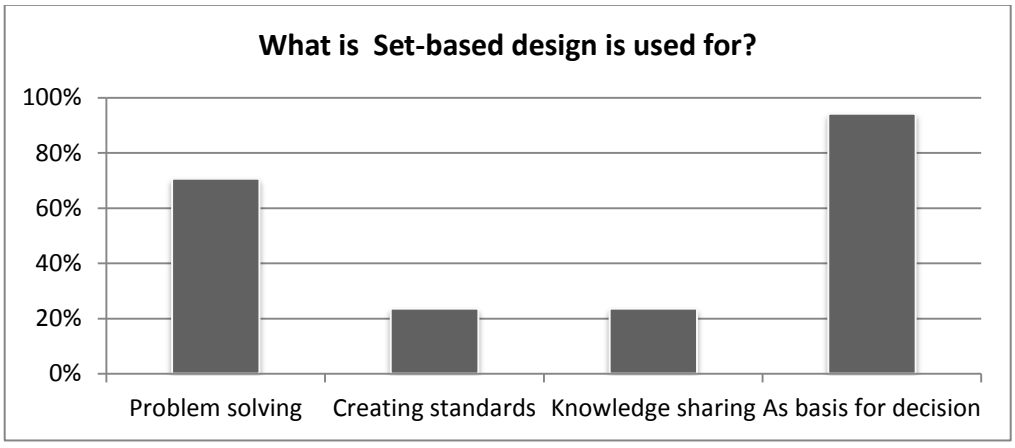

Figure 25. The diagram shows what Set-based design is used for.

The most common experienced benefits from using Set-based design is better basis for decision-making and increased product quality, see Figure 26. When the result is segmented with regard to how long the companies have used Set-based design, overall no general indications was found that the time of use affects the benefits of Set-based design, see Figure 27.

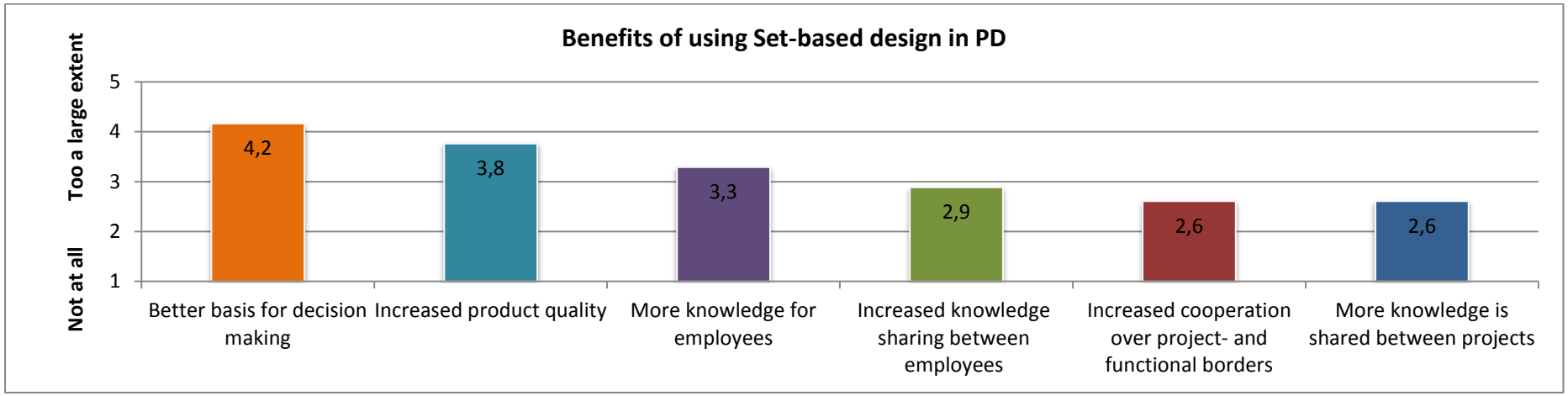

Figure 26. The diagram shows the average specific benefits that companies have experienced from using Set-based design.

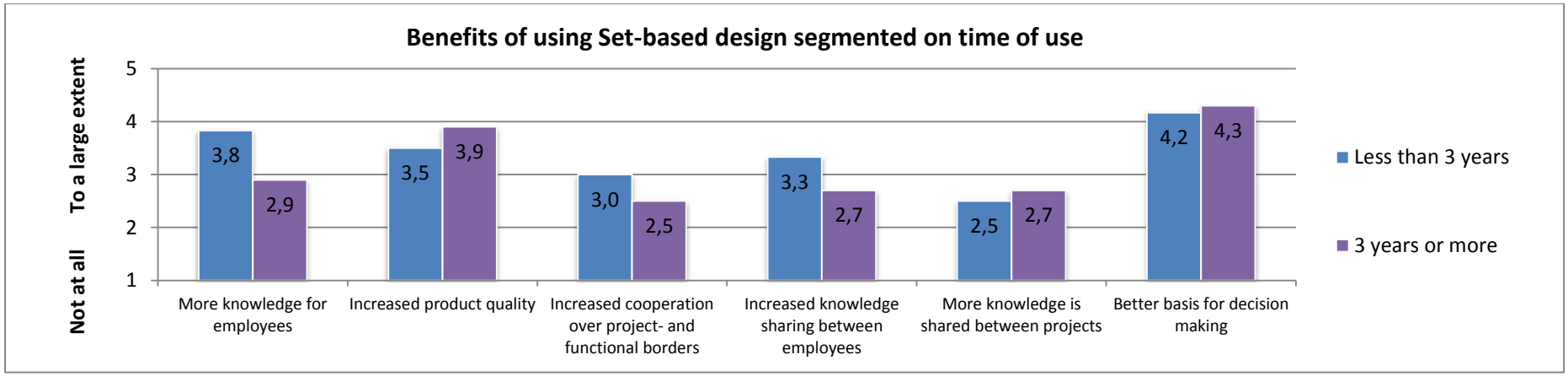

Figure 27. Benefits of using Set-based design segmented on time of use.

One respondent describes that they don't, due to cost and time, have the possibility to do late changes, but that the method is used in earlier phases of the PD process. The same company moreover describes attempts to frontload in order to avoid late changes because of the complexity degree of changing late. Another company describes that the goal with Set-based design are *"In early phases several possible solutions are considered. After testing validity at different levels a "Winner" is finally selected".* Finally, one respondent describe Set-based design as the best insurance for a manager to meet stated goals.

4.2.7 Trade-off Curves

The numbers of companies that are using Trade-off curves are strictly limited and only one of the companies has implemented it fully. Seven of the companies who answered the survey are using it sporadically. Further, only 6 companies answered about Trade-off curves in the survey. One of the users, which are the company that is using the method most extensive, describes a problem to use the method due to problems to describe the benefits for the user. Most of the companies that are using Trade-off curves have used it for more than 3 years, see Figure 28.

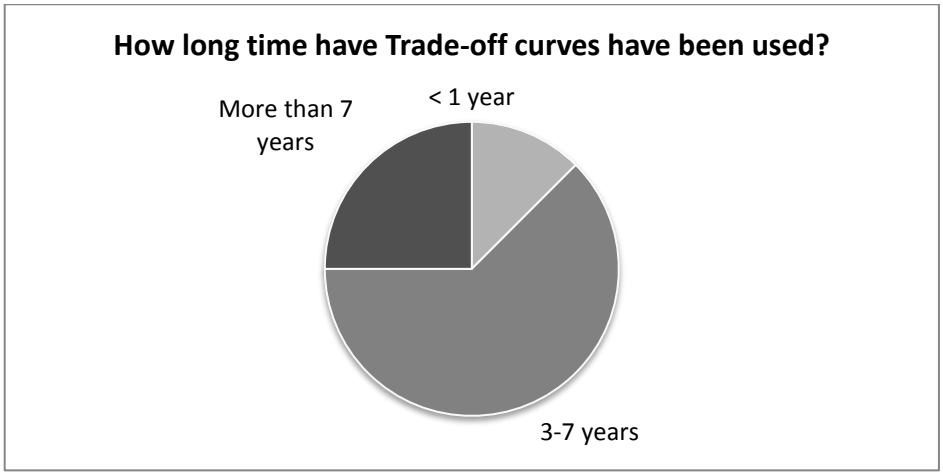

Figure 28. How long time Trade-off curves have been used in companies.

The Trade-off curves are mainly used for creating standards and as basis for decision. The main effect of using A3s is better basis for decision-making. Other effects that are seen are increased product quality and better documentation of information and knowledge. However likely, the small sample of Trade-off curves users also discards any result that the purpose of the usage of the tools would affect the benefits off it. Further segmentation of the data regarding Trade-off curves could not be done due to the small sample.

4.2.8 Other Tools and Methods that are Used

When asked what other tools and methods companies use, it is evident that the most frequent tools and methods that companies use to manage knowledge and

Lean PD that not were included in the survey are tools for visualization such as Visual Management System (VMS), visualization boards and visual planning by notes. It is furthermore common with different kinds of databases and wikis for storing and reuse of knowledge. Different events for orally sharing experiences and information among the employees exist as well, such as seminars, regular meetings and dedicated days for sharing experiences from projects.

4.3 Expert Interviews

Following is the findings from the interviews with two experienced persons in the field of Lean PD. The findings have been used as input for the survey and as a support in the analysis. One interview with Håkan Swan and Stefan Bükk respectively were made at the beginning of the project to gain important industrial insight prior to the company interviews. Further, a second interview was held with each of the experts after the result from the survey was received.

4.3.1 Interviews with Håkan Swan

Two interviews were held with Håkan Swan, consultant at ISEA (Industrial Senior Advisors) and who has a long experience of working with Lean PD at companies. For Lean PD tools and methods in general, Swan believes they are simple and not rocket science. However, they can be used both in a simple and more extensive way. Experienced benefits are a result of how extensive the tools and methods have been used, and the interesting part is, according to Swan, hence *how* the tools and methods are used.

According to Swan most companies have not worked that much with Lean PD tools and methods. However, PD managers have in general quite good knowledge about the existence of the tools and methods, and people who are using the tool, even if they don't call it exactly e.g. A3s users are usually familiar with the word A3s. As problem-solving methods there are other tools such as six sigma and 8D that companies have implemented instead.

Swan describes A3s as a mean for changing the cultural behavior and more specifically to develop problem solvers. The tool is therefore beneficial not only for solving the specific problem but also for improving the employees' problem solving skills.

According to Swan, PDCA is exactly the same as LAMDA. He further thinks that Toyota have never heard of LAMDA, they call it PDCA. However, you can do PDCA in many different ways, e.g. the "P" can be done in cycles. LAMDA is just a description of Toyotas work from an outsider. Common tools used in companies are e.g. A3s and Continuous Improvement-tools. In general for the tools and methods, Swan stresses the importance of having a problem-solving

dimension. If this is missing, then you are not Lean. Furthermore for Lean as such problem solving is important.

Further, it was discussed if everything good is Lean? Swan's input to the area is that maybe everything good is Lean. However, he emphasizes there are a lot of strange things that are called Lean but which in fact includes aspects that are opposite of Lean principles. Finally, Swan states that Lean PD probably will be used for a long period of time but in the long run might be replaced by something else.

Apprehension regarding the result of the survey
Swan's general apprehension of the result from the survey is that many companies have stated that they are using the tools and methods, and a cautiousness should thereby be taken regarding to the number of companies that are using the tools and methods. Regarding the time of how long the companies have been working with the tools and methods, Swan argues that was expected to have a greater shift towards present time. Companies are moreover described to pay more and more interest in the area of Lean PD. Specifically for Set-based design Swan states that no company used it for more than three years ago.

Moreover Swan states that specifically Hansei, Brainstorming and Root Cause Analyses have been used prior to Lean PD and companies are therefore stating that they are using them even if they don't use them in a Lean PD perspective. These tools and methods should thereby not be seen as specific Lean PD. Furthermore he describes that Trade-off curves are difficult to implement and is thereby not used by many companies.

4.3.2 Interviews with Stefan Bükk

Stefan Bükk works at the research center Swerea and carries out research and development. He is a Lean coach and educates in the area of Lean PD, in association with Chalmers and the industry. He has extensive experiences on the subject and shared his view on it, and below is a summary of the interview that will be used for the analysis.

According to Bükk, having the right culture is a prerequisite to succeed with Lean PD; "*the culture eats tools and methods for breakfast*". To look at only tools and methods is to have a wrong view on Lean PD. His experience is that many companies have knowledge about e.g. A3s and Checksheets but may have different names on it. When it comes to LAMDA he strongly argues that PDCA is not the same as LAMDA. Additionally he suggests looking at *Obeya* rooms and the role of *Chief engineer* to gain a better understanding of how a company is working with knowledge and Lean PD. The benefits that Bükk finds with using Checksheets are that the knowledge is written down and that it secures a quality level by the reviews done with the Checksheets. He believes Set-based

design is “true frontloading” by gaining knowledge early the process “when it is cheap”. Further, the benefits of A3s are simply that they are brief, clear and visual.

One way to measure knowledge improvements in Lean PD is to look at knowledge gaps in the PD process (Lindlöf, Söderberg, & Persson, 2012), this is not easy and not yet developed. Also the aspect of *how* to make space for new knowledge e.g. unlearning the old ways is of importance to consider when working with Lean PD.

Finally we discussed the importance of knowledge in Lean PD, where the three factors; cost, quality and time often are regarded as tradeoffs in the PD. However that the forth factor, knowledge, changes the rules of the game and could support the PD process in lowering the need for tradeoffs in-between cost, quality and time.

Apprehension regarding the result of the survey

Overall, Bükk is slightly skeptical to the amount of companies that have answered that they are using the tools and methods. One view could be that companies are using some aspects of the tools and methods but not in the “right” way and is hence not Lean. This could moreover affect that benefits are not seen to such a large extent as in literature. That traditional tools and methods are greater than Lean PD tools and methods depends, according to Bükk that they remain from previous initiatives such as 6σ. Moreover he is doubtful of the time companies have used the tools and methods, e.g. it is highly unlikely that companies have used Checksheets for more than 7 years. Those companies probably use them as a list at gates for verifying that certain aspects has been taking under consideration.

5 Analysis

The following section is an analysis of the findings from the study. The result from the case study, survey and expert interviews will be compared and discussed and relevant conclusions will be drawn. The main goal with the chapter is to answer the research questions.

5.1 Connecting Lean PD and Knowledge Management Theories

The goal with this section is to analyze the role of KM in Lean PD and the connection of the both areas. This analysis is hence the foundation of the answer to the first research question.

Influenced by (Lindlöf et al., 2012) the tools and methods presented in this thesis can be compared with the SECI-model, (Nonaka & Takeuchi, 1995). The four ways of transferring knowledge presented in the SECI-model, implies that the tools and methods could be used in one of these four ways for transferring knowledge. In other words, the tools and methods could be related to different modes of knowledge transfer, see Figure 29. Working with Set-based design is generally a method for transferring knowledge and has therefore a central position in the model. When using A3s, tacit knowledge becomes explicit by externalization. On the other hand A3s could also be seen facilitating for making explicit knowledge tacit when used as a problem solving tool. Trade-off curves have a role of both facilitate externalization and combination. When an engineer is articulating and generalizing both tacit and explicit knowledge into explicit knowledge by making a Trade-off curve, the knowledge is externalized and combined respectively. When the Trade-off curve is made, the employee externalizes existing knowledge by creating and writing down knowledge. When the curve is used, an employee could gain new tacit knowledge from the explicit knowledge in the Trade-off curve. Checksheets are on one hand transferring knowledge explicit to explicit when an engineer is using or updating an existing Checksheets without creating tacit knowledge. On the other hand, when using or updating Checksheets the employee might gain tacit knowledge and internalization has hence occurred.

When looking at the proposed model seen in Figure 29, it is clear that there exist tools and methods for all parts of the SECI-model, which is essential to create knowledge for the organization. Furthermore the model shows that according to the SECI-framework, to create knowledge and organizational knowledge, it is important for a company to not only implement one of the tools, since the spiral then is incomplete. Tools and methods to support a successful knowledge-creating organization with Lean PD exist, but actions should be taken to make sure tools and methods are implemented for all four knowledge transfers to complete the knowledge-creating circle. Moreover, as described by Nonaka et

al. (2000), the model should be supported by Ba. A physical place to share experiences to facilitate knowledge creation could, in a Lean PD environment be e.g. an Obeya-room. This was found at many of the case study companies, which have e.g. Visual Plans and A3s placed on the walls.

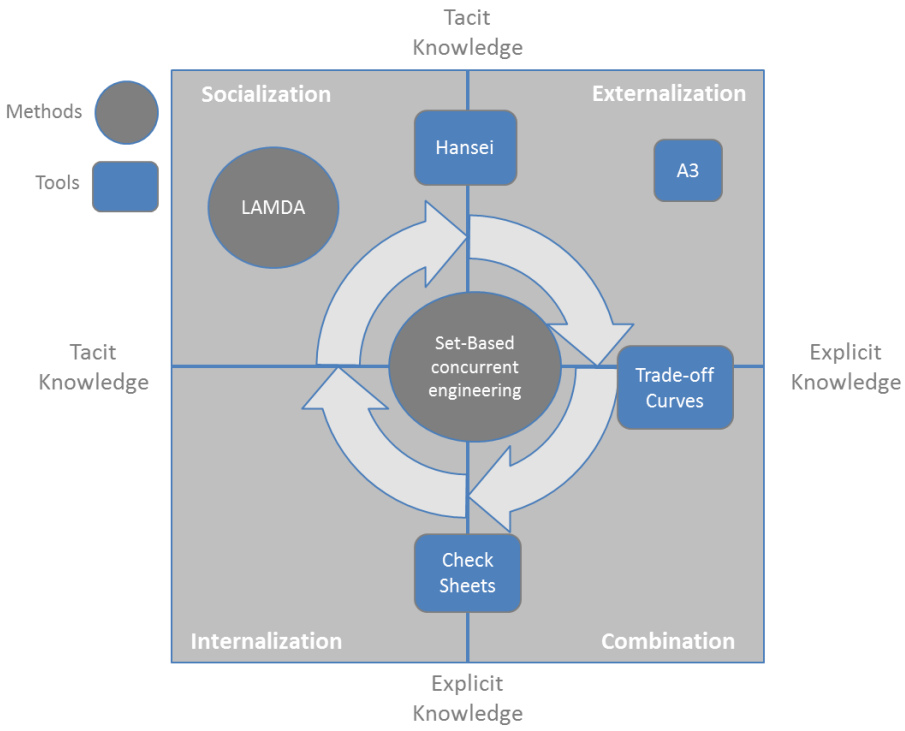

Figure 29. Tools and methods used in Lean PD analyzed with help of the SECI-model. Influenced by Lindlöf et al. (2012).

Interesting is to compare how literature describes how individual learning is transformed to organizational learning compared to the SECI-model. The three ways presented are personal facilitation, shared facilitation and artificial facilitation (Crossan and Inkpen, 1992 in Mehra & Dhawan, 2003). Personal facilitation could be compared with Externalization, which both could be described by a leader enabling transfer of knowledge (compare with Nonaka's (2007) example of the bakery machine) which in turn will create organizational learning. However, there is no coherence found between personal facilitation and the SECI-model. Lastly, artificial facilitation is to some extent similar to Ba since both describe settings in the company that should facilitate the transformation from individual to organizational learning. However, the differences are that Ba focuses more on interactions and meetings, and artificial facilitation includes the structure of the company in a broader meaning.

The tools and methods presented in this thesis could moreover be said to have similarities to most of the described knowledge theories, which might be natural since Lean PD has a focus on handling knowledge and learning (Kennedy et al., 2008). For example the Lean PD tools and methods have a focus on double-loop

learning. The reason for this lies in the nature of Lean PD that has a self-evident focus on Kaizen (Morgan & Liker, 2006) and LAMDA/PDCA (Bergman & Klefsjö, 2010; Kennedy et al., 2008), which both stress the importance of continuous improvements and a learning organization. Moreover the tools and methods could be analyzed with the theory of individual and organizational learning. As found in the literature review, one model of describing how individuals learn is by the experimental model that is similar to the PDCA-cycle. There is hence in literature a strong connection between theories about individual learning and Lean PD.

Based on the theory presented in this master thesis, the expert interviews and the case studies, knowledge has a large and important role in Lean PD. Frequently cited literature such as Kennedy et al. (2008) emphasize the importance of knowledge in Lean PD by describing a product value stream and a knowledge value stream. This is in our view the core of Lean PD since an efficient and sustainable competitive PD will not be possible without a successful managing of knowledge. Moreover the importance of knowledge in Lean PD is stressed by Bükk who emphasize the importance of identifying knowledge gaps within PD and take suitable actions to fill these gaps. Moreover we believe that the role of KM in Lean PD can be described to be the support and focus area that will facilitate for a company to stay competitive in the long run. Without a focus on knowledge in PD, it would be hard for companies to decrease the PD time and produce products at lower costs that will be necessary for companies to stay competitive. When looking at the result form the survey and the case study companies, generally, the focus on knowledge was less than in theory. However, at e.g. Kongsberg Automotive is switching towards a more knowledge focus where they have a system of Knowledge owners and Knowledge briefs that indicate the importance of knowledge for the company. This implies that knowledge has a big focus in their view of Lean PD since Lean PD is described to pervade their whole PD. This knowledge focus is important for Lean PD and needs to be taken into the use of Lean PD tools and methods.

To summarize, based on the discussion above, the view of knowledge in Lean PD is to a large extent similar to KM theories presented in literature, e.g. by the similarities of PDCA and organizational learning, and how tools and methods presented in Lean PD fulfills the requirements for knowledge creation in the SEC-model. The correspondence of the way knowledge is viewed in Lean PD compared with KM theories implies that Lean PD, as stated by e.g. Kennedy et al. (2008), Swan and Bükk, has a focus on knowledge, which in turn is beneficial for companies according to Nonaka (2007). KM and Lean PD appears as separate concept in theory. However it seems clear, after we have studied the two areas, that by applying KM in a PD environment we come close to the Lean PD concept where knowledge is of great importance.

5.2 Tools and Methods in Lean Product Development to Manage Knowledge

In this research it was found that there are different views on Lean PD in literature and among practitioners, nevertheless the view on what tools and methods that are used at Toyota are fairly similar. However, little literature on which tools and methods that are commonly used in the industry were found. This thesis contributes by presenting this. The result from the survey and the case studies shows that many companies use either one or a few of the tools and methods, or even that they have adapted their PD to a whole Lean PD concept. However, it is stressed in the literature that companies need to adapt the tools and methods to fit the people and their specific processes (Morgan & Liker, 2006). This is the situation at the case study companies, where they continuously select and adapt the tools and methods for their organization, but also make an effort to create the right environment to succeed with the tools and methods. Moreover, our apprehension is that no company uses an exact replica of the theoretical Lean PD, maybe not even Toyota. Yet, as we seen in the result of this research, many practitioners of Lean PD are found to be successful and are continuing to develop a more Lean PD. Even though many of the tools and methods are strongly connected, it was found in the case study companies that it is not possible to do everything at once but that tools and methods are implemented gradually and with continuous improvements of the tools and methods.

Root Cause Analysis, Barnstorming camps and Mentors are according to the findings in the survey, most frequently used of the Lean PD tools and methods that were included in this research. These are not specific tools and methods for Lean PD, but are also used outside this concept. This argumentation is moreover supported by Swan and Bükk. Hence, this could be the reason why these tools and methods are more widely spread among companies. Further, both Root Cause Analysis and Brainstorming are methods that have been used for a long time and that can be used successfully also in small efforts. Therefore, the use of the more Lean PD specific tools and methods are more interesting. As the result shows, around 50% of the participating companies are using, either sporadically of fully; Checksheets, Set-based design, Obeya, A3 and LAMDA/PDCA.

However, Hansei and Trade-off curves are not common among companies today. Trade-off curves are widely mentioned in Lean PD theory, hence it was surprising that so few companies are using it. However, the case studies at both Kongsberg and Atlet gave the explanation that some of the tools are difficult to use, and Swan states that particularly Trade-off curves are difficult. In the literature study of Lean PD, A3s, Checksheets, Set-based design and Trade-off curves were found to be a large part of Lean PD (Kennedy et al., 2008; Morgan & Liker, 2006). Moreover, the survey indicates that Obeya and LAMDA/PDCA are used to the same extent in the industry. Nevertheless, the case study

companies, that have a larger experience than most of the companies in the survey and that are relatively large, are found to have an even larger focus on Obeyas than the average companies. Also, Visual planning is widely spread in the industry according to the survey.

The result indicates that there are few companies that have fully implemented the tools and methods. Hence, there is a large potential for many companies. On this subject, it is important to be aware of what was found in the case studies; that companies need to find tools and methods that suits their organization and way of working and also adapt the tools to fit. Similarly, according to Palmér at Scania the usage of tools and methods also needs Kaizen (continuous improvements). Moreover, Bükk and Swan are slightly critical to the amount of companies that have answered that they are using the tools and methods and the time they have been used. This is an indication that companies, who answered that they are using a tool and methods sporadically, might use it to a very low extent. This is of course an effect of the design of the survey, but is nonetheless affecting the result.

Lean PD is a part of Toyota, and no specific time exists for when it was implemented. Yet, in the literature study it was found that Lean PD was presented more commercialized during the first decade of the 21th century by e.g. Kennedy et al. (2003) and Morgan & Liker (2006). This was early picked up by several Lean PD pioneers who now have used the Lean PD tools and methods for over 7 years. However, generally the studied companies have used many of the Lean PD tools and methods for more than 1 year and even for most of the tools and methods, over 3 years. However, to point out that the Lean PD tools and methods are still current, it is worth noticing that many of the tools, especially A3s and Obeyas, have also been implemented during the last 3 years. The number of publications on the subject of Lean PD has not appeared to be decreasing and a lot of interest from the companies participating in the survey regarding the subject of Lean PD was found. This finding is in line with Nonaka (2007), Dalkir (2011) and Lucas (2005) that describe knowledge, which is an important part of Lean PD, as an increasingly important factor to stay competitive.

To gain a "Lean" PD does not happen overnight. The survey result shows that many companies have yet not implemented the tools and methods fully. If not implemented fully, the tools and methods might not become a natural part of the organizations and thereby not gain fully commitment and all benefits are hence not seen. The nature of Lean PD as a continuous improvement could be one reason for this. The case study companies have come further but are still continually improving the way they are working with Lean PD. E.g. at Kongsberg, they started early with Visual Planning, but are now focusing on knowledge e.g. with help of K-briefs (A3s). They state that K-briefs are much harder to use than Visual Planning, but they see long-term benefits. Further,

Visual planning was easier to implement and hence a good start according to Kongsberg. This tendency was also found at other companies e.g. at Atlet, and Visual Planning appears to be an easy starting point for Lean PD since benefits are gained fast. Also, it was found at Atlet that tools and methods that are used by everyone, often and regularly have been the easiest to get to stick to the organization.

The importance of knowledge in Lean PD is stressed in theory, by the interviewed experts and at most of the case study companies. The knowledge transfer approaches Codification and Personalization in regard to the Lean PD tools and methods were considered in this research. The result of the survey shows that companies use the tools in different ways. For example A3s may be used as a pure summarize sheet (Codification) or as a discussion board between employees (Personalization). Further, if taken Hansen, Nohria, & Tierney´s (1999) views into account, an organization should choose one of the two approaches to successfully transfer knowledge, and the second should be used to support the first. However, when looking at the literature around how Toyota works, no indication was found that one approach is more important or "Lean" than the other, but instead that both support KM in the organization.

Reviewing the settings of the companies participating in the survey (e.g. type of customers and PD time) it shows that some of the settings have a connection to what type of tools and methods that are used. The settings that appear to affect the use of the investigated tools and methods especially A3s, Obeya rooms and LAMDA/PDCA, are product complexity and the PD time. The general trend in these cases is that companies with complex products and long PD time, use more often Lean PD tools and methods. Interestingly, the opposite relation was found for the non Lean PD specific tools and methods such as Brainstorming camps. The reason for that many companies are using it is probably due to that it is a tool that has been around for a while. However, companies with complex products and long PD time and have probably had a need for implement and focus on other tools and methods to manage knowledge in the PD and are therefore not focusing on Brainstorming camps any longer. The two settings (PD time and product complexity), may many times be related to each other; e.g. a company with complex products will most likely have a long PD time. The connection to the companies' settings could be explained by e.g. that these companies have more resources to implement the tools and methods, that it might be a larger need for it or that these companies have more to gain from it.

Finally it is interesting that number of components in the products, which could be viewed as related to complexity of products and PD, have no correlation to used tools and methods. One reason for this could be that companies have judged the alternatives in different ways.

5.3 **Benefits from Lean Product Development**

An implementation of Lean PD takes a lot of resources and it is therefore necessary to clearly know which benefits that could be expected. From the literature study, general benefits found were e.g. easier manage of knowledge (Kennedy et al., 2008), standardization and visualization (Morgan & Liker, 2006). This will in turn be a way to stay competetive on a global and rapidly changing market. Furthermore, e.g. Oosterwal (2010) and Morgan & Liker (2006), argue that the PD time will be significantly reduced and that the quality will increase when Lean PD is implemented correctly. This discussion is supported by Bükk who argues that reduced PD time is seen as a result from using Lean PD. Improved performance for the PD department was also found during the case studies.

The benefits of using Lean PD tools and methods could be described by a reduction of knowledge gaps. In the begining of a project, there is a lack of knowledge and there hence exist knowledge gaps within the organization, see Figure 30. A knowledge gap could e.g. be lack of information of the customer's requirements or how a material behaves under certain conditions. The goal for a succesful PD is to decrease these knowledge gaps as fast as possible in order to reduce the number of unnecessary loop-backs due to lack of knowledge. Our apprehension is that there exist tools and methods within Lean PD that will facilitate to decrease the number and the magnitude of knowledge gaps. As seen in the result from the survey and literature study are e.g. Checksheets beneficial to improve the basis for decision and A3s facilitate problemsolving, which in turn decreases the knowledge gaps. Moreover, the tools and methods presented will facilitate to decrease the magnitude and number of knowledge gaps between projects and in the organization as such. The next project hence starts with less and smaller knowledge gaps which make the company a learning organization.

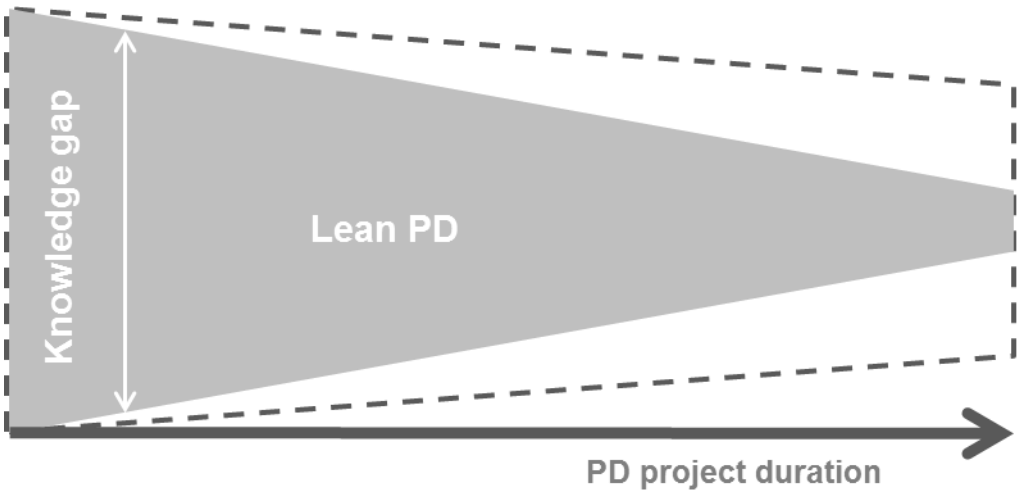

Figure 30. Illustration of how knowledge gaps decrease over time.

To gain great benefits from the tools and methods are, according to e.g. Swan, related to *how* the tools and methods are used. In literature it is emphasized that a focus should be on the tacit aspects of the tools and methods (Morgan & Liker, 2006). For example could A3s be used as summary documents but could also be used for discussions where e.g. a more senior employee have a discussion with a younger colleauge, and thereby is tacit knowledge transferred. A focus on the tacit aspect was not found in the survey nor during the case study and could therefore be an area for improvement. Moreover, when looking at the result from this research it is seen that, in line with Kennedy et al. (2008) and Morgan & Liker (2006), companies need to focus more on knowledge.

Benefits with A3s

The survey shows that benefits from using A3s are better basis for decision and increased shared understanding of projects, which to some extent are similar to benefits described by Morgan & Liker (2008). Increased shared understanding of projects is most likely seen since A3s easily visualize information that they are standardized and easy to access for employees, and finally that they provide a good summary of information. That A3s improve decision-making is probably due to that they are used as summary documents showed for decision makers that easy get an overview of the subject. This reasoning is to some extent supported by Swan who furthermore states that doing a summary for decision makers is not the point with A3s. That A3s are used at gates to facilitate for management by showing the status of the project, was also found during the case studies, e.g. at Atlet and Kongsberg Automotive. It is worth noticing that there are many different types of A3s, e.g. problem solving and decision making A3s (Sobek & Smalley, 2008) and it is hence expected to gain different benefits from its use. However, in common for all types of A3s is the importance of visualization. Furthermore it is interesting that reuse of information is not seen as a large benefit of using A3s. This could be a sign that old A3s are not reused, maybe due to the problem of storing and search for A3s, a problem that was described at Kongsberg Automotive and that Bükk also have found. Finally, that A3s are not reused could be an area of improvement to enhance the performance of managing knowledge.

Benefits with Checksheets

The largest benefits from using Checksheets that were found in the survey were e.g. better basis for decision, fewer changes late in processes and better documentation of information and knowledge, which all are benefits expected from working with Checksheets since the tool facilitates that existing knowledge regarding design concepts are taken into account. However, more knowledge for employees is not seen as a significant benefit from working with Checksheets in the survey. This is a bit contradictory due to that Checksheets are found in the survey also to make knowledge easier accessible for employees. In other words; knowledge is found to be easier accessed for employees but the employees don’t

get more knowledge, which is contradictory. The result hence indicates an area for improvement to increase the knowledge within the organization.

Morgan & Liker (2006) describe that knowledge reuse is a benefit from using Checksheets, which, as described above, were not seen in the survey. The difference between literature and the survey could be that Checksheets are not used in companies in the same way as they are described in literature, or that they are not fully implemented. Our apprehension from the research is that Checksheets sometimes only are used as a list, used at gates to check that everything is done correctly. Instead, if used as a Lean PD method, it should be an updated document that is used during the whole development process and hence transfer the knowledge through tollgates. However, since most companies have worked with Checksheets for a longer period of time (see Figure 20) it is likely that benefits likely to be seen, from the way Checksheets are implemented and adapted to the company, should have become visible at this moment.

Benefits with Set-based Design

In the survey, the most common experienced benefits for Set-based design were increased product quality and better basis for decision. These benefits are in our opinion related since quality is improved as a consequence of that better decisions are made. Further, these results indicate that by having parallel concepts and delaying decisions, a product with better quality can be developed. Furthermore, one reason is that having multiple concepts allows the designer to compare decisions and hence make decisions based on knowledge and not coincidence. In contrast to A3s and Checksheets, the largest benefits for Set-based design found in the survey are not coherent with the literature, where e.g. knowledge capturing is stressed more in both Kennedy et al. (2008) and Ward (2002). One simple reason for this could be that the benefits from Set-based design are affected by how it is used at the companies. Hence, if companies are not using Set-based design to share knowledge and create standards, those benefits are hard to gain.

It could be expected that some of the benefits, such as more knowledge sharing between employees, of Set-based design, come after it has been fully implemented, but it is fully implemented in very few companies in this survey. Further, the result indicates that companies are missing out on the knowledge gain (increased general knowledge and knowledge sharing between employees and between projects) by not implementing it fully and thereby including the! purpose of knowledge sharing and creating standards. We found that the reason for this, according to some of the case study companies, is due to mature products, specific requirements or cost limits. Moreover, little indication was found that companies are actually eliminating concepts instead of the traditional way, by selecting concepts, which therefore also gives another outcome of its use. Thereby are opportunities for knowledge creation lost. Further, one could argue that this could be due to that Set-based design is not completely easy, but

that if used correctly could be powerful. But, since many companies have large and very specific customer requirements it can be difficult to start a Set-based design initiative in the PD, hence for Set-based design to work for those companies, a more revolutionary implementation of Set-based design together with the customers might be necessary. However, companies that have worked with Set-based design for more than 3 years are experiencing more knowledge sharing between employees than other companies, which indicate that the benefits might take some time to gain.

How Benefits Depend on Time

For A3s and Checksheets, slightly greater benefits are experienced by long-time users, but for Set-based design that relation is not found, and the result is almost the opposite; the long-time users experience less benefits. Even if the result from the survey only shows minor differences, the result is interesting and the reasons could be many. One could be that the long-time users have had the time to develop and improve the tool to fit their organization and is therefore experiencing greater benefits. E.g. for Checksheets it is clear from the survey that long-time users are experiencing more benefits related to knowledge. We argue that the reason for this is that it takes time to get information and knowledge that can be reused, and the benefits is thereby not gained immediately.

For the opposite relation, where benefits are decreasing with time, one explanation could be that during an implementation greater resources are dedicated and the employees are more actively being coached to use the tool in the right way. The benefits could thereby be greater. After a while these resources are taken away and if the implementation has not been succesful, the tool might not be used in the right way and not used as frequently as it should. Benefits of the tool may thereby be lost. This reasoning is supported by Ulmestrand at Atlet, who argues that some initiatives acheive better results after some time since the routines have been adapted by organization. But furthermore he argues that the opposite could be true for some tools and methods when no-one puts the effort of making it stick. Specifically for A3s, Östman at Kongsberg Automotive argues that benefits become visual after 3-4 years when the effort of documentating the knowledge is paid-back since there exist documentation of the information and e.g. the engineer don’t have to put resources to do a re-test of a specific characteristic since the information already exist on the A3s. Finally it could be argued that some tools are simplier to work with and is thereby easier to stick to the organiszation, which in turns facilitate that the organization use them for a longer period of time and hence experience the wanted benefits.

Comparing the Benefits

A summary of the benefits described in the result are presented in table X. As seen in the table there is a coherence between benefits described in literature and

used in companies for Checksheets and Set-based design. However, for A3s this is not valid since companies are using A3s to facilitate decision making and to make decisions rather than for problem solving. There is however important to remember that there are different types of A3s and the survey do not distinct between these.

Table 2. A comparison of benefits between literature and companies' experiences from using Checksheets, Set-based design and A3s.

	Literature	**Survey**	**Expert interviews**	**Case Studies**	**Alignment?**
Check-sheets	Better design decisions	Better basis for decisions Fewer changes late in the process Better documentation of information and knowledge	Knowledge is written down and standards are created for making sure errors are not reoccuring	Front-loading Better basis for decisions Better documentation of knowledge and information More knowledge for employees	Yes, to a large extent
Set-based design	Better basis for decisions Saves money	Better basis for decisions Increased product quality	Knowledge in gained early in the process. Decisions are based on knowledge	More knowledge for employees Increased product quality Better basis for decisions	Yes, to a large extent
A3s	Problem solving Improved documentation Improved knowledge sharing	Better bassis for decisions Information easier accessed Increased shared understanding	The format is brief, clear and visual. Improves employees problem solving skills.	Better basis for decisions Improved structured thinking Improved shared understanding	Yes, to some extent

Furthermore, the survey and the case studies show that benefits from the investigated tools used in Lean PD often are related to knowledge management (Checksheets- better documentation of knowledge and information and A3s- knowledge is easier accessed), and this is in our view what is important and make these tools Lean. In the survey and case studies, only a minor coherence was found that Set-based design facilities knowledge handling. However, our apprehension is that if Set-based design is used as described in literature, where knowledge is collected and documented for elimination of concepts, knowledge benefits will be seen. Benefits regarding knowledge management could be put in

relation to Kennedy's description of Lean PD as a product value stream and a knowledge value stream (Kennedy et al., 2008). To handle and manage knowledge is furthermore described in literature to be necessary for companies to stay competitive, (Nonaka, 2007). And according to the survey, there exists Lean PD tools (Checksheets and A3s) that facilitate this.

Many of the benefits that are found in the literature are not perceived instantly. Companies need to change their culture, find and adapt tools and methods that fit their organization and finally use it in the right way in order to succeed. Regarding the specific benefits that can be found from using the different tools, it is also important to realize that the Lean PD tools and methods are more or less connected. E.g. in Set-based design, Trade-off curves cab be used and this can be visualized on an A3 in an Obeya room. Moreover it could be argued that the tools and methods become more beneficial together with Hansei; the reflection event creates opportunities for enhancing how the tools and methods are used. Sometimes, longer time is needed to gain the expected benefits from implanting a tool. Therefore, it is important e.g. according to Kongsberg Automotive to have a strong initiative and support from management that keep the initiative going even though the results are not seen instantly. Furthermore, according to e.g. Atlet, the tools that are used by many employees in the organization and are used frequently are easier to stick to the organization.

5.4 The Importance of Culture

Throughout this master thesis we have found a consensus between, Lean PD authors, KM literature and case study companies, that tools and methods is not everything and not the solution to effective PD. Bükk and Swan are both stressing the importance of having a good culture, by e.g. pointing out that "the culture eats the tools for breakfast" and that a cultural change is even necessary to succeed. Furthermore, almost a resistance to focus our thesis on tools and methods in Lean PD was found from interviewees, due to the experienced importance of the cultural part of Lean PD. The reason for this could be that if looking at Lean PD just as tools and methods, success is hard to reach. Further we argue that since tools and methods are a part of Lean PD, they are important. Likewise, in line with theory, e.g. Morgan & Likers´ (2006) description of a system view, and findings in this thesis, it is strongly recommended to see tools and methods as a part of a whole effort. Moreover, implementing the tools and methods could be a good start in a Lean PD effort where a cultural change can be developed in line and together with the tools and methods. Benefits of the tools and methods can be two folded. The tools and methods themselves create advantages and benefits, but they can also be used to change the culture within the company and peoples' mindsets.

Further, we argue that a combination of the tools, e.g. Set-based design together with A3s and Checksheets, with a supportive and knowledge sharing culture is

what provide the possibility to make Lean PD powerful. Further, coherent with the findings in literature and in case studies, the tools and methods needs to be adapted to fit into the cultural framework. On the other hand, many companies need to work on developing their culture to be perceptive to Lean PD. E.g. Dalkir (2011) refers to changing the culture from "knowledge is power" to "sharing knowledge is more powerful". Finally, continuous improvements of the culture and the tools and methods to support the culture, is in our belief the rightfully way to work with Lean PD.

5.5 The Future of Lean Product Development

Even if not directly included in our research questions, the area of whether Lean PD is a fad that will be replaced or implemented to stay is interesting. This discussion could be compared with management fashion (Abrahamsson, 1996) which is described as a "management technique that leads rational management progress" (Abrahamsson, 1996, p. 257). Moreover, management fashion is described to be the interaction of supply by management fashion setters (such as business schools and consultants) and the demand from management fashion users. One example of a management fashion is according to the author quality circels. However, Lean PD as explained in literature, case study and expert interviews are described to have a focus on continuous improvements and enhancing the knowledge for the organization. The concept of Lean PD could therefore be seen as a subject of its own medicine, where new knowledge about e.g. market, industry and technology can help to continuously improve the concept itself and hence making it a long lasting way for the industry to stay competitive in a changing environment. If implemented successfully it could therefore be argued that the concept could be a long-lasting initiative. On the other hand, looking in retrospective, theories for a more efficient and effective organization have been introduced every now and then. It could thereby be argued that as the academic knowledge, and the evolution among companies advance, newer, more developed and up-to date approaches might replace Lean PD in the long term. Summarizing, even if changes in the global environment will occur that affect the prerequisites for a successful PD department, Lean PD, focusing on continuous evolution and improvement could, in our view be applicable for a long time.

5.6 Recommendations for Future Research

This survey is a mapping and analysis of the current state in Swedish companies regarding tools and methods used in Lean PD and what benefits that are experienced. A recommendation for future work is to once again investigate which tools and methods that are used in Swedish industry, and which benefits that are experienced. By doing this an interesting comparison will be possible, especially regarding if more or less tools and methods are used and if the magnitude of the benefits are consistent. Also it would be interesting

complement to this research with a more qualitative approach and investigate *why* companies have selected the tools and methods they have and further *why* they see the benefits they see. In relation to this it is interesting to research why the companies don't experience as large benefits as described in literature.

Furthermore, we recommend investigating prerequisites and settings for a beneficial work with the tools and methods, such as organizational structure. Noteworthy is that that such a survey might demand a larger population than was possible in this thesis.

6 Conclusions

RQ1. *What role does Knowledge Management have in Lean Product Development?*

In literature KM has a large role in Lean PD and is described as the core of a successful Lean PD initiative. To manage knowledge in Lean PD is described to be important and there exist different tools and methods, described in this thesis, to facilitate this. Lean PD tools and methods can have many purposes and effects, and knowledge is one element that is significant and present in all. Furthermore, many of the case study companies in this research are aware of this and are indeed putting effort on KM and thereby gain a PD that is closer to Lean PD. However, in the survey it is clear that many companies are not realizing the importance on knowledge. Thereby they are not utilizing the full potential of the Lean PD tools and methods.

RQ2a. *What tools and methods from Lean PD are companies using to manage knowledge?*

Of the more Lean PD specific tools and methods, the most commonly used in companies today are Checksheets (59%), Set-based design (56%), Obeya (53%) and A3s (47%). The tool that is used significantly less frequent is Trade-off curves that only one of the 47 companies have implemented fully. The tools and methods that are used to the largest extent are Root-cause Analysis and Brainstorming camps. However, these are not seen as specifically Lean PD methods. Generally for the tools and methods that are presented, only a fraction of the companies have fully implemented the tools and methods. Further these tools and methods are according the research, helping to manage knowledge but to a much smaller extent than what were found in the literature.

RQ2b. *What are the benefits of the tools and methods?*

It was found that the benefits gained from using Lean PD tools and methods completely depend on how the company is using them. Companies need to select and adapt the tools and methods to suit their organization. If they manage to do this and then utilize the tools fully potential, this can gain benefits such as better knowledge sharing and knowledge creation. Further Lean PD facilitates a reduction of knowledge gaps in the PD process. However the largest benefit found at the survey companies for Checksheets, A3s and Set-based design is better base of decision. Further, it is argued that this base is due to increased knowledge and knowledge sharing among the employees.

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Appendix A- Survey distributed to companies

Following is a description of the tools and methods included in this survey.

A3: Also referred to as Knowledge-briefs, one-pager etc. Can be a problem solving tool or a visual and summarising document, but it is also a tool to spread learning.

Trade-off curves: Can be used for decision-making and to generalize the knowledge for reuse. The Trade-off curve shows, according to the company's best practices, feasible design options regarding two parameters.

LAMDA/PDCA: Is a systematic learning and knowledge development process. LAMDA stands for Look-Ask-Model-Discuss-Act, and PDCA stands for Plan-Do-Check-Act.

Obeya: A dedicated room for visualisation and knowledge sharing.

Mentor: An official mentor used for sharing knowledge and are working as a role model for others to share their knowledge. In Toyota Chief Engineers have a role as a mentor.

Checksheets: Standardized way of documenting learnings (on Checksheets). These are often inherent in stage-gate models and used to check that the design concepts are feasible. Checksheets are updated continuously and used actively. They can be used to standardize and review knowledge.

Set-based design: Sets of concepts are developed and evaluated in parallel and concepts are rejected after not passing evaluation.

Root Cause Analyses: Can be 5 Whys, Ishikawa diagram etc. and is a tool that in a systematic way supports to identify the root cause(s) to a specific problem.

Brainstorming camps: Are informal meetings where discussions are held to solve difficult problems. The meetings are held outside the workplace and are open to any employee. Criticism without constructive suggestions are taboo.

Hansei: Reflection events where actions and problems are discussed. One example of a Hansei event is when an employee and a manager meet to discuss failures and how to prevent these failures to reoccur. A written plan for improvement is a part of the event.

1. Which company do you represent?
2. What is your name?
3. Would you like to be anonymous in the result of the survey? In that case the company name will not be presented in the report nor in the presentation.
4. Generally, what kind of products do you develop?
5. Based on the description of the tools and methods above, to which extent are your company using the following tools and methods in your product development?
    a. A3
    b. Trade-off curves
    c. Set-based design

    d. Checksheets
    e. LAMDA/PDCA
    f. Obeya
    g. Mentors
    h. Root Cause Analyses
    i. Brainstorming camps
    j. Hansei
6. If you are using the tools and methods, for how long have your company used them?
7. Do you use other tools and methods for managing knowledge in your product development?
8. Does your company experience the following in the product development?
    a. Gained knowledge from projects is documented well
    b. Gained knowledge is easily accessible
    c. Gained knowledge is reused
    d. Gained knowledge is reused
    e. Knowledge is shared between employees
    f. Collaboration occurs over both project- and functional borders
    g. Other functions than R&D are involved early in product development
    h. Good basis for decision for concept choices exists
    i. Changes occurs late in the product development
    j. Products meet costs requirements
    k. Projects deliver on time
    l. Products meet quality requirements
    m. Time pressure in projects is high
    n. Work load in projects is high
    o. It is ok to make mistakes
9. Who are end-users of your products?
10. The distribution of responsibility between projects and functions is clear.
11. What is the level of complexity in your products?
12. In general, what is the number of components in your products?
13. Are project members within a project co-located?
14. What is the employee turnover at the product development department during one year (%)?
15. How many employees are there at the product development department?
16. How long does it generally take to develop a new product from decision to market launch (not including pre-research)?
17. Generally, how many employees are included in development projects for new products?
18. What is the general time horizon for operative goals in the product development?
19. Input for your next step in the survey
20. Please estimate the general effects after the implementation of the tools and methods.

a. Reduced Product Development lead-time?
b. Reduced Product Development costs?
c. Increased Product Quality?
d. Increased Product Quality?
e. Increased knowledge?

21. How are you working with A3?
22. What is included on an A3 in your company?
23. Are A3 used for in your company for:
    a. Problem solving?
    b. Creating standards?
    c. Knowledge sharing?
    d. As basis for decision?
    e. Visualization?
    f. Documentation?
24. Which effects do you see with A3 in your product development?
    a. Better visualization in the product development process
    b. Better documentation of information and knowledge
    c. Better documentation of information and knowledge
    d. Increased shared understanding of projects
    e. Increased shared understanding of projects
    f. Increased knowledge sharing between employees
    g. Increased knowledge sharing between employees
    h. More knowledge is shared between projects
    i. Better basis for decision making
    j. More knowledge and information are reused
    k. Information is easier accessed
    l. Better solutions for problems are found
25. What other effects do you see with A3 in your product development?
26. How is your company working with set-based design?
27. Are Set-based design used in your company for:
    a. Problem solving?
    b. Creating standards?
    c. Knowledge sharing?
    d. As basis for decision?
28. Which effects do you see with Set-based design in your product development?
    a. More knowledge for employees
    b. Increased product quality
    c. Increased cooperation over project- and functional borders
    d. Increased knowledge sharing between employees
    e. More knowledge is shared between projects
    f. Better basis for decision making
29. What other effects do you see with Set-based design in your product development?
30. How are your company working with Checksheets?

31. How often is a decision regarding a concept checked against a Checksheet?
32. Are Checksheets used in your company for:
    a. Problem solving?
    b. Creating standards?
    c. Knowledge sharing?
    d. As basis for decision?
    e. Visualization?
    f. Documentation?
33. Which effects do you see with Cheecksheets in your product development?
    a. More knowledge for employees
    b. Better documentation of information and knowledge
    c. Increased knowledge sharing between employees
    d. More knowledge is shared between projects
    e. Better basis for decision making
    f. Less changes late in the process
34. What other effects do you see with Checksheets in your product development?
35. How are you working with Trade-off curves?
36. How often are Trade-off curves used as a basis for concept decisions?
37. Are Trade-off curves used for in your company for:
    a. Problem solving?
    b. Creating standards?
    c. Knowledge sharing?
    d. As basis for decisions?
    e. Documentation?
    f. Visualization?
38. Which effects do you see with Trade-off curves in your product development?
    a. More knowledge for employees
    b. Better documentation of information and knowledge
    c. Better basis for decision making
    d. More knowledge and information are reused
    e. Less changes late in the
    f. Increased product
    g. Better visualization in the product development process
39. Do you have any other comments or feedback to us?

Appendix B– Tools and methods used segmented on time

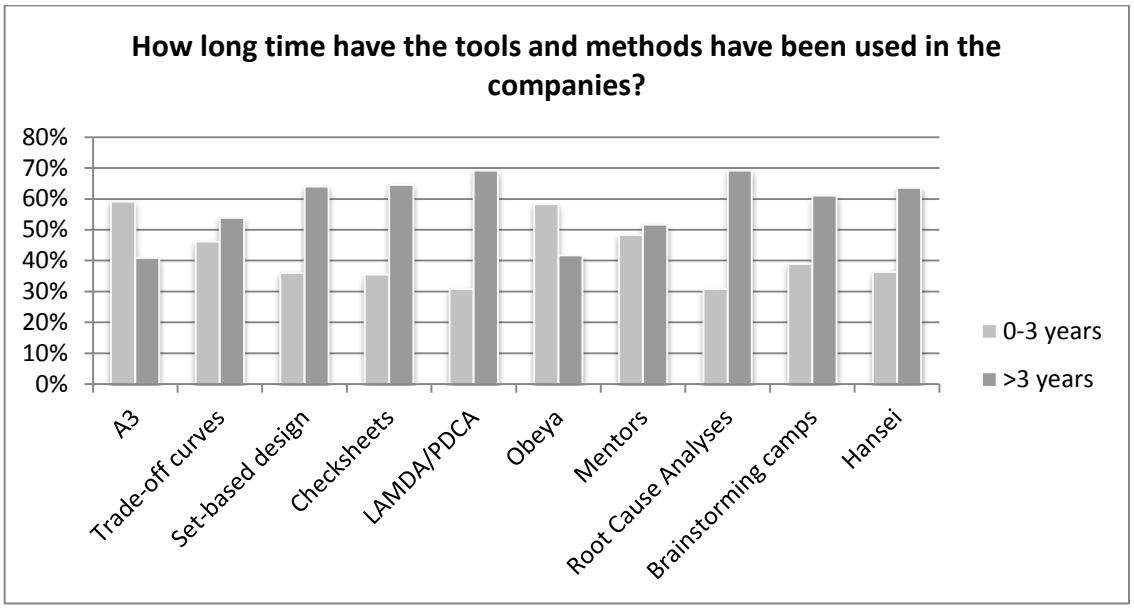

Figure 31. The time the tools and methods have been used divided in 0-3 years and more than 3 years.

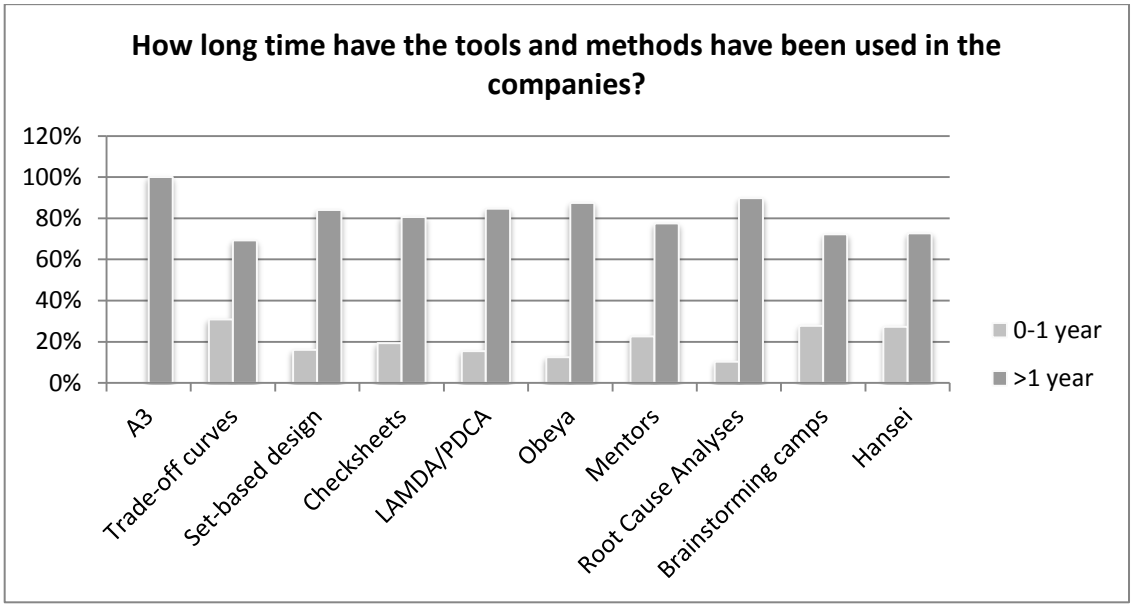

Figure 32. The time the tools and methods have been used divided in 0-1 year and more than 1 year.

Appendix C– Companies settings in relation to what tools and methods that are used

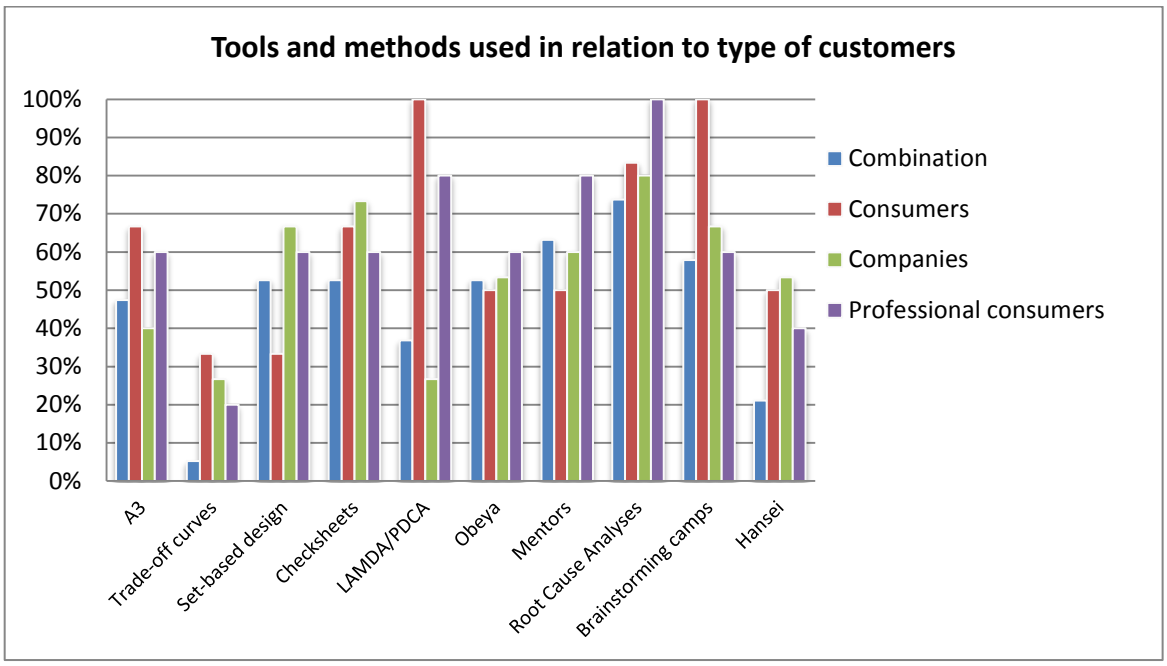

Figure 33. The diagram shows how many in each segment (type of customer) that uses the different tools and methods.

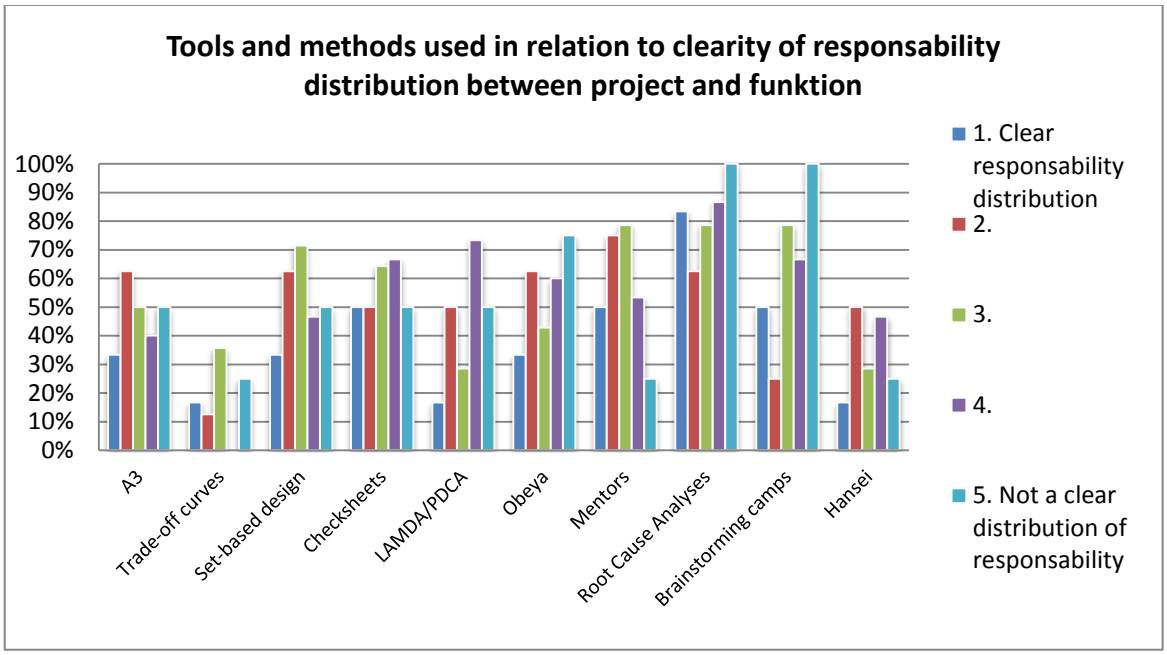

Figure 34. The diagram shows how many in each segment (clarity level of responsibility distribution between project and function) that uses the different tools and methods.

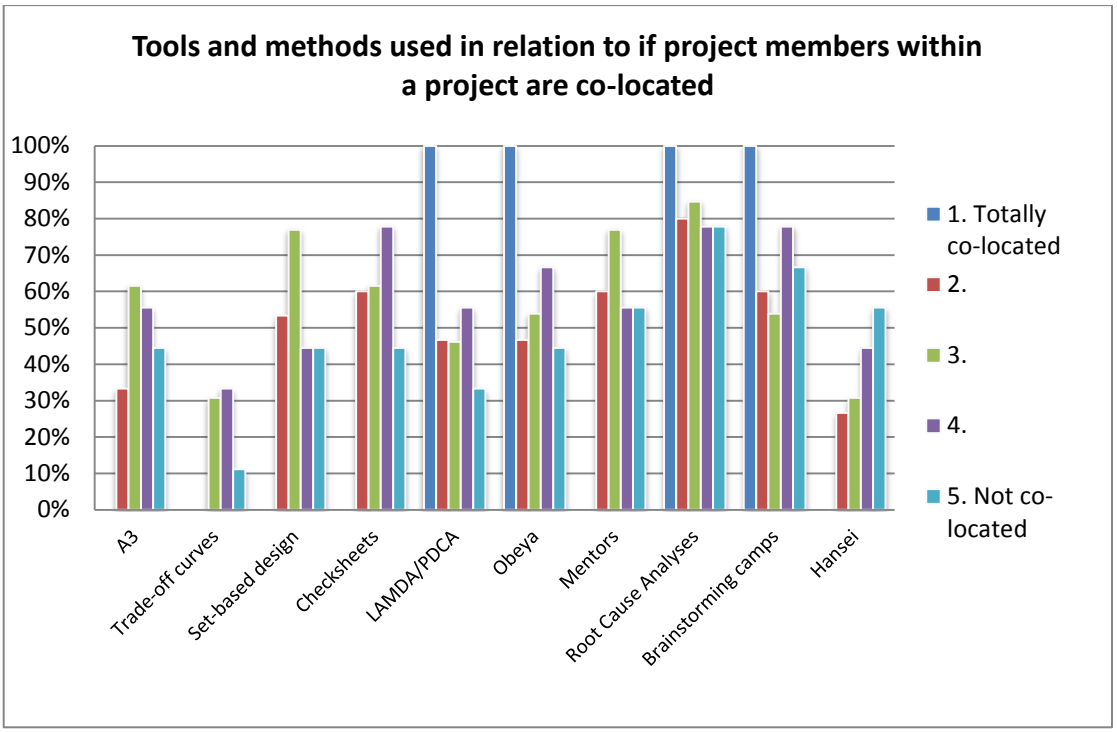

Figure 35. The diagram shows how many in each segment (level of co-location of members in a project) that uses the different tools and methods.

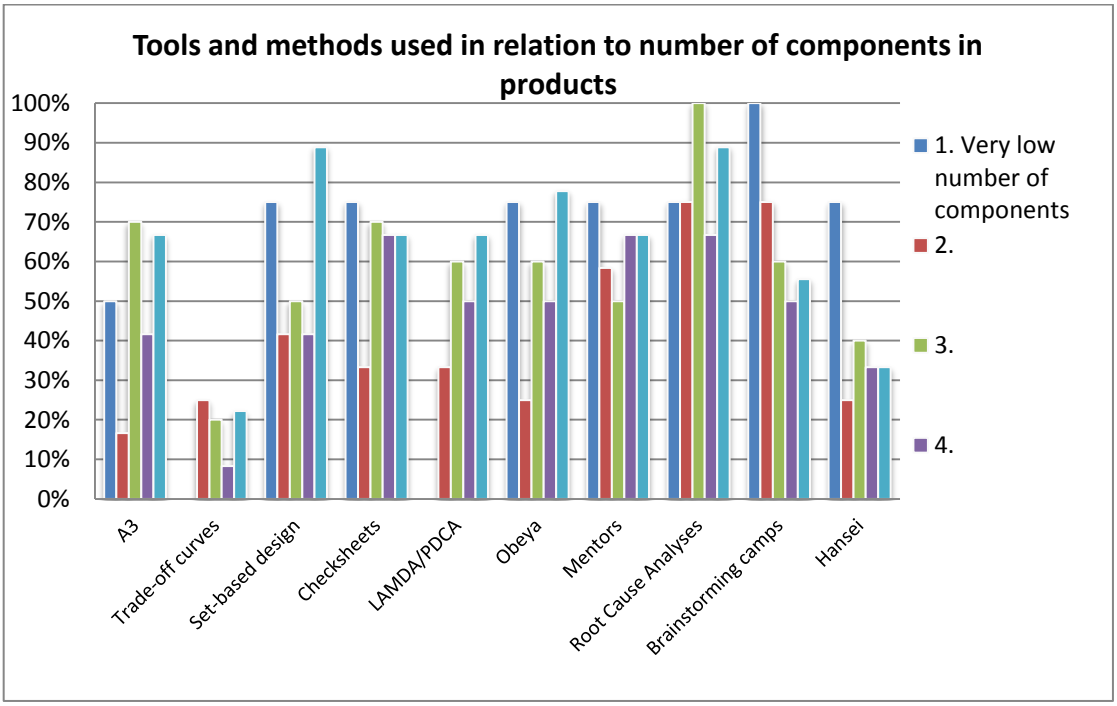

Figure 36. The diagram shows how many in each segment (number of components in products) that uses the different tools and methods.

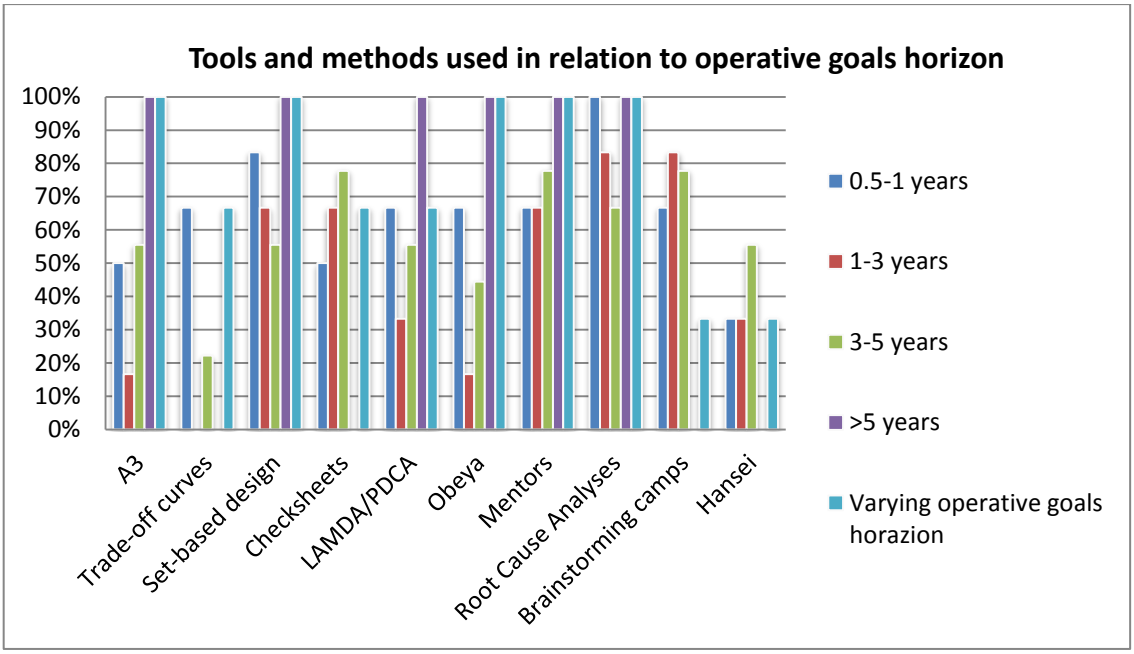

Figure 37. The diagram shows how many in each segment (operative goals time horizon) that uses the different tools and methods.

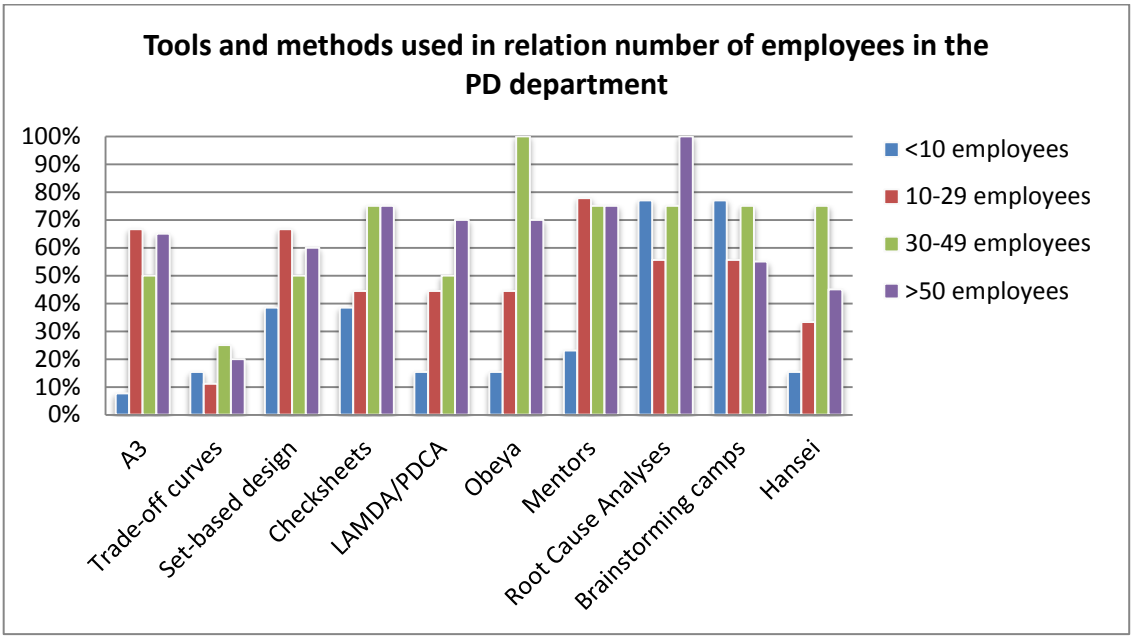

Figure 38. Tools and methods used in relation to number of employees in the PD department.