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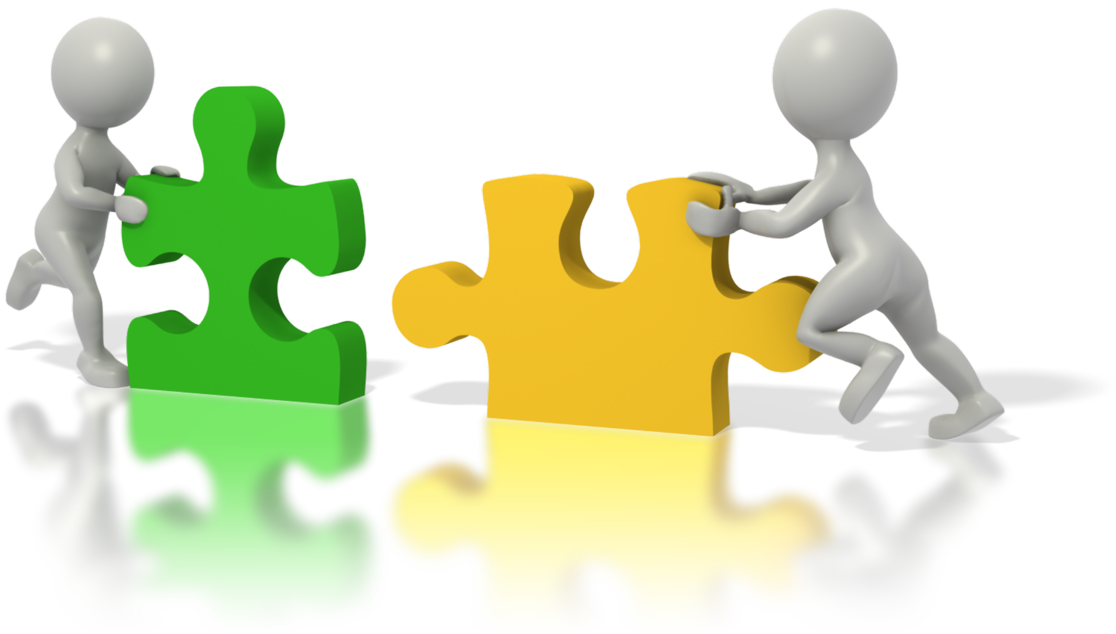

Towards the Integration of Lean Product Development and Knowledge Management

A Creation of an Internal Process' Value Stream

Master of Science Thesis
In the Quality and Operations Management Programme

SHARI ABRAHAMSEN
ERIKA DANIELSSON

Department of Technology Management and Economics
DIVISION OF SERVICE MANAGEMENT AND LOGISTICS
CHALMERS UNIVERSITY OF TECHNOLOGY
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SHARI ABRAHAMSEN
ERIKA DANIELSSON

Tutor, Chalmers: Hendry Raharjo
Tutor, company: Christian Almberg, Torgny Falk

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Department of Technology Management and Economics
Division of Service Management and Logistics
Chalmers University of Technology

SE-412 96, Gothenburg, Sweden
Telephone: +46 (0)31-772 1000

Cover:
Illustration of reaching alignment between two different parties.

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Abstract

Efficiency in organizations has become increasingly important as globalization has put pressure on faster development. To increase the efficiency, management theories such as Lean and Knowledge Management can be applied. The case company operates on a global level, making it important to have an efficient product development process to launch products rapidly. Therefore, it lies in the company's interest to understand how the internal Define-Measure-Evaluate-Process (DME-process), is carried out and how it can become more efficient.

The purpose of this master thesis has been to investigate how techniques from Lean Product Development and Knowledge Management can be integrated in the DME-process to reduce waste. To do the investigation, a literature review was conducted, qualitative data was collected through interviews with employees, and a workshop was conducted to validate or discard potential improvements. A value stream mapping of the process was conducted, where the company's theoretical process was studied, the current-state was mapped, and a future-state was proposed. Issues that were found, were lack of standardization, insufficient communication, and uncertainty regarding roles and responsibility. To improve the DME-process, suggestions were to ensure completeness of information, increase initiative when working in the process, use more tools to improve communication between the parties, and provide traceability of the process.

The theoretical implication of this study is to give insight of how Lean Management and Knowledge Management can be useful in internal processes with an internal stakeholder and customer relationship. Additionally, it can benefit companies which experience waste in product development processes and waste in terms of knowledge capture and reuse. The employees at the company have experienced difficulties in the DME-process. Therefore, the practical implication is to continue applying value stream mapping on several internal processes to increase efficiency and eliminate waste.

Keywords: Lean Management, Knowledge Management, value stream mapping, visual management, Lean Product Development, waste, internal process.

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List of Abbreviations

DME-process	Define-Measure-Evaluate-process
KMS	Knowledge Management System
KPI	Key Performance Indicator
LIMS	Laboratory Information Management System
NPD	New Product Development
R&D	Research and Development
TPS	Toyota Production System
VS	Value Stream
VSM	Value Stream Map

1. Introduction

Globalization has increased the competition on the market. This has led to a higher pressure on product development organizations in various industries to innovate new products at a faster pace, to be the first on the market or close the gap to the competitors. To be able to achieve this, companies rely on internal processes working efficiently, developing products with high quality and meeting customer expectations. To reach efficiency, it is important to avoid making mistakes along the way of the developing process, as this can result in higher costs and poorly developed products. Two management theories which can be used to reach efficiency are Lean and Knowledge Management. During the last century, Lean Management has been a tool for improving internal processes and reducing waste through standardization and continuous improvement, while Knowledge Management has become a competitive weapon by maintaining and reusing knowledge within the company. By combining the theories, possibilities for an organization to develop are unlimited.

The case company in this research is a leading global hygiene and health company, developing, manufacturing and selling products within the business areas of personal hygiene. Some of the largest markets are Germany, Sweden, Mexico, Colombia and Russia. The company has a major part of its global research and development (R&D) department located in Sweden.

1.1 Background

In 2015, a group within the product development and lab department at one of the offices in Sweden, started using more Lean techniques. These techniques were divided into four steps: process culture, improvement culture, learning culture and innovation culture. By introducing each step slowly and enable enough time to mature in the characteristics of each step, the company wants to maximize value of the introduced techinques. Currently, the company focuses on its improvement culture and learning culture. During the process culture-step, the company introduced visual management to make information more available. This was done by introducing cross-functional Pulse meetings with an overview of the progress of each project and additional meetings on a more detailed project or department planning level. After the implementation of the process-culture step, problems became visible.

The R&D department consists of several teams such as product development and laboratorium. The product development team works with innovating and improving products for future needs. They work closely together with the lab team, who is responsible for testing samples such as materials and products, and ensuring that documentation of the tests is available. The Define-Measure-Evaluate-process (DME-process) is a process between the lab and other teams, to assure that aspects such as external and internal requirements are fulfilled.

The DME-process is a working plan for creating, executing and presenting results of a request ordered internally. It includes several departments, such as product development, lab and different business units at the company. The process instruction was reviewed during an improvement project finished in 2016 and was changed from a text based instruction to a flow chart, see Figure 1, making it more visualized and simplified. Each phase guides the user through the required steps of the process, which should be fulfilled in order to move on to the next phase. The flow chart clarifies areas of responsibility for each step in the process and provides the user with supportive documents, such as working instructions. The DME-process has four stages of completion: ‘Received’, ‘Confirmed Agreement’, ‘Concluded’ and ‘Final Report’. Two of these stages are used as key performance indicators (KPI) for the process. The first KPI implies that requests should be set as ‘Received’ by the assigned lab representative within a target of one week after initiation. The second KPI measures if the final lab report has been created by the agreed deadline.

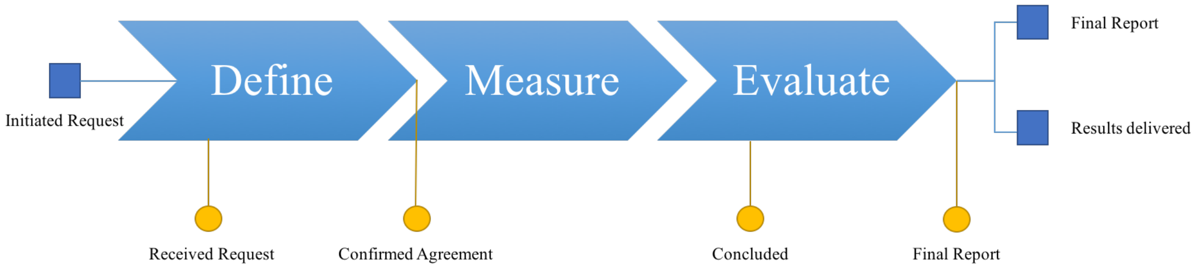

Figure 1 - The overall conceptual process flow of the DME-process, from initiating a request to receiving the results and a final lab report

When the need of a request arises, it is initiated by a test initiator. The need can be to test a new product or material in development or a competitor’s product. The request is created when the test initiator fills in the required information in the software Laboratory Information Management Systems (LIMS). The information which should be included in the request is the background, assignment and ‘wished deadline’. When this information is added, the request is either sent to the lab manager who then assigns the request to a lab representative or it is directly assigned to a lab representative by the test initiator and the Define-phase begins.

When entering the Define-phase, the request has been sent to the lab team. The lab representative should aim to respond within the target of the first KPI and the stage ‘Received’ has been reached. When the request has been received, the test initiator and the lab representative discuss the assignment, method and the deadline to complete the full request. In these discussions, aspects such as previous experiences and knowledge should be considered. In cases where there is no lab method suitable to carry out the request, a new method should be developed before the work proceeds. When everything has been agreed upon, ‘Confirmed Agreement’ is reached.

During the Measure-phase, the lab representative prepares and conducts the tests according to the agreed lab method. The lab representative is responsible for adding the test results in LIMS. After tests have been conducted and the data has been collected, the request enters the Evaluate-phase. The lab representative begins the phase by analyzing and evaluating the data with statistical tools e.g. Minitab or Excel. Based on the analysis, a conclusion is drawn. The conclusion is confirmed with the test initiator. If the request needs further measurements, the current request can be updated, a new request can be created or a new lab method needs to be developed. When both parties have agreed upon how to proceed from the conclusion, the stage 'Concluded' has been reached. The lab representative is responsible for finalizing the documentation of the request in LIMS, which includes writing the results, conclusion, summary and adding figures. When the documentation is finalized, the request reaches the stage 'Final Report' and LIMS generates the final report. In parallel, the results are delivered to the test initiator in a format that has been agreed upon.

Management at the case company wants to conduct a value stream map and has found the DME-process to be a suitable pilot project, as several issues in the process are affecting the everyday work. Some of them are mentioned by management as high variation regarding the quality of the lab reports, difficulties keeping deadlines, insufficient information in the requests, issues with the system LIMS and knowledge scattered over multiple areas of the organization, making it problematic to find what is needed. Solving these issues can result in identification of waste in the process, decrease the time for product development and testing, and thereby the products can reach the customer faster at a lower cost.

1.2 Purpose

The purpose of this master thesis is to investigate how methods from Lean Product Development and Knowledge Management can be integrated in the DME-process, in order to provide recommendations on how waste can be reduced.

1.3 Problem Formulation and Research Question

In order to fulfill the purpose, the areas of research have been divided into smaller sections supported by research questions. These questions will allow the researchers to dig deeper into the subject and provide an analysis supported by a theoretical framework.

The company has articulated issues in regards to the DME-process and its efficiency, since they are unable to reduce some of the current waste and thereby unable to achieve a smooth working process. As the company has implemented Lean techniques, e.g. visual planning, other Lean Product Development tools could support the organization when working towards reducing waste in its processes. In order to understand where the company can improve, the researchers want to map the current Lean Product Development in the DME-process. Hence, the first research question is:

RQ1: What are the aspects of Lean Product Development in the DME-process?

As the DME-process enables employees to both capture and reuse knowledge, it is of interest to see how Knowledge Management currently is carried out in the process. Hence, the second research question is:

RQ2: What are the aspects of Knowledge Management in the DME-process?

Based on the answers to research question one and two, the third research question will investigate Lean Product Development and Knowledge Management and focus on how the areas can be integrated in the process. Hence, the third and final research question is:

RQ3: How can Lean Product Development and Knowledge Management be integrated in the DME-process?

1.4 Limitations

The DME-process is used on a global level and is aligned with the way the company works worldwide. As there can be geographical differences in the way the DME-process is carried out, this thesis will focus on the DME-process at the development office in Sweden and the data gathered is limited to this location. The thesis will provide recommendations of how to implement possible improvements to reduce waste, but not cover the implementation itself.

2. Theoretical Framework

This Chapter will present the theory used for this master thesis. To gain a general understanding of the topics, the theory found in a literature review was divided into two main parts: product development and Knowledge Management. The theory about product development covers both traditional and Lean aspects of the product development process, such as visual management and value stream mapping. The Knowledge Management theory presents several aspects of knowledge types and how to handle them. In addition, some theory about Resourceful Sensemaking is presented to get an understanding of how organizations can work for their employees to better grasp the comprehensiveness of their coworkers' tasks.

2.1 Traditional Product Development Processes

All concepts will go through a process of product development in order to turn an idea into a purchasable product (Radeka, 2016). Riedel and Pawar (1991) describe the concept of sequential engineering as a traditional product development process, in which the manufacturing does not begin until product specifications are completely decided upon. Del Rosario et al. (2003) describe sequential engineering as throwing facts over the wall or handing over the result to an expert of the next phase, where "upstream decisions will constrain downstream decision" (p. 243). Wheelwright and Clark (1992) define the communication pattern in sequential engineering as 'serial mode'. In serial mode, there is one-way communication between the upstream and the downstream groups. The information flow is typically communicated from upstream to downstream whereas the error information flow is communicated the other way around, visualized in Figure 2. Because of the lack of two-way communication throughout development, Trygg (1993) expresses that products are seldom a perfect fit for manufacturing but instead requires resources in reworking the product from multiple different departments. Additional drawbacks with sequential engineering are longer lead times and no consideration of what happens downstream, since each department focuses on its own tasks and fulfilling set requirements. However, an organization can benefit from using sequential engineering by avoiding early investments in equipment (Riedel & Pawar, 1991).

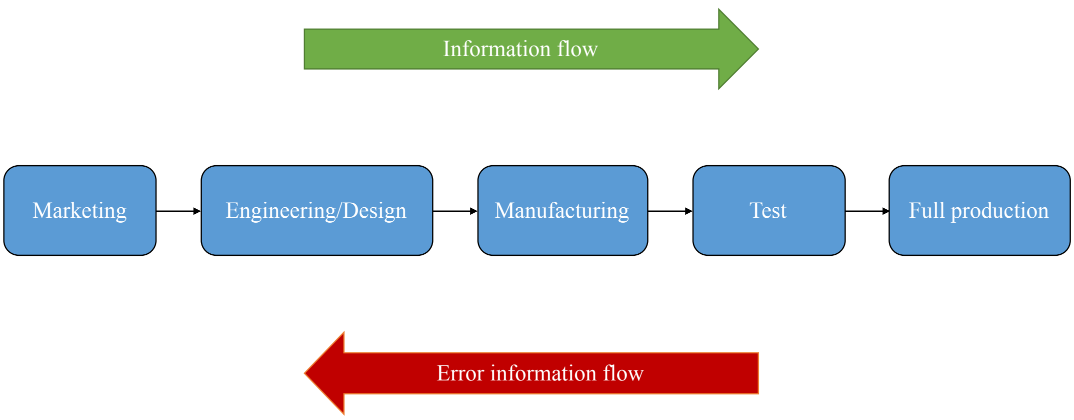

Figure 2 – The flow of communication in sequential engineering, showing the information flow from upstream to downstream and how the error information flow travels the opposite way

A common way to select an organization's product development project is by using a development funnel, see Figure 3. In general, the funnel is characterized with different stage-gates, screens or checkpoints. Inside the funnel, multiple projects compete for the same resources of the organization (Figueiredo & Loiola, 2012). Organizations adapt the development funnel by defining requirements in the different stages that the projects need to fulfill in order to move on to the next stage of the funnel. Using the funnel is beneficial as organizations can work with multiple concepts at the same time without ruling out potential winners at an early stage and the possibility to merge different concept ideas into one (Wheelwright & Clark, 1992). However, the difficulties with the funnel include aspects such as capabilities and objectivity. The development funnel requires large amounts of resources, making it difficult to end projects which do not fulfill screening requirements when the project has gone a long way through the funnel. In addition, comparing a planned funnel with what is carried out in reality is in general very different (Wheelwright & Clark, 1992). There are often multiple views of the funnel, which can make it difficult for organizations to be aware of what their screening requirements are.

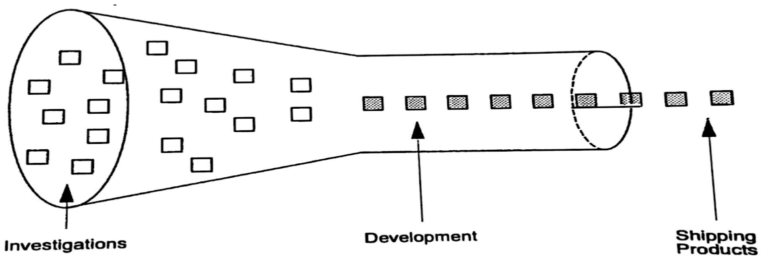

Figure 3 – A traditional development funnel showcasing how several ideas are investigated and narrowed down throughout the funnel, before shipping finished products (Wheelwright & Clark, 1992)

2.1.1 Seven Common Wastes in Traditional Product Development

Radeka (2016) mentions seven common wastes in product development:

1. *Reinventing* refers to ignoring existing knowledge and solutions or information not being accessible to others and therefore the same work has to be repeated.
2. *Design loopbacks* are when changes must be done or action has to be taken at a late stage of the development, delaying projects extensively.
3. *Unproductive meetings* are considered waste when the purpose is to only communicate status or when there is no purpose at all.
4. *Insufficient customer empathy* is when companies fail to fulfill customer value because they do not understand or know what the value is. In these cases, the customer does not receive the right product, which is considered wasteful.
5. *Excess requirements and specifications* can consist of three types of waste: not fulfilling customer needs, specifications not aligned with company capacity (not maximizing value) and maintaining excessive product complexity throughout the life cycle.
6. *Excess project management overhead* is always present and necessary, as project management rarely adds value to the customer. However, when project management is excessive, it makes it difficult for others involved in the project to add value to the customers, as management occupies an excessive amount of time.

7. *Overloading resources* occurs when employees have a large number of projects going on simultaneously with no prioritization. This waste can cause product development to slow down and reduce the innovation pace in an organization.

2.2 Lean Product Development Process

Lean emerged as a term in the late 1980's as a way to describe the Toyota Production System (TPS). Due to great domestic competition and scarcity of resources after the second world war, Toyota developed a business philosophy focusing on creating value for the customer and eliminating waste. The interest in Lean became common in the western world when the performance gap between Toyota and other car manufacturers grew remarkably (Hines et al., 2004). Today, Lean thinking has been spread worldwide and leaders have adapted it to suit not only manufacturing, but also logistics, service, retail, healthcare and other sectors.

Lean is by many known as tools and methods used to improve businesses. Radeka (2016) defines Lean Product Development as "the ability to get ideas to market faster, by maximizing value and minimizing waste every step of the way" (Chapter 1) and delivering the right product to customers at the right time and at the right price. Lean Product Development has proved to make organizations more profitable, more innovative and time efficient (Radeka, 2016) and thereby bringing products to the market faster with less exertion (Karlsson & Åhlström, 1996). An organization should not consider Lean as a state to be reached, rather a direction that continuously should be revised (Liker & Hoseus, 2008).

2.2.1 Lean Philosophy

One of the ground pillars in Lean philosophy is kaizen, meaning that one should never be easily satisfied with achievements, but instead always focus on how improvements can be done and continuously encouraging innovation. According to Lean philosophy, one must know what the benchmark is in order to improve, meaning that a standard must be present. In Lean processes, standardized work is used as a foundation for improvement to create a repeatable process resulting in the desired outcome. Without a standard, there will be many different ways of performing the same job and therefore impossible to improve. Additionally, in Lean philosophy, companies which do not have a high degree of standardization, should focus on achieving stable processes and only improve the standards when the process is stable. (Liker & Hoseus, 2008)

One way to work with improving processes is by introducing a learning cycle where time is set aside for evaluation of the process after an operation has been conducted. One such cycle used in Lean appears in the Toyota Job Instruction process. The learning cycle focuses on preparation before the task is carried out, how the operation is carried out, evaluation of the operation and finally actions to follow up the work. This ensures that every action is evaluated and taken into consideration the next time the learning cycle is performed. (Liker & Hoseus, 2008)

2.2.2 Lean Product Development Techniques

In order to reduce waste in traditional product development, Lean Product Development techniques can be applied. Karlsson and Åhlström (1996) describe an organization's transformation from traditional product development to Lean Product Development as a challenging journey affected by both hindering and supporting factors in regards to the techniques that can be applied. Discovering waste in a product development process is more difficult compared to a manufacturing process, as it depends on the knowledge in the product development process. Karlsson and Åhlström (1996) describe that a common mistake is to consider product development Lean because a few techniques have been implemented. Lean is rather about creating a coherent development process as a result of the implemented Lean techniques. Karlsson and Åhlström (1996) present some techniques for Lean Product Development called concurrent engineering, cross-functional teams and project management through visions and objectives.

Concurrent engineering is a technique where multiple activities in the development process are carried out during the same time, which can result in shorter development time. However, it can be difficult to operate several activities in parallel, due to the risk of making the wrong decisions. Karlsson and Åhlström (1996) state that it is important to strive for agreement before starting to use concurrent engineering and that all levels of the organization must settle with the same understanding of how to work with concurrent engineering. If not, the development cost can increase quickly. The reasons for this is that the product development process can be interpreted differently by different departments. Riedel and Pawar (1991) express that when implementing concurrent engineering, an organization needs to consider the risk of early investments and analyze if capabilities are sufficient in order to design a product in parallel.

Another technique is cross-functional teams, which Karlsson and Åhlström (1996) describe as teams where members are from different functions within the company and therefore can contribute with various input. One aim with cross-functional teams is that all functional aspects are integrated from the beginning of the process. This can give a positive input to the product development process, as involving different functions will make more people feel included in the project. Involving competent engineers in an early stage of the development process has shown to make a remarkable difference in terms of the development flow. One difficulty with this technique is that by focusing more on cross-functional teams, the focus on R&D might decrease. Another hindering factor is the difficulties in coordinating projects as people from different areas of an organization are involved in multiple projects. As the size of the cross-functional group often is bigger than the previous group size, meetings tend to take longer time and can sometimes become uninteresting for those who are not equally involved in the discussion.

Project management through visions and objectives is another technique in Lean Product Development, which can be very helpful when treated right but which also can create frustrations. When working according to Lean Product Development principles, the process should be guided by long term visions and objectives. If project management demands many updates and detailed specifications, the employees' focus might not be on the long term, but rather get stuck in the short term mindset. By making the visions cross-functional and continuously concretize them, people from different functions can be involved in creating the long term goals, which additionally facilitates the further work with cross-functional teams. The most important factor is considered to be top management support, where management shows presence and gives projects attention, which show significant difference in the success of a project's outcome. Meetings with management early in the process create more involvement from all other functions, as putting pressure on projects makes it more likely for the project to be successful. However, it is important to maintain the meetings with the management to keep the positive trend of development. (Karlsson and Åhlström, 1996)

In conclusion, the study carried out by Karlsson and Åhlström (1996) describes that the benefits of Lean Product Development are many, but the difficulties in implementation cannot be predicted or ignored. Change of behavior needs to be dealt with and new ways of working need to be communicated to those in the product development process.

2.2.3 Set-Based Concurrent Engineering

Toyota has been known for its rapid development of products while still maintaining high quality. Ward et al. (1995) describe set-based concurrent engineering as one of the success factors. While concurrent engineering allows for development in parallel, set-based concurrent engineering is described as "designers explicitly communicate and think about sets of design alternatives, at both conceptual and parametric levels. They gradually narrow these sets down by eliminating inferior alternatives until they come to a final solution" (p.44, Ward et al., 1995). Set-based concurrent engineering can have multiple concepts of a product, called sets, in the development process. By comparing with targets, different designs are eliminated (Kennedy, 2008). Further, Kennedy (2008) state that "interfaces stay loose to allow flexibility" (p. 20), which results in more designs being involved throughout the process instead of making an early selection. Ward et al. (1995) present advantages of Toyota's set-based concurrent engineering being communication, greater parallelism in the working process and promotes institutional learnings.

The first advantage is communication, which is described as "eliminating work on solutions that must later be changed" (p. 58). In addition, Ward et al. (1995) state that "it reduces the number and length of meetings. In the conventional approach, every change requires a new, lengthy meeting" (p.58). This is possible as Toyota's engineers work concurrently with a defined set of parameters for a product. By using set-based communication, employees are less likely to delay work, as the information needed to proceed will only change within the defined limits. Trust in relationships can be increased in set-based communication as the information is shared at an early stage and as the employees are trusted to do their work in the defined set of parameters.

The second advantage of working more in parallelism is possible as set-based concurrent engineering allows sub-teams at an early stage in the process. By having a set of defined parameters to work within and by working in sub teams with different responsibilities, the process can proceed without having to change at a later stage. Ward et al. (1995) describe it as "the product will be designed as much to fit the new manufacturing system as the manufacturing system to fit the new product" (p. 59).

The third advantage of set-based concurrent engineering influencing learning, is done by documenting experiences throughout a process of development. In Toyota's case, this is the lessons-learned book where important parameters regarding development and manufacturability can be found. By having the knowledge written down, others who face similar experiences can work more efficiently. The knowledge can be from all parts of an organization, which allows employees to find information from other departments as well as their own.

2.3 Visual Management

All processes are to some extent affected by uncertainty, such as duration and final outcome of a project. Galbraith (1977) defines uncertainty as "the difference between the amount of information required to perform the task and the amount of information already possessed by the organization" (p. 37). Therefore, it is important for organizations to efficiently handle information to minimize uncertainty and enable valuable decision making (Nonaka et al., 1994). Visual management supports the communication between individuals by making information more accessible and can improve the capability of processing information. This is of high importance since accessibility of information determines usage in a higher degree than quality in decision making (O'Reilly 1982). Furthermore, visual management is a method which facilitates common understanding and thereby decreases ambiguity (Lindlöf, 2014).

Lindlöf (2014) states that there are two main types of communication in product development, technical communication and task communication. Technical communication refers to the conceptual development of the product, while task communication regards the processes, planning and execution of activities. This means that task communication is used to discuss areas of responsibility and when tasks are supposed to be done. Visualization is frequently used in technical communication, such as computer-aided design models and prototypes, but is not used sufficiently in task communication, e.g. Gantt-charts which tend to change frequently and therefore require many updates.

One reason technical communication is used in a higher extent than task communication is because of the difficulties of updating the process with real-time information. A process, such as a development funnel, is often conceptually presented as the ideal process, but is not the actual process with uncertainties and real time changes. This leads to ambiguous understanding of the process because the actual implementation does not match the plan. A stage-gate chops the process into pieces and creates an illusion that the process is understood. In reality, the development funnel is only a plan of how the project should be carried out, but it does not contain any real time information (Lindlöf, 2014).

Visualization implies to choose which information that should be visually communicated. When something is difficult to understand, people tend to add more information, making the essence of the information less accessible. However, by changing the way of communicating, rather than adding more information, it could be easier to both grasp the information and continuously update it. Lindlöf (2017) states that it is very important to limit the visual content and only show what is useful when performing a task. Furthermore, by showing less information, it is easier for the individual to remember the information and faster grasp "the big picture". Additionally, the employees can make sure the information is updated and feel that they are in control of the project, which makes them more focused and more motivated to work. (Lindlöf, 2017)

2.3.1 Visual Planning

In all information exchange, the sender must choose what information to give the receiver, but still keep it on a level where it is easy to understand. By showing who is responsible for what and when, task communication helps visualize the actual progress of a project which can lead to a better project performance. (Lindlöf, 2014)

One way for an organization to navigate through an uncertain project is by using visual planning. For a project to be executed in a satisfactory way, the project group must stay focused during the whole process, while continuing to communicate and visualize the tasks which need to be carried out. In task communication, visual planning is used to both send and receive information. In contrast to a Gantt-chart, where the manager is in charge of the project planning, it is the individuals working hands on with the project who are in charge of communicating the actual progress of a project by visualizing the process (Lindlöf, 2014).

Pulse meetings are one example of visual planning, which are short weekly meetings with focus on the project portfolio level (Lindlöf, 2014). By using planning boards and frequent meetings, the Pulse methodology aligns the organization with the progress of each project (Kaya et al., 2014). The meetings focus on problem solving and openly discuss all issues which deviates from the plan. They therefore enable knowledge sharing across borders. Due to rapid changes in projects, it is important to check the organization's status frequently if time is needed to react to problems. The Pulse boards are structured like a matrix, where the organization's departments are put on one axis and projects on the other axis. The Pulse meetings use color coding to convey the status of each department and project in the intersection between the squares (Kaya et al., 2014).

2.3.2 KPIs in Lean Product Development

In Lean Product Development, the visualization of work is important to facilitate work procedures and set standards. One way to ensure that standards are present is by measuring some KPIs. A KPI should be a number which is important for the company. An example is Toyota, using visual management in their production in form of boards for their Floor Management Development System. The boards measure KPIs, daily activities, monitor the job and focus on long term goals and theme activities (Liker & Hoseus, 2008). The boards at Toyota are used for two-way communication of progress; for the manufacturers to communicate the status of the manufacturing to the management and for the management to communicate long-term visions and objectives to the manufacturers.

2.4 Value Stream Mapping

A value stream (VS) is defined by Martin and Osterling (2013) as "the sequence of activities required to design, produce and deliver a good or service to a customer" (p. 2). These activities can be both value-adding and non-value adding (Rother & Shook, 2009). A VS can be adapted to the level of analysis; on a cross-functional level between departments or on an organizational level from customer request to delivery of a product to the customer (Martin & Osterling, 2013). The VS mainly looks at two flows in an organization, the information flow and the material flow. Furthermore, a timeline can be applied as a third flow (Martin & Osterling, 2013). Rother and Shook (2009) describe the two flows as two different aspects of the same situation and both flows are equally important to map. In order to visualize the flows, value stream mapping can be applied.

Value stream mapping (VSM) can be used as a planning tool, business tool and a tool supporting organizations with change processes (Rother and Shook, 2009). According to Martin and Osterling (2013), the reasons why an organization wants to map the value stream can differ. Reasons mentioned could be to initiate transformation, to define strategic or business goals or to better understand the work flows between functions. Liker and Hoseus (2008) describe a VSM as identifying processes through visualization.

Martin and Osterling (2013) describe five reasons why VSM gives a holistic view of the flows in an organization.

1. It provides a macro level perspective that can be used in improvement work on a strategic decision level.
2. It visualizes the process in a full cycle, described as "a storyboard—of how work progresses from a request of some sort to fulfilling that request" (p. 8).
3. It "deepens organizational understanding about the work systems that deliver value and support the delivery of value to customer" (p. 8). This can enable components of complex processes being simplified and thereby understood throughout a higher level of an organization.
4. It allows for continuous improvement by quantitatively mapping value stream performance (by measuring time) and being able to improve identified barriers. By doing so, "an organization is able to better meet the needs of both its customers and its internal operation" (p. 10).
5. It takes into consideration the customers' experiences and the organization's internal processes. This allows organizations that are traditionally set up in a functional way to work cross-functionally and by cooperating, they fulfill customer needs.

These five steps can be challenging for organizations to consider when doing the VSM, as it can differ from how business is traditionally carried out. However, when successfully conducted it can benefit in positive changes regarding mindset and behavior.

2.4.1 Value Stream Mapping Approach

When initiating a value stream map, it is recommended by Martin and Osterling (2013) to start simple or in relation to the organization's maturity and how experienced the organization is with Lean principles. Rother and Shook (2009) visualize the steps of conducting a VSM in Figure 4 and suggest to start looking at one single product family rather than a whole production process. In this stage, a value stream map manager should be appointed. The role of the manager is to be responsible for understanding the map and improving it with help from the people from the different departments involved with the product family. The manager thereafter reports the findings to top management. Rother and Shook (2009) state that it is of importance that the manager can "see across the boundaries over which a product's value-stream flows and make change happen there" (p. 6). This is instead of having different department managers reporting their individual view of how the VSM appears to be in their own departments.

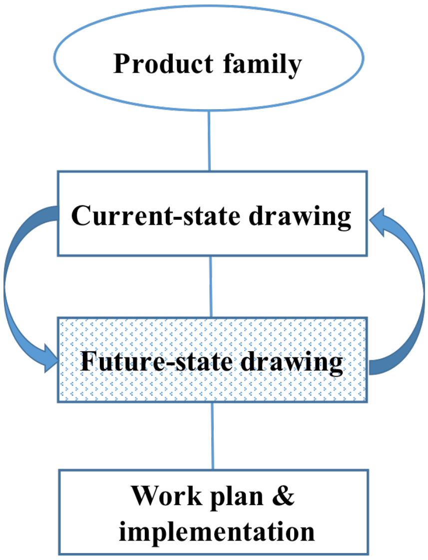

Figure 4 - Visualization of steps when conducting a VSM. This is a continuous process as the future-state becomes the new current-state after implementation (Rother & Shook, 2009)

Rother and Shook (2009) suggest to continue the VSM by mapping the current-state through collecting information from the flow of the product. During this time, information of how the future-state could be, will appear and should be noted. When mapping the current-state, it is important to walk the process backwards, i.e. upstream (Rother and Shook, 2009). This is because the process that is the closest to the customer, should define the work that is carried out. The information that is observed when walking the current-state should include information such as the customer of the product, the different sub-processes and the inventory held between these processes. After the drawings have been made, these can be translated into a current-state map.

Before creating the future-state map, Rother and Shook (2009) highlight the importance of understanding general Lean principles in order to integrate Lean into the future-state map. Rother and Shook (2009) say that focus should be on the root causes and how to eliminate that waste.

The next step is to draw the future-state map, which is essential for the VSM. Without a future-state map, there are no Lean value stream improvements to be made. The future-state value stream map should contain the implementation and changes to eliminate the waste of the current-state. It is important to consider the VSM as a continuous procedure, as the future state in time will become the current state, i.e. the next state to improve, illustrated in Figure 4 (Rother & Shook, 2009).

In order to achieve the future state and have a VSM that is valuable for the organization, a work plan should be defined by the value-stream manager. The plan should focus on creating a flow and should contain instructions on how to achieve deliverables. Rother and Shook (2009) suggest to circle areas of the VSM that are connected. They define them as value-stream loops, as seen in Figure 5 below.

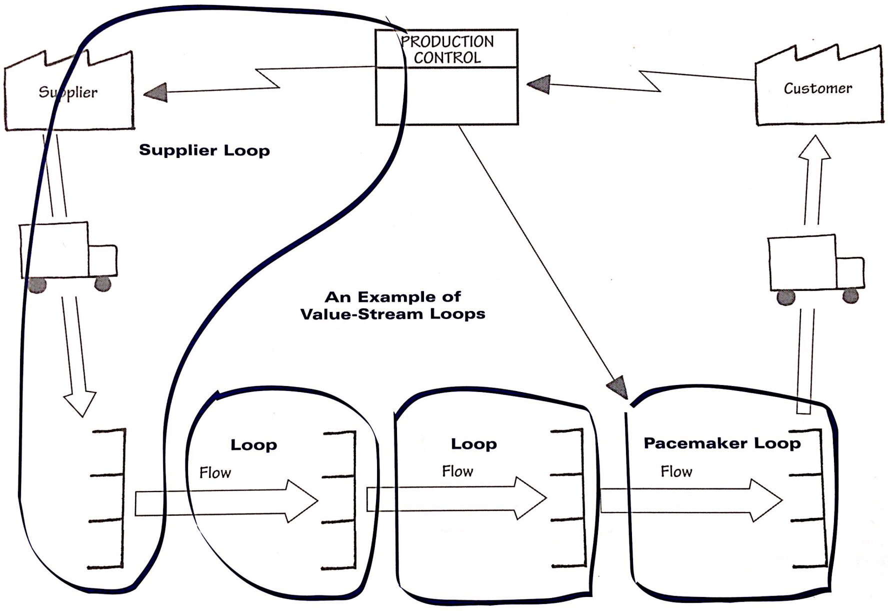

Figure 5 – A VSM with applied value stream loops focusing on smaller areas of improvements (Rother & Shook, 2009)

Thereafter, specific goals can be set for the different value-stream loops instead of the entire VSM. This makes the future state more achievable since it is divided into smaller sections that are more manageable. When using the value-stream loops, these can be prioritized in order of implementation. Furthermore, the plan for improvements and implementation should contain the following: what is planned to do, when it should be done, measurable goals, and checkpoints with deadlines. In addition, a yearly VSM review plan can be created in order to emphasize continuous improvement. When starting the implementation phase, it is suggested to start at a point where people have the most knowledge and the process is well understood. This is because an implementation is most likely to be successful in a point with high maturity and is generally where great savings can be achieved. As described earlier, the VSM is a continuous working process and needs to fulfill its purpose to gain motivation to be repeated.

2.5 Knowledge Management

In the later decades, the interest of treating knowledge as a resource for organizations has increased. Becerra-Fernandez and Leidner (2014) define Knowledge Management as promoting "the creation, capture, sharing and application of an organization's knowledge" (p. 3). Through Knowledge Management, organizations can gain competitive advantages, such as accelerated innovation and time-to-market, facilitated decision making, improved commitment to the organization, and more visible business core competencies (Becerra-Fernandez & Leidner, 2014). As organizations grow, the importance of making knowledge and experiences accessible for all employees independent of their location, increases. Hence, a big challenge is to develop methods for managing the expertise of employees. The following Chapter will describe the different aspects of Knowledge Management and how it potentially can be used as a competitive advantage.

2.5.1 The Knowledge Hierarchy

Several research articles describe knowledge as the highest level in a hierarchy, consisting of knowledge, information and data, see Figure 6 (Becerra-Fernandez & Leidner, 2014; Alavi & Leidner, 2001; Shin et al., 2001). In the Knowledge Hierarchy, data is presented as facts and observations that lack context and meaning, but which are easy to capture, store and communicate (Becerra-Fernandez & Leidner, 2014). By giving the data the right context and a purpose, it is transformed into information, making it possible to see patterns and trends in the data. The information turns into knowledge when it is possible to act based on the information, e.g. in decision making. A distinction between knowledge and information is that knowledge is anchored in a person's previous experiences and beliefs, while information only is a flow of messages (Nonaka, 1994). Knowledge is connected to human actions, while information is the foundation of an organization and creation of its knowledge. Shin et al. (2001) present several definitions of knowledge, information and data, which agree to knowledge being placed on the top of the hierarchy. One example is Bohn (1994) in Shin et al. (2001), proposing that "knowledge is something that describes what to do, information is organized or structured data, and data is raw material" (p. 336). However, it can be argued that information and knowledge represent different aspects of the same matter, meaning that when information is processed by a human it turns into knowledge and when the knowledge is articulated it transforms back to information (Shin et al., 2001).

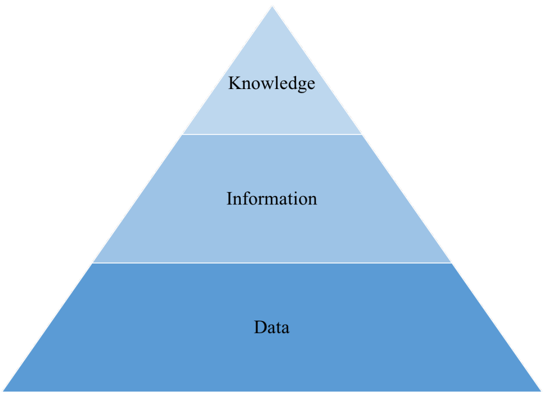

Figure 6 – Conceptual illustration of the Knowledge Hierarchy, showing that without data and information, knowledge cannot be created

2.5.2 Explicit and Tacit Knowledge

Knowledge can be divided into two types of knowledge: explicit and tacit knowledge. Explicit knowledge is formal and easy to communicate and share, while tacit knowledge is difficult to formulate and communicate, as it has a personalized character and is rooted in actions and involvement from a certain experience. The tacit knowledge can be divided into a technical and a cognitive part. The cognitive elements include personal beliefs and perspectives that make each individual interpret information differently. The technical aspect of tacit knowledge regards specific know-hows, such as the skill of riding a bike. (Nonaka et al., 1994)

2.5.3 Knowledge Creation and Transfer

Tacit and explicit knowledge creation are transferred and captured in different ways. Tacit knowledge is transferred between individuals in a continuous process, which is based on possessing the same knowledge and share a mutual understanding of a situation. Explicit knowledge transfer happens within a specific timeframe and can be gained from sources, e.g. databases and archives (Nonaka et al., 1994). Nonaka et al. (1994) state that "Any organization that dynamically deals with changing environment should not only process information efficiently, but also create information and knowledge" (p. 338). According to them, processing information is seen as problem solving and a way to understand how the organization can gain a competitive advantage. The competitive benefit of knowledge does not only rely on possession, but in addition the ability to generate new learnings and understand how these learnings can be kept and reused within the organization.

Nonaka (1994) presents four modes of knowledge conversion used to transfer old knowledge to new knowledge: socialization, combination, externalization and internalization. Socialization is the mode which allows knowledge conversion from tacit-to-tacit knowledge and is characterized by the value of the experience. This type of knowledge creation can happen without a mutual language because it is deeply rooted in observations, imitations and practices. The socialization process is difficult to implement without a shared perspective of knowledge and the people involved in this knowledge conversion should have a common understanding of experiences. The socialization knowledge conversion is associated with the behavior of people in an organization (Alavi & Leidner, 2001).

Explicit-to-explicit knowledge conversion is called combination (Nonaka, 1994). An individual can create new information through combining one explicit information source with another explicit information source. New information is created through reconfiguration of existing information in a new document (Alavi & Leidner, 2001). IT-solutions are helpful tools in combination knowledge creation (Nonaka, 1994) as they can reconfigure and code data in a systemized way.

The externalization and internalization modes include both explicit and tacit knowledge. When knowledge is converted from tacit-to-explicit knowledge, it is called externalization, which is described as expressing what cannot be expressed. This knowledge concept of externalization is not well developed and difficult to handle, as tacit knowledge is connected to experiences whereas explicit knowledge is not. In contrast, the internalization process, which is the process of transforming explicit-to-tacit knowledge, is often called traditional learning (Nonaka, 1994). Both Nonaka (1994) and Tsai and Lee (2006) describe learning by doing as a way to turn explicit knowledge into tacit.

2.5.4 Reuse of knowledge

Watson and Hewett (2006) claim that there are two main aspects which affect the effectiveness of knowledge transfer within a firm. From the Social Exchange theory there is the aspect of the willingness from the employees to contribute with their knowledge to the knowledge system, and from the Expectancy theory there is the aspect of how frequently employees access and reuse knowledge. How the theories affect the frequency of knowledge contribution can be seen in Figure 7 below.

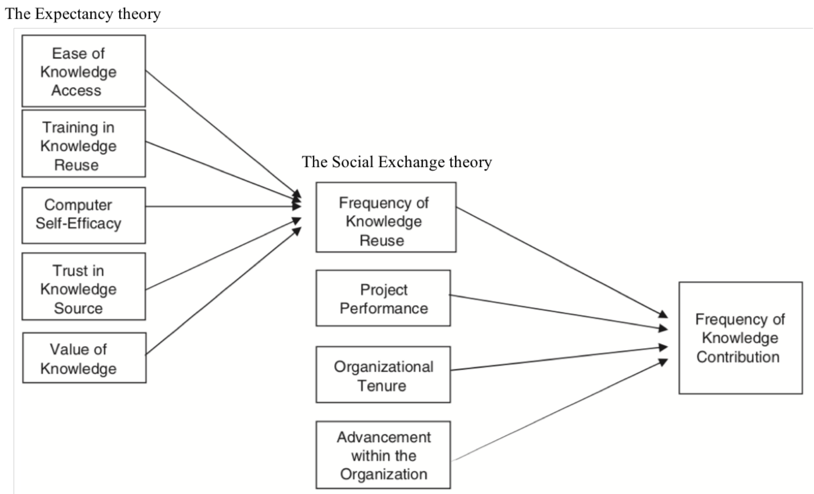

Figure 7 – How the frequency of knowledge contribution is affected by factors from the Social Exchange theory and the Expectancy theory (Watson & Hewett, 2006)

The Expectancy theory looks at motivation in the work environment and states that when people believe they will get what they want from doing a task, they are more motivated. There are three perceptions and beliefs which make the foundation for this theory: that a person's effort will result in the desired outcome, that the person will get something when the outcome is achieved and that there is a value with the achievement.

The Expectancy theory further describes five factors which affect the frequency regarding knowledge reuse. The factors are (1) ease of knowledge access, (2) training in knowledge reuse, (3) computer self-efficacy, (4) trust in knowledge source and (5) value of knowledge. The first factor, ease of knowledge access, implies that knowledge will be reused more frequently if it is easier to access from the Knowledge Management system. This factor supports the perception that the effort will result in the desired outcome. The second factor states that when employees are trained in activities they are supposed to do, it is more likely that the effort will result in the expected outcome. Similarly, the risk of not achieving the expected outcome increases when the employee is without the right training. Therefore, by teaching employees in knowledge reuse, an organization can establish an environment where more knowledge is accessed. This is connected to the perception that the employees know where to find the information and that they believe the desired outcome is more achievable by reusing the knowledge. Thirdly, when knowledge is managed from a database, the employees should feel that they master to use the computer. Watson and Hewett (2006) state that an individual who believes he or she has the capability to perform a task, is more likely to put more effort into the actions of the task. Regarding the Knowledge Management system (KMS), computer skills, defined as computer self-efficacy, are important to possess. There is a positive link between the intentions to use a computer application and the ease of using it, which results in increased motivation to reuse knowledge. The fourth factor, trust in knowledge source, suggests that individuals are more likely to believe that the information gathered from a source is useful if he or she trusts the source, hence positively affect the frequency of reusing the knowledge. The final factor affecting the frequency of knowledge reuse is the value of the knowledge. This regards the value one wants to receive for achieving the sought outcome.

The Social Exchange theory implies that the frequency of knowledge contribution from an individual is affected by four factors. The first factor is (1) frequency of knowledge reuse, which is affected by the factors mentioned in the section about the Expectancy theory above. The other factors are (2) project performance, (3) organizational tenure and (4) advancement within the organization. The first factor states that when someone receives a benefit by reusing knowledge, the individual will feel obligated to do the same in return. Therefore, when the individual does something to return the reused knowledge, this will benefit the company's Knowledge Management system, the person who contributed with the knowledge from the beginning or someone else. This means that the part who exchanged the knowledge will get something back and thereby increase the frequency of knowledge reuse (Watson & Hewett, 2006). As the Social Exchange theory states that individuals will contribute more to knowledge when they benefit from the exchange, the second factor of project performance can affect the frequency of knowledge contribution. If the knowledge is valuable for the performance of a project, the more an individual works with the project will contribute to adding more knowledge. Similarly, the third factor of organizational tenure will contribute to more frequent knowledge contribution because individuals will work harder when the organization is important to him or her. When an employee feels ownership and gets positive feedback from the firm, trust is built between the parties and the commitment increases. Therefore, the degree of organizational tenure can be seen as an idea of how much knowledge the employee will contribute with. The final factor, advancement within the organization, regards how organizational support can increase an employee's contribution to the knowledge creation. If an employee feels that his or her contribution to the organization has been appreciated and recognized, the employee usually performs better, often at a level higher than expected by the firm. As promotions often are associated with recognition, it has been found that employees who advance in the organization more frequently contribute to add knowledge.

2.5.5 Knowledge Management Systems and Alternative Knowledge Perspectives

Alavi and Leidner (2001) present how knowledge can be interpreted based on five different perspectives. Every knowledge perspective demands different strategies in being managed, each connected to different Knowledge Management systems, which support organizations to create, store, transfer and apply knowledge. The perspectives are:

1. Knowledge as a *state of mind* is described as the state of understanding and knowing, based on having experienced or learned something and the ability to apply the knowledge on the organization's needs. A strategy to handle this perspective is that knowledge should be learned and understood by the individual through arrangement of information. Therefore, it is important to have a KMS which gives access to knowledge sources, rather than knowledge itself.

2. Knowledge as an *object* considers knowledge as something which can be stored and should be managed through knowledge stocks, where it can easily be retrieved. When managing this type of knowledge, the KMS should facilitate gathering, storing and transferring of knowledge.
3. Knowledge as a *process* underlines that knowledge can be known and acted upon at the same time. It highlights the importance of expertise and focuses on knowledge flows such as creation, sharing and distribution of knowledge. The task of the KMS is to connect knowledge sources to simplify the creation of both depth and breadth in the flows.
4. Knowledge as an *access to information* implies that accessibility of information is important and that structuring knowledge must be facilitated. The KMS must provide mechanisms for effective search and retrieval to find the suitable information.
5. Knowledge as a *capability* is presented as the way of influencing future action based on the ability to use information from previous experiences. This implies that individuals can interpret older information and experiences in a decision making situation. It can be managed through strategic understanding of how to perform a certain task and through building core competencies. By developing individual and organizational capabilities, the KMS can gather knowledge.

2.5.6 Knowledge Waste

Ward and Sobek (2014) describe three categories of waste in knowledge: hand-off, scatter and wishful thinking. They state that "the wastes frequently occur together, so that the same practice creates all three kinds of wastes" (Chapter 3), which makes it important to focus on waste as it easily increases in scale.

Knowledge scatter occurs when one gets disrupted in work because a new or uncertain situation has occurred which requires that person to put time and effort firefighting the uprising situation. Two examples given by Ward and Sobek (2014) are that a reorganization requires employees to adapt to a new situation and find a new way of working or adding new people to a group and having to provide information to the new group members to proceed with the work. In order to reduce the amount of scatter, Ward and Sobek (2014) suggest to stop reorganizing and avoid having subordinates requesting information on short notice. This can help ensuring that the right knowledge is at the right place instead of having it scattered in the organization.

Ward and Sobek (2014) describe hand-off as a separation between knowledge, responsibilities, actions and feedback. Hand-off becomes wasteful when the person making a decision does not have sufficient knowledge to do it well or cannot turn it into reality. To avoid this, organizations need to ensure that the knowledge is understood by the person who will act upon it.

When decisions are not based on facts or data, they become wasteful leading to wishful thinking. One might think that all knowledge has been acquired in order to proceed development, when in reality, there is insufficient information to proceed. Ward and Sobek (2014) describe wishful thinking to potentially create large amounts of waste late in a development project, as decisions not based on data can create problems such as quality issues, high costs and misperception of market needs. In the final stages of development, project teams must solve issues under high pressure while looking for other alternatives to finalize the development.

2.6 Resourceful Sensemaking

Wright et al. (2000) define Resourceful Sensemaking as "the ability to appreciate the perspectives of others and use this understanding to enact horizon-expanding discourse." (p. 808). This theory can be applied when there are differences in the perceptions between people, departments or organizations (Wright et al., 2000).

According to Beverland et al. (2016) studies have shown that conflicts between departments can be a result of different ways of thinking. In order to have departments work closer together and create a better understanding, their study from 2016 between a marketing team and a design team working with new product development (NPD), applies Resourceful Sensemaking. The study shows differences in the perspectives of how the teams view the relationship to environment, relationship to time and the nature of truth. The differences that were identified, became the foundation when applying Resourceful Sensemaking. The aim with Resourceful Sensemaking is to create a mutual concept between departments rather than having one department adapting to the other.

2.6.1. Exposing, Co-opting and Repurposing

Beverland et al. (2016) describe three practices to reach Resourceful Sensemaking: exposing, co-opting and repurposing. First, exposing was used for the departments to expose their ways of working, as a practice "to reveal the interpretive schemes" (p. 637). The article describes these meetings for exposing as challenging and uncomfortable, but still enlightening as it resulted in realization that the two departments work individually rather than cooperatively. Second, co-opting was done to showcase the tools, concepts and languages used in the different departments. This enabled the different departments to express their perspectives and come to realization of how they differed. The intentional strategy was to have cross-sectional discussions and as the study showed, the marketing team and design team in this case realized that to improve the collaboration, breaking the barriers between the departments was necessary. Finally, repurposing combines exposing and co-opting to define a common ground by deploying the tools, concepts and languages of the other department. This enabled joint knowledge development, as both departments were engaged in repurposing the findings of the other department and concluded in a greater understanding for the work carried out in the NPD. (Beverland et al., 2016)

2.7 Conceptual Framework

To understand the correlation between the different theoretical variables, a conceptual framework has been created, see Figure 8. The conceptual framework describes the independent variables, the correlation to the other independent variables and the relationship to the dependent variable of 'High Efficiency'. It defines the purpose of the theoretical areas and the usefulness of these in the research.

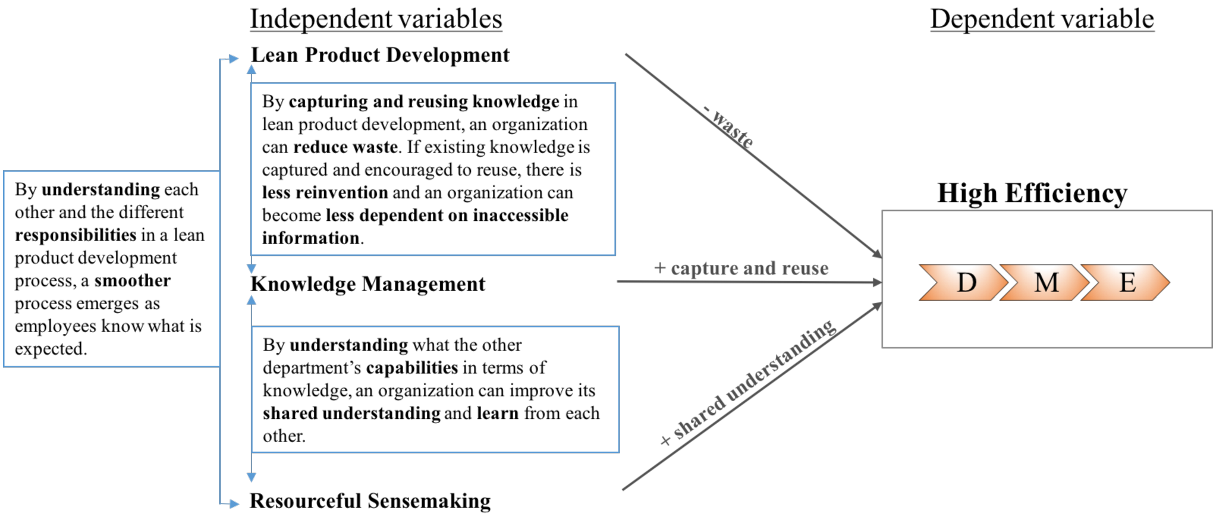

Figure 8 – A conceptual framework showing how the areas in the theoretical framework relates to the dependent variable of reaching high efficiency in the DME-process

3. Methodology

The following Chapter will present the method used in this research and justify how the methods were chosen. The research approach will be described, followed by research strategy, research design, research method and the ethical principles that were taken into consideration when conducting the research.

3.1 Research Approach

Bryman and Bell (2015) present two research approaches, deductive and inductive research. In a deductive research, the researcher deduces a hypothesis based on theory. The researcher collects data with the hypothesis in consideration. From the findings of the data collection, the hypothesis is tested, resulting in confirmation or rejection of the hypothesis and thereafter a revision of the theory. This research approach is suitable when existing information is used for further investigation within the same area, with the opportunity of gaining a deeper understanding. The other research approach is an inductive research, where the goal is to generate new theory based on data. An inductive approach is preferred when there is a lack of conducted investigations within an area and when the collected information is limited.

This thesis had both an inductive and deductive approach. As the DME-process was used as the base for the research, the information and aspects regarding the process were used to potentially build new theory and therefore an inductive approach. In the research, the DME-process was used as a hypothesis. By collecting information in regards to how it is carried out, the hypothesis has been tested and therefore this research in addition has a deductive research approach.

3.2 Research Strategy

The research strategy refers to what orientation the execution of the study has. Bryman and Bell (2015) define two research strategies, quantitative and qualitative research. A quantitative research demands data which is measurable and usually has a great focus on numbers. Because of this, a quantitative study can provide the researcher with a brief understanding of the results, often based on statistics. However, intangible parts can be difficult to investigate through a quantitative strategy and in those cases a qualitative research structure is more suitable. A qualitative strategy usually collects data containing words rather than numbers. This makes it possible to get a deeper understanding of the underlying meaning and to emphasize the way people interpret their surroundings and social world.

In this research, a qualitative strategy has been chosen because of the type of data that has been gathered. The data consists of observations, interview transcriptions, workshop material and literature review, which can be difficult to quantify.

3.3 Research Design

In order to provide a framework for the collection and analysis of the data, a research design has been defined (Bryman & Bell, 2015). A case study has been conducted, as this research studies one case, in a single organization at a single location. Bryman and Bell (2015) describe case study as "the focus on a bounded situation or system" (p. 68) which in this research is the DME-process. In addition, Bryman and Bell (2015) describe that "the researcher aims to provide an in-depth elucidation of it" (p. 68), referring to the object of interest, i.e. the DME-process.

To ensure a trustworthy qualitative research, Bryman and Bell (2015) present four quality criteria: credibility, transferability, dependability and confirmability. The usage of reliable literature sources such as journals that are indexed with science citation index and an accurate reprint of the interviews ensure a credible research. In this research, the interviews have been recorded and the parts which were used in Findings, were translated, as the interviews were held in Swedish. As qualitative findings tend to be unique, it is of importance to ensure the transferability of the study. Therefore, an adequate description of the process has been written. The dependability can be ensured by keeping records of each step in the research. Interview transcriptions and descriptions of how the data has been analyzed are presented. To ensure confirmability in the study, it has been necessary to make sure all researchers of the thesis acted in good faith. This means that no personal values were included in the research.

3.4 Research Method

The research methods used have been literature review, observations, semi-structured interviews and a workshop. By triangulating the research methods, the validity of the findings has increased and the risk of misinterpretations has decreased.

3.4.1 Literature Review

The literature review has been conducted continuously throughout the study and has laid the foundation of the knowledge needed to answer the research questions. The reason why the literature review has been carried out throughout the study has been to allow new information to be introduced during the research.

The literature has been used to develop the research questions. By researching existing literature, it has been possible to understand the significance of this study. The literature review made it possible to find relevant concepts and theories, and if there have been any inconsistent findings within the area. Both physical and web-based platforms have been used in order to collect literature used for the research. Physical platforms have been books only available in print. Web-based platforms that have been used are Google Scholar (https://scholar.google.se/), the Chalmers Library website (http://www.lib.chalmers.se/), Web of Science (https://webofknowledge.com/) and other search engines. Key words for the literature has been: product development processes, Lean Product Development, visual management, value stream mapping, Resourceful Sensemaking, Knowledge Management, waste in product development, waste in Knowledge Management.

3.4.2 Observations

The observations have been non-covert by Observer-as-participant observation (Bryman & Bell, 2015), as the observer has been able to gain insight from the participant about the DME-process. The observations were carried out by having the process map of the DME-process described by employees and having steps in LIMS showcased and explained. Notes were taken during the observations in order for the researchers to gather background data to support the understanding of the process. The material gathered has not been shared in the research, instead the material has been used as a base for the interview questions.

3.4.3 Semi-Structured Interviews

Interviews are one of the most common methods used for qualitative research (Bryman & Bell, 2015). In this research, semi-structured interviews have been held, which covered areas of interest with prepared questions and with the flexibility for additional questions that arose during the interviews. Before the interviews were carried out, an interview guide, see Appendix 1, was prepared to define the topics to be covered and to inform the participants about the topics. Bryman and Bell (2015) describe basic elements that can be taken into consideration when preparing the interview guide, such as creating a flow between the questions, a logical order of the questions, creating questions related to the research questions, avoid asking leading questions and use terminology known by the interviewees. These elements were taken in consideration when preparing and conducting the interviews.

When formulating the questions for the interviews, the data from the observations was used as a foundation. The observations provided the researchers with an understanding of areas of interest. When structuring the interviews, the 'Criteria of successful interviewer' (Kvale, 1996 in Bryman & Bell, 2015) and the structure for 'Formulating questions for an interview guide' presented by Bryman and Bell (2015) were followed. Additionally, a test interview was conducted in order to get feedback on the questions from one of the employees. It made it possible to test the relevance of the questions, how to ask the questions and if any questions could be misunderstood.

The interviews were held at the development office in Sweden and interview participants were people working closely to or with the DME-process. The data has been gathered by recording audio, which is recommended by Bryman and Bell (2015) as "it allows more thorough examination of what people say" (p. 493). In addition, it enabled the interviewers to remain concentrated on the interviewee. After conducting the interviews, they were transcribed and coded into areas of the chosen questions, as proposed by Bryman and Bell (2015). This was done in order to create categorization and make the analysis of the results easier, as the answers were grouped. All used interview answers were sent to the interview participants with the English translation of the Swedish statement for approval before using it in the master thesis.

3.4.4 Workshop

A method to gather people, learn from each other and share experiences is by conducting a workshop. Selman and Zorn (1998) state that "there is no one best way to conduct a workshop. The essence in planning is to be flexible and creative." (p. 43). The leaders of the workshop were the researchers of the thesis, whom were responsible for planning, conducting and evaluating the workshop. Following the steps described in Selman and Zorn (1998), establishing the goals of the workshop was essential when making decisions regarding the workshop throughout the planning process. Important decisions regarded who to invite, when to invite them, where to conduct the workshop, what materials will be needed and setting a preliminary schedule for the workshop.

When conducting the workshop, Selman and Zorn (1998) mention that it is important for all participants to get the chance to present themselves and learn about each other. In addition, the leaders should ensure to follow the timeline that has been planned, however, flexibility will be allowed in cases where the participants are adding value to the research (even if this stretches the time that has been set for a specific topic). The discussions and results of the workshop were analyzed based on the notes that were taken throughout the workshop and thereafter concluded.

The workshop was conducted at one occasion in May 2018, as the last part of the information gathering in this thesis. The goal of the workshop was to verify or discard the recommendations, to see if they were possible to accomplish. This was done through input from employees who work with the DME process. The researchers wanted an even number of lab representatives and test initiators attending the workshop, preferably some of the interviewees who knew the subject. During the workshop, the researchers presented six cases regarding problem areas. The cases were discussed before the recommendations were presented. This concluded in whether or not the recommendation would be able to accomplish.

3.5 Ethics

When conducting research that involves gathering data from people, it is of importance to ensure that ethical principles are followed to protect the participants. Bryman and Bell (2015) describe four ethical principles, which were taken into consideration when conducting the research in this thesis. The four ethical principles are avoiding harm to participants, lack of informed consent, invasion of privacy and deception.

In order to avoid harm to participants, this research has been carried out in a way that did not pressure, stress or physically harm the participant. By providing information to participants beforehand, the participants were informed regarding their rights when participating in activities, such as being able to stop the interview at any time. The material collected has been used for this research only and not distributed to others, in addition, participants were coded to assure anonymity.

To avoid lack of informed consent, the purpose and rights of the participants have been stated clearly when invited to interview and re-informed at the point of participation. In case of observation, only non-covert observations were carried out, where the participant was aware that he or she was observed. In this thesis, change of behavior from participants during interviews has been avoided by focusing on the knowledge through asking in depth questions that do not have a “correct answer”.

To avoid invasion of privacy, this thesis has respected the boundaries and rights of the participants. The participants had rights such as not answering questions, aborting interviews and retrieving answers previously given. In Bryman and Bell (2015), it is emphasized to give the participant the opportunity to refuse answering questions, as this minimizes the risk of them experiencing invasion of privacy. In addition, there was the aspect of respecting the privacy of the company, as confidential information has been accessible to the researchers. This was reassured by a Non-Disclosure Agreement provided by the company and an open communication between the researchers and company to avoid confidential information and pictures being shared.

In order to avoid deception, which implies that information is described in a different way than presented (Bryman & Bell, 2015), all material has been approved by participants contributing with data. The participants have had the right to take back information in case they felt disagreement in how the material has been used in a particular context.

4. Findings

This section covers the findings of the 16 interviews that were held with employees working with the DME-processes on a daily basis. Additionally, how they work with Knowledge Management has been covered in the interviews. Among the interviewees, there were eight lab representatives and eight test initiators. In order to get interviewees with various backgrounds, it was requested to interview employees from different areas of the company with different length of employment. For the test initiators, the sampling was purposive, which implies that it was possible to make a selection among the employees, since the information of the employee's background was known. For the lab representative, the sampling was random, as the background information was not provided beforehand. The interviews lasted for 60 to 90 minutes and were conducted during the months of March and April 2018. The interviews were semi-structured and the original set of questions can be found in the interview guide in Appendix 1. The structure for presenting the findings follows the order in which the questions were asked and the flow of the process.

4.1 Purpose of the DME-Process

The interviewees have expressed similarities in the purpose of the DME-process and no difference between the lab representatives and test initiators has been found. The purpose of the DME-process is defined by the company as "this procedure describes the workflow of how to define a test assignment, and to measure and evaluate results as agreed with the test initiator". The interviewees expressed a purpose that was more focused on the roles in the process, structure of the process, storing the information ensuring traceability and assuring that everyone works in a similar way. One test initiator states:

"I think the purpose is partly that it is a process that is used in order to have the same expectations of what needs to be done and who should do what. I believe that if you get the right input at the right time, it is easier to carry out the work, so you do not get the information too late. If everyone knows when the information needs to be received or when you are receiving it, it will be easier to plan the work. To give the right information at the right time will make the end result better."

4.1.1 If the DME-Process Did Not Exist

One interviewee stated that *"The company has traditionally not used many processes, which has led to individuals working in a way that suits them"*. Therefore, when the interviewees were asked "What would happen if the DME-processes did not exist?" 4 of 16 said *"nothing"*. Three of the interviewees expressed that the DME-process is *"helpful documentation"* when new employees are introduced to the way test initiators and lab representatives cooperate. Two interviewees take into consideration the historical aspects of way of working. One lab representative says:

"It would be very difficult for new employees to start working, as the DME-process is based on how we work and how we have worked previously. It is not a new process, if you have worked here for a while you know the DME-processes without the documentation. We know how it works, but we have a hard time retelling it to others."

A test initiator states a similar picture of the historical aspects:

"*I think that it is good that there are clear processes that you base your work on and that you become less dependent on people. The process guides the way of working instead of employees involved in the DME-process being dependent on how each individual works. If I look back on how we worked previously without processes, it was more unclear, we experienced duplication of work and we missed details. I think we would be slower without the process."*

More aspects of how not having the process would affect the work is stated by some of the lab representatives as *"no process, more variations"*, *"less structured and not as clear what should be done in some of the phases"* and *"we would work differently and it would not have been traceable"*. Whereas the test initiators state that *"the documentation is more for the lab representatives"*, *"we still would be required to work together"* and *"communication can solve anything"* which is a slightly different view between the two parties.

When the interviewees were asked "Is there anything you do or the test initiator/lab representative does, that does not have a purpose?" 9 of 14 said *"no"* where a majority were test initiators. One lab representative states:
"It can be difficult when you have not been included when defining the request [...]. It makes it difficult to put your own personal touch to a request, to know why you do certain methods and be able to question like you are supposed to in our professional role. Sometimes where there is not enough time, you do not have the possibility to dig deeper into what needs to be tested."

4.2 Initiating the Request

The instruction of the DME-process states that it is the test initiator who initiates and writes the request. There is a general understanding among the interviewees that these instructions are followed. In most cases, the test initiator writes the request themselves, however sometimes the process deviates. Some of the lab representatives state that *"sometimes I write them myself"* and *"sometimes I assist the test initiator when they write the request"*. One lab representative states:
"In the beginning when we implemented the new LIMS, our test initiators were not educated in using the system. Since then, some test initiators still do not want to write the requests themselves as they do not like the system, they think it works poorly or just 'refuse' to do it. After some time of discussion with the test initiator I just give up and write it myself."
One test initiator states:
"I am not comfortable using LIMS, which leads to me e-mailing the information to the lab representative instead of putting it directly into the system, making the lab representative do it for me."
Another test initiator states that they always write the request themselves unless something comes up and the lab representative offers to do it.

There are mainly two types of requests that can be initiated. The first type is requests within a project where the test initiators are involved in the project team. The second type is the independent request, where the test initiator can come from different parts of the organization. The lab representatives and the test initiators can work with both types of requests. When

discussing if there are any differences in working with a project request or an independent request, one lab representative states:
"In projects, we help out a lot when writing the requests. They get our input in what needs to be included, which usually ends up being good."
Another lab representative talks about the independent requests:
"The requests from the business units or other independent requests, almost do our jobs by telling us "test these methods". But it could also be that the assignment is a bit different."
A third lab representative states when asked about differences in the process depending on who the test initiator is:
"The process varies. People have different knowledge, different expectations in the process depending on where you come from. In some cases, it is very straight forward, but in other cases you have to figure out what people want. Sometimes when you receive unclear requests you have to talk to each other. I thought we were supposed to be able to write in the request at the same time. But instead there is a lot of communication through e-mails and in meetings."
One test initiator who works in projects states:
"I wonder if I really should be the one writing the request, maybe it is better if the lab representative writes the request and instead we sit together and write the conclusion together in order to have more input, but also to have more of a team feeling and a larger commitment for the whole R&D."
Another test initiator states:
"*The system is stiff and the requests become too general. We are in technical teams and we make better documentation in Excel. It gives a better perspective of the request, but it also means we do some duplication of work. Therefore, I usually do a very simple request [in LIMS] and a more useful Excel document which is shared on SharePoint for everyone in the project to see."*

4.3 Define-Phase

The findings in the Define-phase regards how the deadlines are decided upon and what the employees expect from them, the selection of the lab method, how the dialogue in the Define-phase looks like in general and how the discussion about the amount of samples is carried out.

4.3.1 Deadline

In the DME-process there are two defined deadlines, 'wished deadline' and 'final deadline'. The test initiator must set the 'wished deadline' in order to finish the request and send it to the lab representative. The 'final deadline' is discussed by the lab representative and test initiator.

Half of the interviewees say that they have a dialogue where they come to an agreement for the final deadline. Often, the agreement includes that the test initiator gets a topline of the result at an earlier date than the final deadline, also seen as an unofficial deadline among the employees. One test initiator says:
"When I decide upon a [final] deadline I set it far ahead. In the agreement with the lab representative, we have decided on an earlier date when I get the results or a draft."

Three lab representatives state that the 'wished deadline' often is too short or not related to how long time the measurement phase takes. One lab representative states:
"The deadline depends on the assignment, priority and other aspects that are considered. Sometimes the deadlines are very short and a discussion is required."
There is only one of the interviewee who states that the dialogue between the parties regarding the deadline is lacking.

When asked about differences between how the deadline is set in a project request and in an independent request, most interviewees claim that there is no difference. However, one test initiator says:
"There is a difference. I would say that deadlines in projects are more sharp because the project follows a funnel checklist which is planned according to the launch date. In an independent request the time plan is more flexible."

One test initiator explains that in cases where it is not clear if a deadline is sharp or not, this should be explained in the background of the request. The interviewee says:
"This is when I state my expectations for the request and that the deadline is sharp. In cases which are less important, I base the deadline upon what I believe is reasonable."
Some of the laboratory representatives claim that it is difficult to handle deadlines when they do not know if they are sharp or not.

Expectations of the Deadline
One great difference is the expectations about the 'final deadline', where the difference between lab representatives and test initiators is compelling. All laboratory representatives agree that the deadline is reached when the status '*Final Report'* is set, the final report is published in LIMS and that no further changes should be done in the report after this step. On the contrary, only two of the test initiators agree with this. The majority of the test initiators expect that a result is presented to them at deadline, but not that the laboratory report needs to be done. The distribution of the answers can be seen in Figure 9.

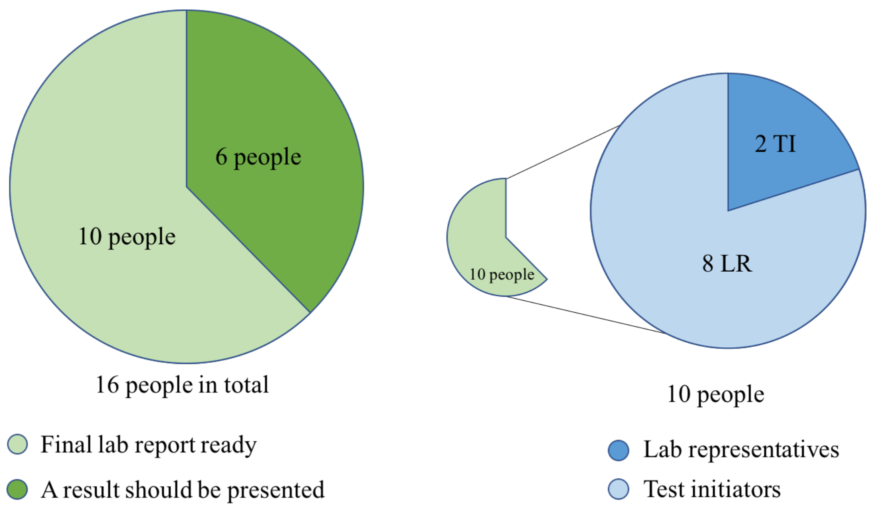

Figure 9 – The distribution between test initiators and lab representatives regarding expectations of what should be ready at the final deadline

One lab representative expresses:
"I do not think our communication with the test initiator regarding the deadline is good enough. We have other demands concerning the delivery. We have two goals in a request. Partly that the result is presented to the test initiator before a certain deadline, and partly that the report is finished before the agreed deadline. If the agreed deadline is not met, we get negative numbers in our KPI. I believe the test initiator is satisfied with the request when they have received the result. I do not believe the report is as important to them."
Similarly, another laboratory representative says about the test initiators' expectations:
"I do not think they care about when the request is set to final in LIMS. They are happy as long as they get the result. It can be in a PowerPoint with a summary and some graphs. That is how it usually is. For the test initiators it is final deadline when they get their result, which they can get before the report is written."

Most test initiators state that they know about the final deadline, but that it is not important for them. One states:
"I know that the lab representatives are measured on the deadline, that the final lab report should be set to final and that the deadline is based on that. For me, it is the result which is important, not the report."

Changing the Deadline
The deadlines are not only important in terms of decision making and expectations, the final deadline is also used as a KPI for the company. However, one problem area which has been emphasized during the interviews is that the final deadline can be changed without consequences for the KPI. Half of the interviewees state that if a deadline is running late, it can be moved to a later date without affecting the KPI. One lab representative states:
"I do not believe we have a good system for measuring this [the final] KPI because we can move the deadline to when we are ready with the report. If we are to measure efficiency, why should we measure something we so easily can change? I think it is better to make an agreement with the test initiator on when they need the results. Maybe it would be better to use the agreed deadline."
One of the test initiators states:
"If we reach the deadline and the lab representative is not done with the report, the deadline can be moved. They can cheat and move it as many times as they want to. I do not understand the purpose with it. […] Nothing happens if they extend the deadline. They are measured on it, but it does not affect my job because I get my result anyway."

4.3.2 Selection of Lab Method

Two categories have been discovered regarding how the lab method is selected. The first category is if the method is selected based on the factors which are supposed to be tested and the second category regards who is responsible for choosing the method.

Regarding the first category, 12 of the 16 interviewees say that the method is chosen through dialogue between the lab representative and the test initiator. There is a common understanding that the test initiator should state what parameters he or she wants to know and let the lab

representative recommend a method thereafter. However, sometimes the test initiator chooses the method without the lab representative. One test initiator states:
"As test initiator, I am not supposed to come with suggestions on methods. I am supposed to let the lab representative know my issue and then he or she should give a suggestion. Still, we have many test initiators who have a lot of competence and who know the methods. They write the method they want in the request."
Another test initiator states:
"I try to ask the lab representative to give me suggestions, because that is their area of competence, but I often fall back into old habits and use the methods I am used to. But I try to have a dialogue with them. One exception is if I do repetitive tests."
The two quotes are representative for most of the test initiators' answers, agreeing that the lab representative is supposed to have the competence to recommend the method. However, depending on the competence of the test initiator and the type of the test, the test initiator might choose the method. From the point of view of a lab representative:
"I believe that they often write in "assignment" in the request that "I want to evaluate" and then they write the method because they do not think that there is any difference. […] It is better if they write the parameters and then we write the method later. If the test initiator has written a method, I usually change it to a parameter."

The second category affecting how the method is chosen depends on the roles and responsibilities of the lab representative and the test initiator. In the DME-process instruction, the lab representative and the test initiator are supposed to agree on the method. Additionally, the lab representative is responsible for confirming the agreement with the test initiator, for the assignment to be performed and to deliver results. As stated before, the test initiator initiates the request and confirms the agreement with the lab. It is not stated in the instruction who is in charge of selecting the final method. One lab representative states:
"It is quite normal that there are requests saying "test this with this method". In those cases, they trespass the role of the lab representative and they do not give us the opportunity to question the method or give suggestions for anything else."
Similarly, another lab representative expresses:
"If the test initiator has worked with the same project for a longer period of time, they know exactly which method they want. Then they create the request and we do not have to discuss that much. However, sometimes they ask us what they should measure. Now, we are part of the project from the beginning and we can give input on the request when it is initiated. We want to be included early, because we have a lot of competence, we know the methods and what to do. Then we can plan for it at an early stage."

The same picture is given by a test initiator who explains reasons why the method is chosen without consultation with the lab representative:
"I try not to write the method, but I often do it anyway because the lab representative changes or because I work in projects where I want to make sure that the results are aligned with previous results. Right now I work in a new project and then I try not to write the lab method, or… I write the lab method in the title, so I guess I do it all the time. In some way I believe it depends on that I get the feeling that the lab representative does not take initiative. It is not

often I get recommendations, I must ask the lab representative, if not, they ask me which method we should use. […] I believe it depends on the company culture. I do not know if it is right or wrong to let the lab representatives decide the method, but the culture needs to change to make it more efficient. […] Additionally, the lab has a lot to do. Therefore, it might be better to write exactly what they should do. […] It neglects some of their responsibility, which is difficult because of their commitment to the job."

There is a different view between the two parties regarding whose responsibility it is to decide the lab method. On the question "Who decides the final lab method?" one lab representative answers:

"I believe it is me. I know more about the method than the test initiators. I can only give recommendations, depending on what they want to know. A discussion might take place and we might do double testing in the beginning. I must persuade the test initiator that the method is as good as other methods."

One test initiator reflects upon the decision:

"Since it is the test initiator who wants something done, the responsibility of the result should be ours. This means that we often choose [the method], but if the lab representative says that they believe it is better to use another method, we follow their recommendation. It is not said that you either decide or you do not, we have a discussion."

4.3.3 Dialogue During the Define-Phase

The dialogue in the Define-phase depends on several factors such as (1) how thoroughly the information in the request is stated, (2) if it is a project or not, (3) if there is a meeting before or after the request is written and (4) how informed the lab representative is from the beginning of the request. In general, the lab representatives have a greater focus on the information in the requests when answering the interview questions, while the test initiators overall focus more on if the dialogue happens before or after the request is written.

When asking about the dialogue in the Define-phase, 5 of 7 lab representatives state that they go back to the test initiator if anything is unclear, which reflects upon the first factor.

"It is in cases when I sit with the report myself that I would want more background and purpose, then I contact the test initiator. Otherwise, I think it is pretty clear and I know what to do."

As an answer to the question "Are there occasions when information in the request is lacking?", three lab representatives answer "*very often*", three answer "*sometimes*" and one answers "*I wish the background and purpose were better*".

One lab representative states:

"Many test initiators are not used to write requests. Those who know how to write requests often write them well. I believe that many test initiators are not aware of the fact that what they write under assignment, ends up in the report. From their point of view, they ask you to perform a task and therefore they can write whatever they want to. Sometimes I ask them "do you understand that this will be in the report?" The answer is no."

The second factor regarding information is when the lab representative is part of the project, the test initiator often assumes that the lab representative holds all information about the project. One lab representative expresses:

"As we have many projects but not so many employees at the lab, sometimes you get involved in a project on short notice, you are a new resource for a project or just supporting a project. In those cases, it can be very difficult to perform the assignment without thorough dialogue with the project team during a longer period of time. You then have to contact the main lab representative for the project and continuously ask for the information, because it might not be sufficient in the request."

It becomes an issue, as the lab representative continues to explain the usual way of working in projects:

"We do not normally require all background information to be in the request when it is issued by a project, because then you assume that the lab representative who is involved in the project has all the information needed. In these cases, it can be very difficult."

One test initiator with previous experience from the lab expresses:

"I believe the test initiators want the lab representatives to write the request. "You are in the project, you hear the background and the research question, why can you not do it by yourself?""

One focus regarding the dialogue area on which the parts seem to agree is the differences between the dialogue in projects and the dialogue in independent requests. Regarding the dialogue, there was no interview question about the difference between projects and independent requests. However, two lab representatives and two test initiators mention that the dialogue in general happens earlier in projects. The lab representatives add that they know when a request is coming when they are involved in projects. On the contrary, the dialogue in independent projects happens later. One lab representative says:

"If you are part of a project, you are often aware of the upcoming request because you have discussed it in a meeting in advance. Then the background is usually known. […] If there is an independent request […] you usually need to contact the test initiator and ideally have a meeting. […] The communication period may be longer in those cases because you do not have the close connection with the test initiator and the opportunity to continuously discuss."

The third factor is from the test initiators' point of view, as they believe there is a difference between if the discussion happens before or after the request is written. 4 of 7 test initiators express that they book a meeting or have a dialogue with the lab representative, and say the lab representative often asks them to write the request in advance of the meeting. One test initiator mentions that:

"The last couple of times, I have written the request before having the dialogue, but then I know that the lab representative already has gotten the assignment orally."

Another test initiator says:

"If there is a new area where I do not have any experience the request becomes very vague. I must write something in the request in order to save it. I usually book a meeting [with the lab representative] to discuss it."

The fourth and final factor relates to the three lab representatives who express the importance of being part of the discussion early in the Define-phase. One of them states:
"Before, we just got the requests, did the measurements and delivered the data. The test initiators analyzed the data, therefore we did not meet as much. We have been working a lot in order to be involved early in the process."
A second lab representative expresses:
"If you are involved a lot in a project, you often know what will come. The unforeseen requests can create a lot of discussions about the purpose of the request. [...] The reason is, to a high degree, that the purpose is not clearly written."

4.3.4 Discussion of the Samples

Another part of the dialogue in the Define-phase which varies, is the discussion about the samples. Again, factors such as involvement and discussion between test initiator and lab representative are brought up. Two lab representatives state that it is difficult to analyze data if you have not been included in the request from the beginning:
"If you have not been involved from the beginning and decided how the tests should be done, you cannot analyze the data. I wish we would talk more about that, both how the samples are selected before the measurements and how many samples we need. It is really important to be included from the beginning."

"It is connected to the background. Why should we test all these samples? Sometimes it is difficult to know what they want."

Five people, both test initiators and lab representatives, say they discuss the number of samples with the other part:
"Before, the amount of samples was already given, but now we have a dialogue about the accuracy of the result."
One test initiator states:
"What we discuss the most with the lab representative is how we can decrease the amount of tests, as they do not want to test too much. It is easy to have a great amount of samples but it is much more difficult to define what the minimum amount is. I think it is very good that the lab representative questions the number of samples so the test initiator must think through it."

Several interviewees mention the accuracy of the result relating to the number of samples. One test initiator says:
"It depends on how far you have come in the development process and how much knowledge you have about your products. It is difficult, because you do not want to test without a purpose, but at the same time you need a lot of samples to make good decisions about the results. I believe a lot of frustration from the lab representatives come from this, that they try to convince us, but people who have no clue about the methods express their opinion about the results. It might be because there are many new employees."
A lab representative states:
"We discuss, then they decrease the number of samples on some tests, because you cannot test everything. However, some needs their safety net. They want to test everything, independently

of how long time it takes. They might not understand how much time some tests take to perform."

4.4 Measure-Phase

The following part of Findings will showcase interview answers regarding the Measure-phase of the DME-process. These include the responsibilities of ordering and handling sample products, communication and improvements that could be done.

4.4.1 Responsibility of Ordering and Handling Samples

All interviewees state that it is the responsibility of the test initiator to make sure that the samples arrive in time to carry out the tests. In general, there is communication of when the products will be arriving and in cases of potential delay. It is the responsibility of the test initiator to label the products as well as enter the sample information in LIMS. However, one test initiator states:

"I never fill out the sample information, I want to save that time. I believe the lab representative can do it, I provide them the information in the field for the background about the samples and then they can fill out the sample information."

When the test initiator got the follow up question "Has there been resistance from the lab representative to do so?" the answer was:

"Not really, once there was a new employee at the lab who said I should do it myself. But I never did, so in the end that person did it anyway. I guess it is a bit of laziness from my side, but it is easier for me to do so."

4.4.2 Communication in the Measure-Phase

The communication between a lab representative and a test initiator during the Measure-phase can vary. The four different reasons that the interviewees present are (1) project request or independent request, (2) special test or standard test, (3) if there are deviations during the testing and (4) who is involved in the request.

The first difference in communication between project or independent request is described by a lab representative as:

"In projects I feel that you have a very continuous communication. [...] Is it a random person which you do not work with where you have only received a request, you continue without communication."

The second difference in communication is if the request is considered a special test or a standard test. A test initiator describes the difference as:

"Is it a standard test where you only need the result and you almost know what the tests will show, then I am not very involved. But I enjoy being involved when it is a new product that is tested and I want to see what happens with the product, because you get a feeling for how the product works."

Another test initiator states:

"I am involved if we do any special tests outside the standard methods, for example when we do project specific testing. If we are testing a unique material, I want to be able to see for myself how the material behaves during the test. In these cases, I will be in the lab to observe. However, if it is a standard test, there is no reason for me to participate and it is better to let the lab do their job."
A lab representative states:
"If they have the possibility to join the lab during tests, I think it is good if they do. They do not have to be there for multiple hours, but I appreciate that they show interest in the tests so they understand what we have tested and what we are talking about. We usually take many pictures, but it is better if they have been there and seen it with their own eyes."

The third reason for communication during the measure phase is if there are deviations during the testing. These deviations can be either that the material or product has behaved in a way which was not anticipated or that the deadline for when the result should be delivered will not be met. One lab representative says:
"It could be that I have questions or something is weird, or that I realize that this will take longer than anticipated."
Test initiators state that *"if something is weird they will contact me [...]. But if everything works fine you are not involved"* and *"if things come up I become more involved".*

The fourth and final reason for communication during the Measure-phase depends on who are involved. A test initiator states:
"It varies between the lab representatives. From some of them I do not hear anything until the results are ready whereas some let me know continuously what they are doing."

4.4.3 Improvements of the Measure-Phase

When asked "Is there anything that could facilitate the work in the Measure-phase?", 2 of 12 said *"no"*. One improvement mentioned by a lab representative was *"if people borrow things they should put it back"* and another one was *"if I had more time to carry out the Measure-phase".* The latter statement is confirmed by a test initiator who states:
"It is a question of resources, in general you do not get the right amount of resources, which has been improved as we now can prioritize some projects. Mainly it is not enough time. It has been too many projects and too much work to do."

Another aspect of improvement is the amount of information that they are provided with. One lab representative states:
"It would be good to know what has happened with the samples or if they have been produced in the regular way. If you work in a project I think everyone expects you to know everything, but sometimes you do not perceive all the information because there is a lot going on."
Another lab representative states:
"I think that many of us have problems with receiving the products labeled with the right information. From the production site of the samples you can receive boxes with diffuse information and you do not know what product is. If the samples are organized and the methods you will carry out are planned, you can go ahead."

One test initiator states that involvement from the test initiator should be improved:
“I believe that if we had been more involved and watched the tests, it might have given us more understanding of how the products behave and what is measured. We can learn from that. We lose knowledge by not being there. On the other hand, I do not know if the lab even wants us there or if they think it is wrong of us to be there. Sometimes, it can be nice not to be interrupted while you work. But out of our perspective we could learn so much if we would have been more involved and had more time to spend at the lab.”
A lab representative agrees with more involvement from the test initiator and states:
“We have previously asked the test initiators to be more involved in the lab, partly to have them understand how a method is carried out so they learn, but also because they should learn how the products behave during tests. We are responsible for carrying out the tests according to the methods, evaluating them in a statistical way and provide representative data. I think that some test initiators have been afraid to spend time at the lab because they consider that our area and they feel like they are intruding. But they provide a different perspective and can see a lot of what happens with the products during simulations and make their own conclusions.”

4.5 Evaluate-Phase

This part of the Findings will present interview data that was gathered in regards to the Evaluate-phase of the DME-process. These findings include topics such as analyzing the data, presenting the data and writing the final lab report.

4.5.1 Analyzing the Data

When asking the question “What decides how the test data should be analyzed?” the interviewees mainly mentioned three aspects. 12 of 16 mentioned that statistical analysis is carried out or that the method will state how to analyze the data, one mentioned the aspect of what has been agreed upon and three mentioned the assignment as the baseline for analysis. Starting with the first aspect, a lab representative states:
“We have a routine called WIN_0064, which tells us how we should evaluate test data. In addition, in every test method there is a description of what is supposed to be the output of the method.”
A test initiator states “*It depends on the experience, on how much knowledge they have about Minitab. It varies a lot.”* and another test initiator states *“How they statistically evaluate the result is nothing I can control, but in the best case I get a good recommendation”*.

The second aspect regards the agreement between the two parties. One lab representative states:
“I try to talk to the test initiator beforehand, so we have an agreement of what the results should be. Based on that I structure the tests and the analysis. No point in giving them something they do not want.”

The third aspect is the purpose of the assignment and what the analysis will be used for. A lab representative states:

"It depends on the assignment. In some tests, you either do a screening or prove claims. In a screening it is about getting a feeling of how the product performs and how it relates to today's material, then it might be enough by just making a graph. If you work with claims and we have requirements that the product needs to fulfill, it needs to be proven by some statistics."
A test initiator states:
"One reason which can decide is how the result is going to be applied. If it is for a business unit, it might be good if it is visualized. In cases for patent applications it is more important to have statistical evaluation. [...] It can differ, it depends on the purpose and use of the analysis."

During the interviews it appears that in some cases the test initiator is only interested in the raw data rather than having the analysis done by the lab representative. A lab representative states:
"Some do not know that we can do statistical analysis. Some know it, but are not very interested as they might only want the raw data, and some appreciate that we do the analysis and think it is nice that they do not have to do it themselves. The idea is that we are supposed to do as much of the analysis of the data as possible."
A test initiator who prefers getting the raw data states:
"In our projects we only want to have the raw data and do the analysis ourselves. Usually we just want a simple Excel matrix with the data, mean, standard variation and sometimes the raw data of the individual measurements, which is "against the rules". But we feel that we do this analysis better than if the lab representatives do it for us."

4.5.2 Presenting the Data

When the interviewees were asked "What decides how the test data should be presented?", 10 of 16 said that the lab representatives decide by themselves on how to present the result and the other six stated that the presentation depends on who the receivers of the results are. One of the lab representatives who chooses by him or herself says that *"I always make a topline"*.
Another lab representative says:
"As I do many assignments for a specific area, they are used to the way I present the results in a PowerPoint. If I get requests from others, I use the same format for presenting the results, but if they want to see it in a different way they can always let me know. The text that I use in the top-line is the same text that I use for the Summary and Conclusion [in the report]."

One of the lab representative who states that they keep the receiver of the results in mind says:
"It depends on who your customer is. We see it from the lab perspective. If you present statistics for a certain team and they do not understand the numbers, you might do visuals such as thumbs up or thumbs down."

When asked "Is it clear from the beginning in which format the results of the final lab report should be presented?" 12 of 13 state *"no" or "not always"*. A lab representative states:
"Not always, it is still a bit vague. Usually you have to find out yourself or know it by experience […] I can imagine it can be hard for new employees to know."
Another lab representative states:
"I do not think it is clear. Very often I provide a topline with the results before I create the report. Usually you get feedback such as "it would be good if…" but it depends on who looks

at it and how detailed the person wants it to be. If the person is satisfied with a number, it does not matter.”

A test initiator states:

“There is nothing in the Define-phase that states it, I do not specify it anywhere.”

Another test initiator states:

“When we go through the collected material there can be follow up questions regarding more comparisons. Then I have not been clear in my request. It is when you look at the results that more questions can arise.”

The last one of the 13, states:

“It is clear since there are technical meetings [in the project] every week, it has become a way of working and we know what to include and how to include it.”

Alignment Between Purpose and Result of the Request

The first part of the final lab report is mainly written by the test initiator and the second part of the report is mainly written by the lab representative. When asked “How is the result of the final lab report aligned with the purpose of the report?” the most common answer, stated by 7 of 11, was *“through discussion”*. It was more commonly brought up by the lab representatives than the test initiators. Two examples from lab representatives are:

“Sometimes it changes throughout the work process and you must change the purpose. At least if you want it to be coherent. I would say that it is a problem if there is a reason behind that the test initiator writes the purpose and the lab representative writes the result, there is a risk of the text not being coherent if you do not look into each other’s parts.”

“I would not say it [the alignment] is good, it is quite one way. Since we are quite many involved in a request it can be hard to know if they got their questions answered. Sometimes the purpose can be quite vague in innovation projects whereas from business units it is more straightforward.”

One test initiator states:

“My expectation is that they make some kind of presentation and we have a meeting where we discuss what the results really tell us. I can then provide them with my reflections and they can give me their reflections, together we can formulate mutual reflections which provide us with the correct answer.”

4.5.3 Writing the Final Lab Report

When asking the lab representatives “How long does it take to write the last part of a report for a request?” the answers vary. Some lab representatives state that it takes half a day to a day, depending on various factors such as the system LIMS, the size of the request and the time that is available for the lab representative. One answer is:

“It depends on how many methods and samples you have. I might work on the report for a whole day. Especially now that we have the new LIMS, as it is not a Microsoft Word file where you can do changes as you want to. This has made it more time consuming for us to write the

reports. If you want a perfect and good looking report with all the pictures in the right place, it takes one or sometimes two days."

When asked if there is enough time to write the final lab report, a lab representative states: "*There should be enough time to write it, but it is easily not prioritized as there are other things to do and you have already provided them with the results. But yes, there is time to do it."*

One test initiator was asked about the time span between having the results presented and when the final lab report is done in LIMS and states that *"it varies a lot, it can take anything between a day or five months."*

4.6 Overall Findings of the DME-Process

Throughout the interviews there were some overall findings which were found through both predefined and follow up questions. They will be presented in this section.

4.6.1 Reading and Using the Final Lab Report

Findings that have become visible throughout the interviews are the reading and usage of the final lab report. When asking lab representatives "Does the test initiator read the final lab report?" the answers vary. The lab representatives are sometimes unaware if the test initiator reads it, as some of them already have received the results in an earlier stage. Three lab representatives have doubts, one states:
"It feels like no one ever reads the report, but some do and some have comments. I think that many of the test initiators just want the results to be able to provide the information to someone on a higher level or externally. Sometimes you receive feedback but it is not very often. If they have gotten the result, they do not care too much about the final lab report, I think they just want the result."

Another lab representative states the following about the lab report in projects:
"In the projects when you have done the lab and delivered the results, you might be multiple steps ahead already and work on your new request. So no, I am not sure if the project group reads the final lab reports. I think it is too bad that the reports are not being used. It will not be used if you work in a project, because it can take some time before it is written. The lab representative might not have enough time, does not prioritize or only makes the presentation and moves on."

Another lab representative states the following about the test initiator's interest in the final lab report:
"9 times out of 10, they are not interested in the final lab report. Instead we always agree upon sending the results in another format, such as a PowerPoint or excel data, because usually they need it fast to make a decision or for changing something in the production."

From the perspective of the test initiators, there are mainly two scenarios. 4 of 7 state that they read the report before it is published in LIMS and the other three state that they do not read or use the final lab report. The first scenario is explained by the following statements:
"Yes, before it is published in LIMS I read it. Because if I have any concerns or comments, we have time to update and change things so we both agree upon the results before we finish the final lab report."

"Yes, I usually read it through. Because I do not want there to be any errors in my requests. It is important that I have a solid background and purpose."

The other two who read the report, mention that they go through both the topline and the report with the lab representative. One states:
"Yes, usually we do it together with the one who carried out the method, during the topline but also often with the report to assure that we have understood it the same way. Usually there is some deviation that might not be so easy to explain."

The other three test initiators who say they rarely use or read the final lab report state reasons such as no longer needed at the point of receiving it, it is difficult to use and it is only for having it traceable in the system.

4.6.2 Time Waste in the Process

Some of the interviewees were asked "Where is the largest waste in terms of time in the process?" and waste was mentioned in every phase of the processes by the seven interviewees. One test initiator mentions waste in the Define-phase as:
"I think there is uncertainty when I fill out the request, what I am supposed to fill out, such as the lab method. These uncertainties regarding the process are the things that take time, not the process itself."

One test initiator mentions waste in the Measure-phase:
"There are many people who need to use the same methods and machines, it can be difficult to make the booking of the equipment and have it synchronized with the schedule."
Another test initiator adds regarding waste in the Measure-phase:
"I wait the most in Measure, but it is only from my perspective as I do not know how they [lab representative] have planned ahead. But since I do not have assignments with very sharp deadlines, the time is running by. I try to have meetings to follow up the assignment in order to know how long it will take."

One test initiator sums up the waste by defining waste in all three phases:
"Waste is that they [the lab representatives] write a report with results that they have already presented to us. Another waste is that they measure the wrong things based on the project's history. There is also a risk of miscommunication that you write the wrong things in the request because you do not do it together."

Two lab representatives mention the report writing as the biggest waste in the process. The first states:
"We waste time during the report writing because it is so difficult to write a report right now. We have talked a lot about that we waste time writing it, in order to get it to look like how we want it. People want to have it in different ways and that does not work right now because there are still improvements that need to be done."

The second lab representative mentions the report writing and other aspects in the Measure and Evaluate-phase:
"You could question that we make double presentations, since there is a lot of people who do not think that the LIMS reports are good, then they request another way of presenting the results which causes double workload."

4.6.3 Status Updates in LIMS

When asked "Do you use the status updates in LIMS?" all eight test initiators said that they do not go into LIMS to check the status, however they are notified through e-mail when the status is changed to 'Received' and 'Final Report'. Among the lab representatives there are 5 of 8 who state that they only use 'Received' and 'Final Report' whereas the other three state that they do use the remaining statuses, which can be seen in Figure 10.

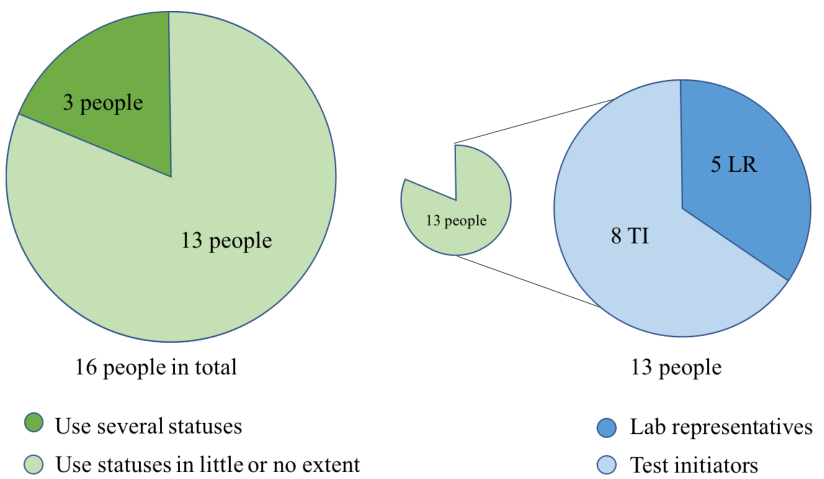

Figure 10. The distribution between test initiators and lab representatives regarding using statuses in LIMS

One lab representative states:
"I try to be good at using them. It is important, as the manager does not want us to have them in received as it looks like we left them hanging. We have a KPI saying that when a request is created, it must be set to 'Received' within a week, or we get negative numbers. During our weekly meeting, we set it as 'Received' and then it is up to the lab representative to contact the test initiator. After 'Received', you set it as 'Confirmed Agreement' when you have reached agreement with the test initiator. This has become quite an important status, before it was a bit excessive."
Another lab representative states:
"I used to do it before, but then I found out that you can go straight to final [from received]. Then it felt a bit unnecessary, because it was said to be an important status that you have

reached an agreement. [...]. As you can skip back and forth between the statuses it has lost its purpose. In an ideal world the status should mean something."

4.6.4 Pros and Cons in the DME-Process

When asked "Is there anything you find positive with the DME-processes?" there is a mutual agreement between the lab representatives and test initiators that the DME-process makes the way of working more clear. A lab representative states:
"It is good that we have supporting documentation and that we have a system that supports me when I do not know what to do."

Some of the negative aspects of the DME-process are mentioned as *"the reports are very ugly"* and *"I still think there are some uncertainties regarding who should do what"*. A lab representative states:
"Part of the issue is that you [as a lab representative] are not always so involved in the Define-phase and therefore do not have the entire background and the assignment, which can make it difficult to set up the right tests for the measure phase. We talk about it a lot in our group, there is a huge gap there."
Another lab representative adds to the problematics in the Define-phase stating:
"It can be difficult to follow it. Especially in the beginning during the Define-phase, that you actually follow it and try to discuss. Usually we just have a quick conversation… But we should have spent more time on having a discussion. I think we should try and find more time for that phase."

A test initiator states the following problematics:
"I think it is a bit difficult depending on who you work with. We put a lot of responsibility on the lab representative to know all of the lab methods, select the right method and also take into consideration the history of the project. It creates a certain complexity. […] I do not know how to consider the lab. Either you see it as a pure resource or you can see it as a part of a team. Right now I think it is somewhere in between. You do not just send the requests to the lab, you go and talk to them and they are also involved in the projects, but at the same time there is a mismatch."

4.6.5 Improvements in the DME-process

One question asked during the interviews was "If you could do one improvement to the DME-process, what would you change or keep?". There were five areas that were mentioned. First, the Define-phase was mentioned by 5 of 16 interviewees. One lab representative states:
"I want more specific instructions of how to do the different activities in the process. I want to keep the cooperation of how you decide what to test and how to test it. That we have more collaboration between the test initiator and the lab representative. So you do not just start the request."
Another lab representative continues:
"The Define-phase! I wish I was more involved, that you had more knowledge and background for the assignment, then you would have had more opportunities to suggest the lab method,

evaluate in a correct way and have a more critical eye during the measure phase. Notice things that are remarkable, which later will be found in the report."
A test initiator states:
"I think that the process itself is good, it contains the parts that should be included. But I would urge that in the initial part where the test initiator hands over the request to the lab, to always have a discussion, preferably get a recommendation from the lab of what should be tested. In many cases it might not be necessary or relevant if the test initiator has a lot of experience, but either way it is good to have that discussion."

The second area mentioned is IT-related, where two (both test initiators) of 16 state:
"The search function does not work so well. I have some difficulties in how to search. It would also be helpful to have a standard way of naming the requests, as it is not crystal clear today."

A third area mentioned by three test initiators is regarding the results and documentation. One example is a test initiator who states:
"I wish the lab representatives questioned me more in the beginning about how I want my results presented and what they are supposed to measure."

One lab representative states a fourth area of improvement being education:
"I feel that I do not know it [the process] very well. Maybe we should have more continuous training, so that it settles into my memory. I have a picture of how it works but some things are just routine. That can lead to us still having different ways of working even if there is a process. Maybe there could be a yearly refresher to ensure it is followed."

The final area of improvement is the quality of the deliverables, which is expressed by one test initiator:
"I think it [the process] is OK, but I think it is important that we ensure quality of what is handed over. Sometimes I feel like they just write something without checking with the test initiator, that this is what we actually have concluded."

Another improvement is mentioned by a lab representative:
"Many times we test things that we do not know if they will use. You can always become better at questioning the test initiator in order to make it more effective and easier to plan. But it takes some time before you start doing that."

4.7. Knowledge Management

As one part of this thesis looks into how to reuse and capture knowledge, the interviews had a specific part about this topic. The findings about reusing knowledge, location of knowledge and capturing knowledge are presented.

4.7.1 Reuse Knowledge

When asked "How often do you reuse knowledge?", all interviewees state that they do, some more often than others. Some of the aspects brought up were accessibility to knowledge, time, communication and content. Regarding accessibility, one lab representative states:
"I can usually go back and read old reports. But it is not always clear where to find the previous knowledge."
A test initiator who saves documentation in own folders on the computer states:
"I would be totally lost if I did not have them there [on the computer] and had to go in to LIMS. I do not know how to search there. That is why I know where I have these reports."

Regarding the time aspect, one lab representative states:
"I do not reuse knowledge often enough. Usually you get thrown into the Define-phase which means that you do not have enough time to look at what previously has been done. You might use your own old final lab reports as you know where they are. [...] I know some people who work with developing methods that have had a lot of planning time, been able to spend time on reading old reports and have said that it has been very helpful, but we rarely get that time."

6 of the 16 interviewees state that they rely on communicating with colleagues to use the old knowledge. One lab representative states:
"If you do not remember the knowledge, you might remember someone who worked with it and ask them how they did it."
An additional test initiator states: *"I try to talk to people who previously have worked with something similar so I can gather some information, knowledge and experience. But it is not always so easy to find."*
One test initiator states that even if you have access to old reports it might not have enough content to reuse:
"There are final lab reports but they only contain the data and no conclusions, which makes it difficult to use. As the data is old, you do not remember the results and nobody has concluded it."

Location of Knowledge

The interviewees were asked "Do you know where to find old knowledge" and all 16 interviewees knew where to find old knowledge. Some of the places mentioned were LIMS, RepoolFacts (a database), R&D SharePoint, project folders, colleagues or in their own heads. One lab representative states:
"We have a lot of material on SharePoint, but you can only retrieve and read information there if you have access. If you have a project and all the information is on that SharePoint, nobody [except the project group] can access it. On the other hand, everyone can access final lab reports in LIMS."
Another lab representative agrees with the difficulties in accessibility to project information:
"Projects are like isolated islands, which is a pity."

One test initiator talks about the advantage of having a large network at the company:
"Above all, I have a large network in this house, so I know what people have done previously."

To see if there is interest in reusing knowledge in a greater extent, the interviewees were asked "What could make you look for old knowledge more often?". 8 of 15 said *"accessibility"* or *"if it was easier to find"*. One lab representative states:
"If there was ONE place to store the knowledge. You store in LIMS today, but there is old information that does not exist there. Older information is in RepoolFacts or in the project folders as they store a lot on their SharePoint. You do not have access to these SharePoints."
A test initiator agrees with the lab representative and states:
"Of course, if the old knowledge would have been more accessible and easier to search for, I probably would have done it more. Now I assume that I will not be able to find it so I do not spend the time to look for it."
One lab representative mentions that it would be easier if there was awareness of what others do by stating:
"If I would have known what others do. You are so busy with your own things so you are not aware of what others are doing. What others do can be discovered during a conference or a meeting with another group or project. Then you realize that they tested something in their project, meaning that we would not have had to test it in our project. I do not know if somebody assumes that the test initiators talk more to each other or if they assume that we talk to each other. I wish we would have a lot more collaboration and knowledge sharing in that aspect. I think that is lacking on many levels."

4.7.2 Capture Knowledge

In order to understand how the interviewees work with saving the knowledge, they were asked "How do you work with capturing your own knowledge?". Some state that they do not work continuously with doing so, whereas some say that they write reports or share information on SharePoint. Five of the interviewees state that they capture knowledge, but that knowledge does not become accessible to others. One lab representative states:
"Everything I do I save or write down on my own computer. Only I can access my OneDrive and we have nothing within the group where we save the knowledge or a place where it says what we have worked with. Unfortunately, it sometimes ends up in my head only."
A test initiator states a similar scenario:
"I try to write project learning reports, but it does not always happen. Either you are thrown into something new or you have time to write these reports. But the project learning reports are not saved in a particular place, they are just on our SharePoint, so we will continue to have the same issues in the future, as we have now."

To understand if there is an interest in capturing more knowledge, the interviewees were asked "What do you think would make it easier to capture knowledge?". Six of the interviewees state that they would capture more knowledge if there was a better place to store the knowledge and that it had a better search engine. One test initiator states:
"There is nowhere to store the knowledge. I think SharePoint is a great tool for projects, but useless when it comes to storing the knowledge. Sometimes I know that I need to find knowledge in a project which has been finalized. I can either contact someone who has been involved in

the project to get the information or contact the owner of the SharePoint who needs to approve my access rights to the IT-department."

4.8 Lean Implementations

The company has introduced the employees to some Lean tools e.g. knowledge briefs and visual planning. Overall, few interviewees know about the knowledge briefs, while visual planning is a more mature tool at the company. One interviewee says:
"I have heard that we are writing knowledge briefs, but I have no clue where they are saved. […] I do not know more than that we are supposed to write four knowledge briefs this year."
When asked about the contents of the knowledge briefs, the interviewee continues:
"I believe the plan with knowledge briefs is that if you find something or have done something beyond the normal stuff, which you believe will be useful in the future, you should write a knowledge brief. It is supposed to end up somewhere it is easy to find. […] It must be located where everyone has access."
Another interviewee says:
"I have heard something about it. If it is easy to find, I think I will use it."
A third interviewee says that the knowledge briefs are sent to a manager and that the documents will be gathered in a SharePoint for the whole R&D department. The interviewee explains what is written in them:
"It depends. It can be a way of working, how a simulation has been used or about a Design of Experiment that has been conducted."

Overall the visual planning meetings have had a positive response. One interviewee says:
"We make decisions faster and see more connections between functions."

4.9 Concluding Findings

In order to summarize the findings from the interviews, a matrix for the interview responses has been made, a VSM of the current-state DME-process has been drawn and the knowledge sources have been mapped.

4.9.1 Summary of the Interview Findings

The findings previously presented are qualitative answers gathered from the interviews. In Table 1, the findings that were possible to quantify are presented in order to summarize what has been found. In the left column, the areas of the questions are defined followed by information about the total number of answers for that question. In the other columns, the different answers to the questions are quantified. In some cases, the total number of answers do not add up to the total amount in the other columns as some of the answers were not quantifiable.

Table 1- Summary of quantifiable interview findings with selected areas of the asked questions and a distribution of different answers in relation to the questions.

Area of question	Distribution of answers		
About the deadline Answers: 16	8 people have dialogues when deciding the deadlines	3 people state that the deadline is too short	1 person has no dialogue
Expectations on final deadline Answers: 16	8 lab representatives have the same expectations	2 test initiators agree with the lab representatives	6 test initiators have different expectations than the lab representatives
Changing the final deadline Answers: 16	8 people, 5 of them lab representatives: the deadline can be changed if late		
Selection of lab method Answers: 16	12 people: the method is chosen through dialogue	2 test initiators: it depends on competence of the TI and the repetitiveness of the test	
Dialogue in D-phase Answers: 14	Lab representative about how often information in the request is lacking: 3: very often 3: sometimes 1: I wish background/purpose was better	5 of 7 lab representatives state that they go back when something is unclear	4 of 7 test initiators express that they book a meeting or have a dialogue with the lab representative before or after they write the request
What decides how the test data should be analyzed? Answers: 16	12 people: statistical analysis, methods and routines.	3 people: the assignment as the baseline for analysis.	1 person: we agree on it.
What decides how the test data should be presented? Answers: 16	10 people: the lab representatives decide themselves	6 people: presentation depends on who the receiver is	
Is it clear from the beginning in which format the results of the final lab report should be presented? Answers: 13	12 people: “no” or “not always”		
About reading the final lab report Answers: 12	4 of 7 test initiators state that they read the report before it is published in LIMS	3 of 7 test initiators state that they neither read or use the final lab report	5 lab representatives do not think the test initiators read the final lab report
Status in LIMS Answers: 16	8 test initiators say that they do not go into LIMS to check the status	5 of 8 lab representatives state that they only use ‘Received’ and ‘Final Report’	3 of 8 lab representatives state that they use the statuses in between as well

What could make you look for old knowledge more often? Answers: 15	8 people: If it was more accessible or easier to find.		
Capture KM Answers: 14	5 people capture knowledge but the knowledge does not become accessible to others.	6 people state that they would capture more knowledge if there was a better place to store the knowledge and if there was a better search engine.	

4.9.2 The Current-State DME-Process

Based on the findings from the interviews, a VSM describing the current-state DME-process has been defined. Traditionally, a VSM is carried out in a production process and it has therefore been adapted to suit the DME-process, which is an internal process. The theory suggests to start with a product family and in this case the product family is considered the DME-process. The researchers of this master thesis are considered the VSM 'managers' as the outside perspective is of importance. A VSM traditionally has two or three flows, the information flow, the material flow and sometimes the time flow. In the DME-process, the information mainly flows in the Define-phase and the Evaluate-phase. The material flows are mainly in connection to and during the Measure-phase, where the samples are received and tested. The time cannot be taken into consideration in this case as the DME-process varies in time as it handles many different requests. The triangle visualizes where waste currently is present in the process and the bolt symbols are used to point out 'wished deadline' and 'final deadline'.

The findings show that the DME-process splits into two branches, see Figure 11. The upper branch represents the project branch and the lower branch represents the independent request branch.

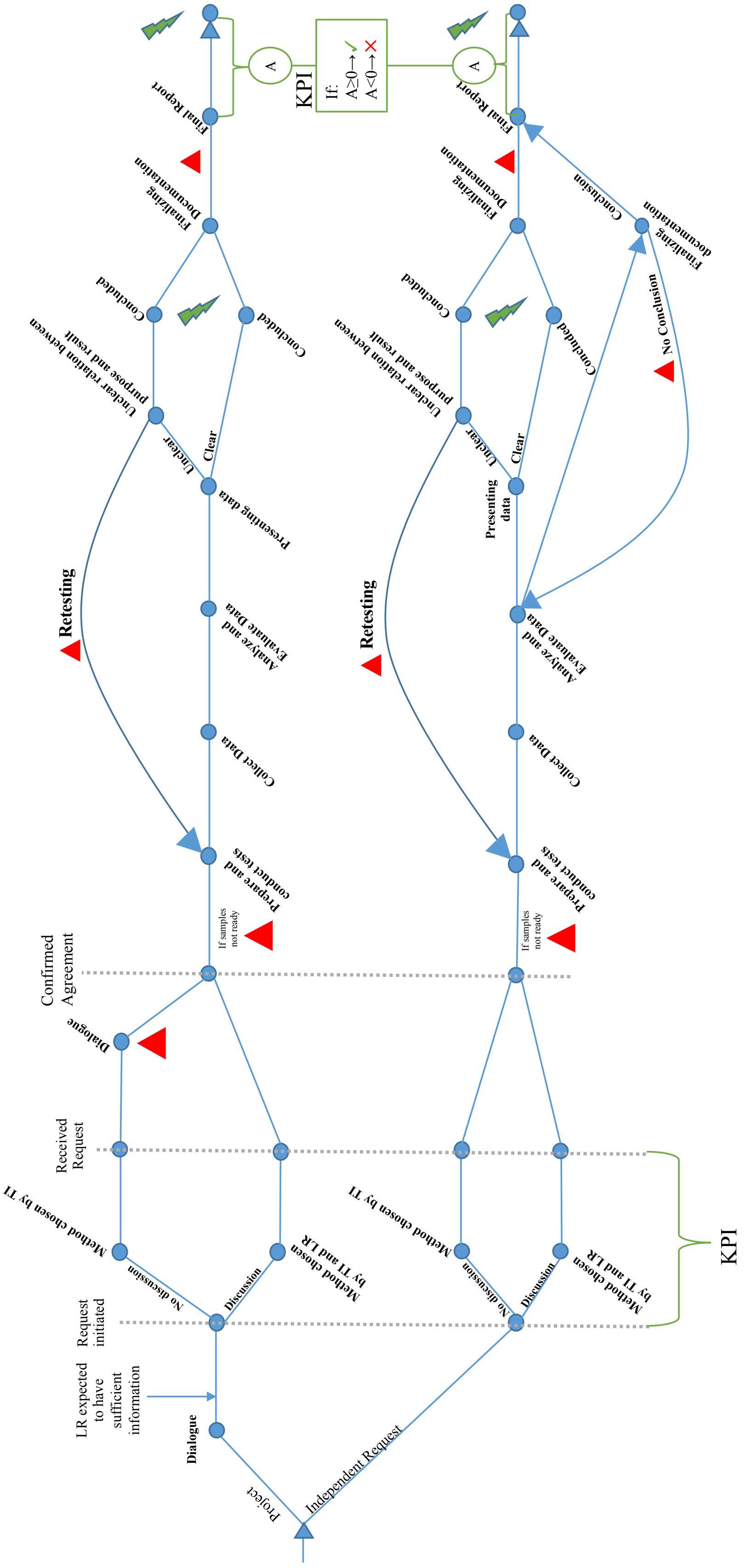

Figure 11 – The current-state VSM of the DME-process showing the different ways the employees work in the process. It visualizes the complexity of the entire process from start to finis

Project Requests

When working in a project, see Figure 12, there is generally a dialogue regarding the request, where the test initiator expects the lab representative to have enough knowledge about the upcoming tests. The request is written after the dialogue. In the Define-phase, the process branches out in two, as there is either a discussion or no discussion. In the cases where there is no discussion, the method is chosen by the test initiator and the lab representative does not get involved in the selection. In the other branch, there is a discussion and the method is chosen by both test initiator and lab representative. The lab representative understands the background and why the tests should be done, and is therefore motivated to conduct the tests. The request is then set as 'Received' and the KPI is positive if 'Received' is set within one week. In some cases, a dialogue is required in the Define-phase in order to clarify uncertainties, this dialogue becomes waste as it could have been more clear if there had been a discussion at an earlier stage. The two branches meet in 'Confirmed Agreement'.

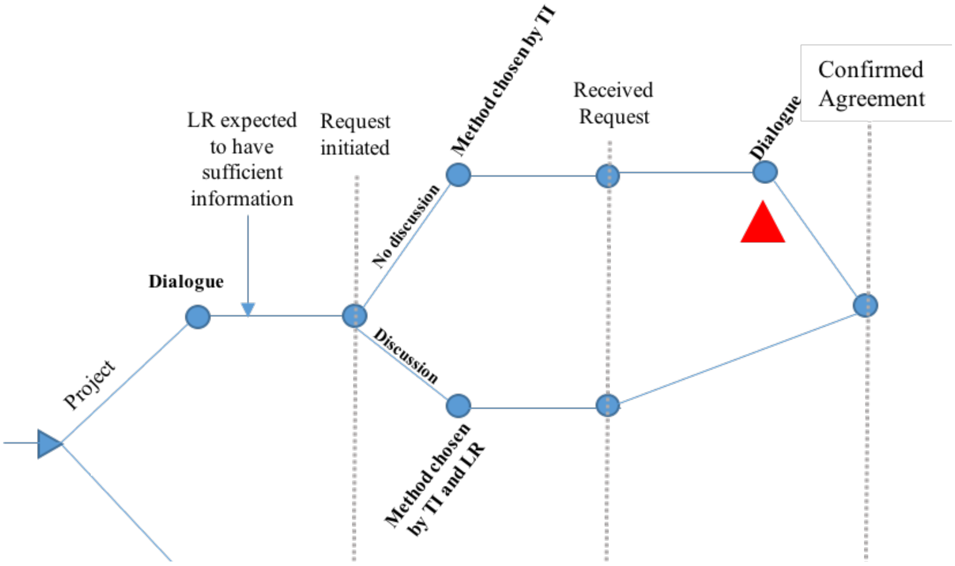

Figure 12 – The Define-phase during a project request, showing that the way the request takes can differentiate depending on if there is a discussion or not

The project request continues in the Measure-phase, see Figure 13, where waste becomes apparent if samples are not ready. During this phase, the tests are prepared and conducted. Discussions may arise if there are deviations and uncertainties of how to proceed. In the final step of the phase, the data is collected.

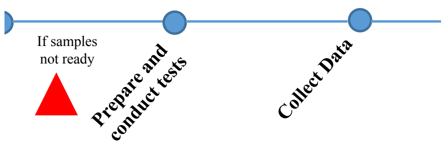

Figure 13 - The Measure-phase during a project request showing the steps of preparing, conducing and collecting data from the tests. Waste can occur if samples are not ready

In the Evaluate-phase, seen together with the Measure-phase in Figure 14 below, the data is initially analyzed, evaluated and thereafter presented to the test initiator. The process branches into two scenarios. The first scenario, which creates extensive amounts of waste is when there is a realization that there is an unclear relation between the purpose and result, as information has been insufficient from an early stage of the process but it has proceeded anyway. In these cases, the test initiator and lab representative might re-scope the request and retest, which become waste as they must go through the Measure-phase again. Another option is that the unclear details are clarified and the request can move on to 'Concluded'. The second scenario is when there are no issues and the request moves straight to 'Concluded' and later merges with the first scenario in finalizing documentation. The lightning at 'Concluded' visualizes that there is a deadline. In this case the deadline is the unofficial or 'wished deadline', where the results at the latest should be handed over to the test initiator, e.g. as a presentation, but not in a lab report format.

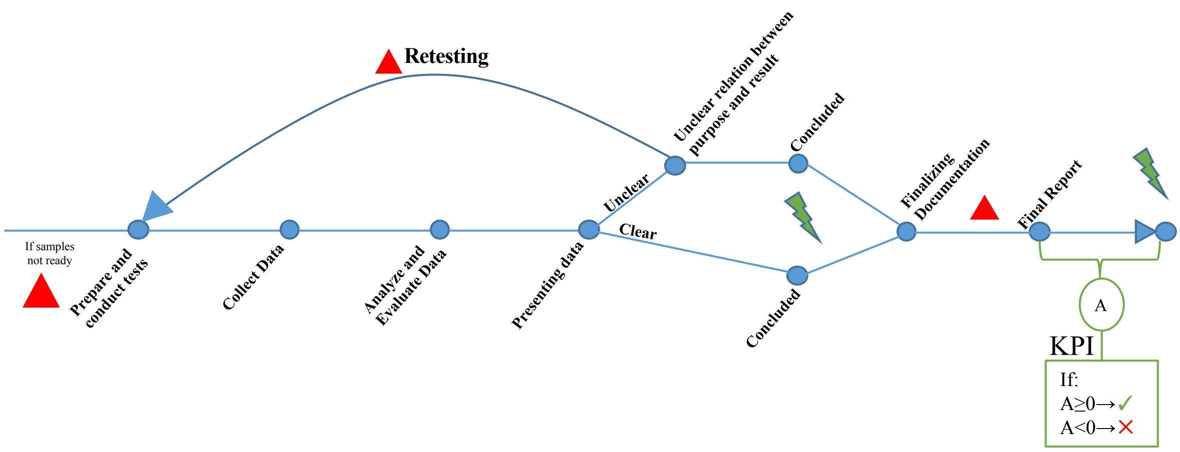

Figure 14 - The Evaluate-phase with potential retesting loop, showing that the relation between the purpose and result sometimes is clear and sometimes unclear

When finalizing documentation, the lab representative assures that all attachments and pictures are added to LIMS before setting the request to 'Final Report', which generates the final lab report. This section of the process can become wasteful in the situations where the test initiator has not filled out all the information during the Define-phase or if the lab representative does not write the final lab report close to when the tests were done. If the lab report has been uploaded in time to reach the final deadline, the KPI will be positive.

Independent Requests

The lower branch in Figure 11 previously shown, describes the VSM for an independent request. The independent request can be sent from an R&D team or a business unit in the organization. The independent request is initially divided in the Define-phase based on if there has been no discussion or a discussion, seen in Figure 15. In the case without a discussion, the method is chosen by the test initiator. The request is thereafter set as 'Received'. In cases where a discussion happens, the lab representative and the test initiator chose the lab method together, as the lab representative has sufficient experience or knowledge to participate. The method is mutually agreed upon and the request is set to 'Received'. The two cases merge in 'Confirmed Agreement'.

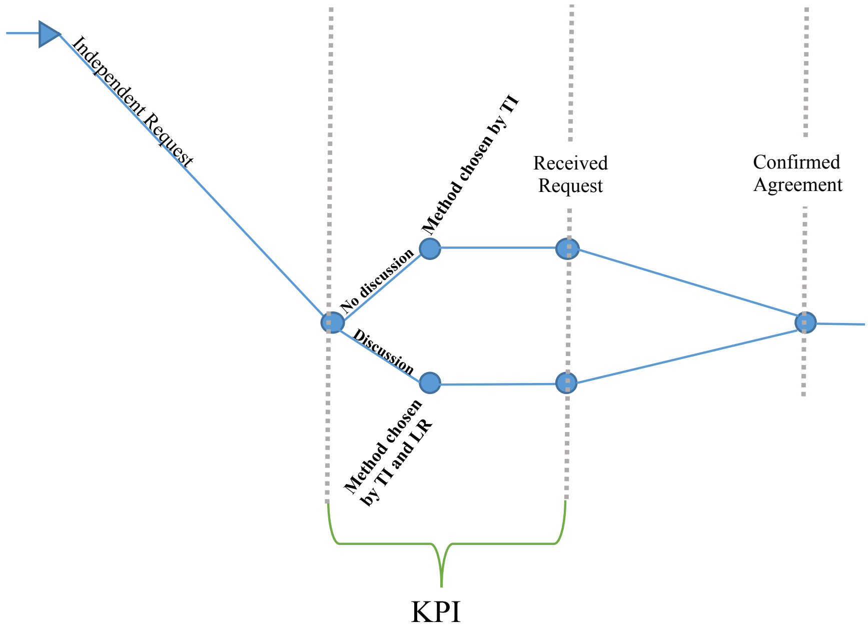

Figure 15 - The lower branch of the Current-state VSM for independent request in the Define-phase, which differentiates depending on if there is a discussion or not

The Measure-phase is generally carried out in the same way as for a project. For the Evaluate-phase, there are three possible scenarios, see Figure 16. Two of the scenarios are the same as previously mentioned for projects. However, the third scenario, going from Analyze and Evaluate Data to Finalizing Documentation, is where the test initiator is only interested in the final lab report. Therefore, no top-line or other results are presented at this stage of the process. In this scenario, the request reaches Finalizing Documentation after the data has been analyzed and evaluated. If the report does not contain any conclusions, i.e. when the test initiator only wants the data but does not want to write the rest of the report, the request moves back to analyze and evaluate as that part must be written. If the documentation is satisfactory, it can move on to 'Final Report' and be generated as a final lab report.

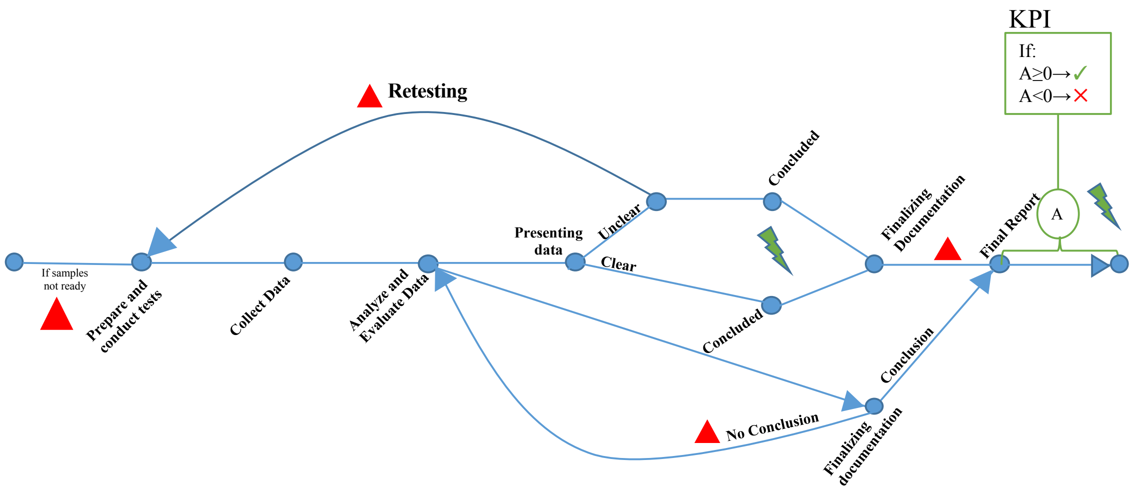

Figure 16 - The Evaluate-phase for an independent request with its three scenarios and loopbacks

4.9.3 Knowledge Source Map

To conclude the findings regarding Knowledge Management and where knowledge is captured and reused, a Knowledge Source Map has been created, see Figure 17. It visualizes when knowledge is captured and reused in projects and the DME-process and where it can be retrieved and stored. The locations of knowledge have been divided into high degree of accessibility, meaning everyone can access the information in those locations and low degree of accessibility, which implies that an employee needs certain access rights to retrieve information or that it is only accessible to the knowledge owner.

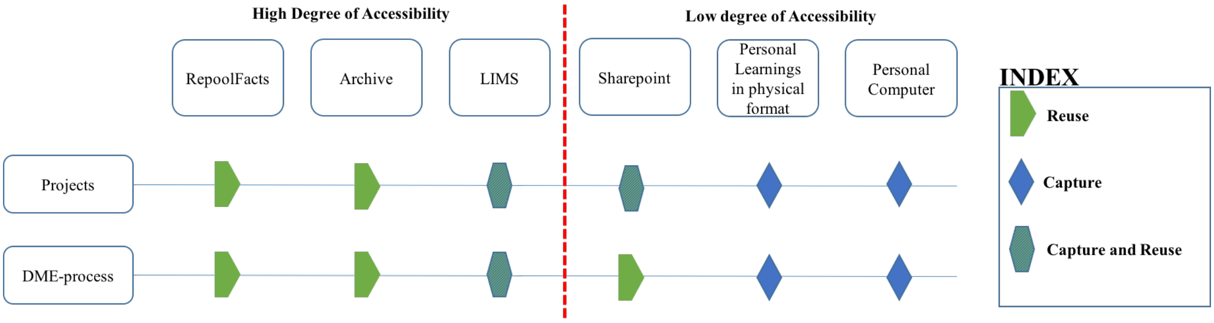

Figure 17 - Knowledge Source Map showing the degree of accessibility to knowledge and where to find the knowledge in the two cases of Projects and the DME-process, with explanatory index for reuse and capture

The high degree of accessibility locations are RepoolFacts, the archive and LIMS. RepoolFacts is a system which is accessible to all and knowledge is mainly retrieved and reused from here. The archive has historical information which is accessible when any employee wants to retrieve information from the archive. LIMS is where the requests are carried out and documented, thereby capturing knowledge. In addition, LIMS stores previous reports and acts as a database for reusing knowledge, both for projects and for the process itself.

The locations for low degree accessibility are SharePoint, learnings in physical format and personal computer. SharePoint is used both on department level and on project level. The documentation on these SharePoints are only accessible to those with access. For projects, the knowledge is both captured and reused in SharePoint, whereas for the DME-process, the knowledge is only reused from SharePoint, i.e. when doing research for a test. However, if one has not been involved in a project, access rights need to be approved. The person then has to contact the IT-department who needs to receive consent from the SharePoint owner in order for the person to retrieve information. Personal learning in physical format is defined as books, articles, educational material, which have been handed out to the individual and stored by the individual. The only way to retrieve this information is by knowing who possesses this knowledge. The last location of knowledge is the personal computer, where employees have stored thoughts and learnings electronically i.e. on OneDrive or Outlook, which is still not accessible to others unless they are aware that these employees possess the knowledge.

5. Analysis

Based on the Theoretical Framework and Findings from the interviews, the Analysis will focus on the difficulties in the DME-process in relation to Lean Product Development and Knowledge Management. These difficulties will later be used as a foundation for the future-state VSM in Chapter 6. The structure of the Analysis will combine different parts of the DME-process and therefore it has a different structure compared to the Findings in Chapter 4.

5.1 Lean Product Development aspects in the process

To answer the first research question *"What are the aspects of Lean Product Development in the DME-process?"*, the first part of the analysis will compare the way the DME-process is carried out today (spring of 2018) with Lean Product Development principles. As 90% of the interviewees stated that there is insufficient initial information of some aspects when reaching the final stages of the process the analysis will focus on locating where these gaps of information arise and eliminate them. As 30% of the interviewees want the Define-phase to improve, the Analysis will focus on having the right information at the right time in the Define-phase.

5.1.1 Communication

The DME-process instruction does not state that physical communication needs to take place when carrying out a request. Instead, it encourages both parties to be involved in every activity in the Define-phase, but does not state how the certain activities should be conducted or communicated. Because of this, the initial part of the analysis will focus on the communication in the Define-phase and how it affects the work later on.

Communication Until Reaching 'Confirmed Agreement'

Set-based concurrent engineering can support organizations in eliminating loopbacks, knowledge gaps and help to ensure that the right information has been received before proceeding development of a product (Kennedy, 2008). Loopbacks are described as one of seven common wastes in product development (Radeka, 2016), requiring actions or changes at a late stage. Set-based communication supports organizations in avoiding working on a solution and changing it at a late stage. Loopbacks can be connected to the knowledge waste of wishful thinking (Ward & Sobek, 2014), where one assumes that the information possessed is the right information. One proceeds the work and ends up with rework at a later stage because the decision to proceed was not based on facts after all.

Throughout the interviews, communication in the Define-phase has sometimes been considered insufficient in order to fulfill a request in an efficient way. Lab representatives have had to ask for more information from the test initiators and sometimes added more information themselves in order to have the necessary information in the request. The Define-phase, as previously mentioned in the Background section, includes reaching agreement between the test initiator and lab representative regarding aspects such as background, assignment, lab method and deadline. The lab representative receives information about a request through the request itself or by having a meeting with the test initiator (or in some cases, both). It has been found that sometimes after having a dialogue regarding a request, the lab representative is expected to have all necessary information to proceed in the process. The problem that arises is the assumption that the information has been processed in a way that makes written clarifications in the request unnecessary. When later reaching the Evaluate-phase, the two parties might realize that the results are not connected to the initially written purpose, since it does not contain the information from the meeting and uncertainty regarding what has been tested arises.

Based on what theory describes and how the company works, there are loopbacks strongly connected to the assumptions that are made with or within the DME-process, especially in the Define-phase, illustrated in Figure 18.

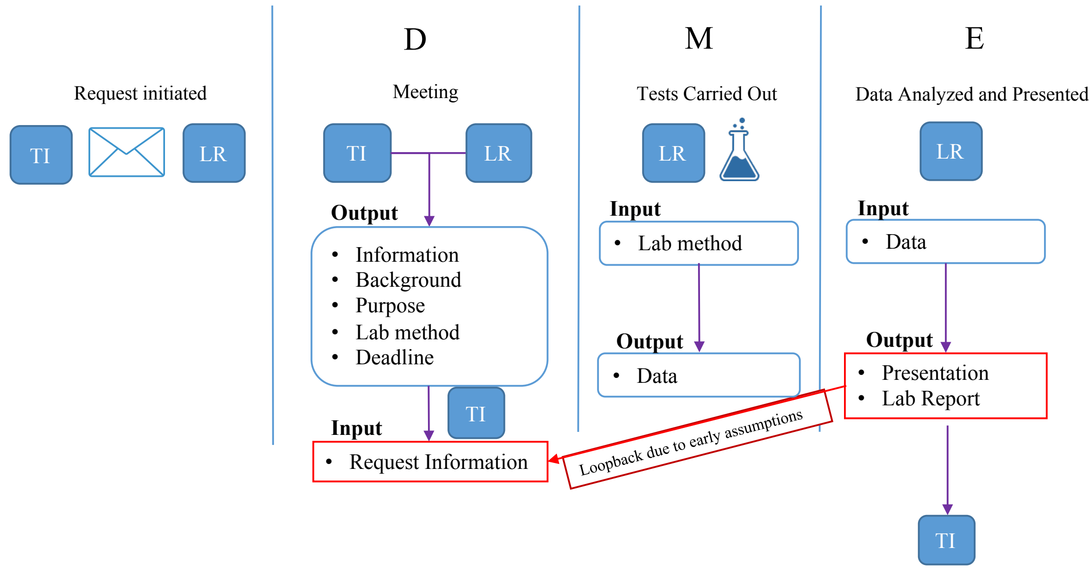

Figure 18 - Illustration of each phase's output and input and how the loopbacks of information affect the work in the process

The process itself does have points of activities and promotes discussion, but the output of these activities are not taken care of in a value adding way. The hard squares in Figure 18 above visualize the knowledge waste in terms of wishful thinking, where one assumes that after a meeting, all the information has been possessed by the lab representative who proceeds to the next step in the process. Later, the lab representative realizes in the Evaluate-phase that the information has not been written down, making it necessary to go back to the Define-phase. Set-based concurrent engineering highlights the importance to ensure that the right information is received before proceeding and wishful thinking implies that the information needs to be facts, not assumptions. Set-based communication indicates that having the right discussions at an early stage can avoid carrying out work which later must be changed. In other words, communicating the right things early in the process can result in avoiding late loopbacks. Combination of these two theoretical aspects could conclude in less knowledge waste and the DME-process becoming more efficient.

Communication in Sequential and Concurrent Engineering

One of the Lean Product Development techniques mentioned by Karlsson and Åhlström (1996) is concurrent engineering where work is carried out in parallel. The opposite to concurrent engineering is sequential engineering which is described as a traditional product development working process, where work is handed over to the downstream department only when the upstream department is done with its work (Rosario et al., 2003). In sequential engineering, the information is communicated one-way, which means that the downstream department relies on the upstream information being correct and the other way around (Wheelwright & Clark, 1992).

A lab representative and test initiator at the company can have multiple development projects ongoing in parallel, as well as many requests related to one project at the same time. Due to technical meetings, there are more discussions regarding the requests in projects. For independent requests there can be either a meeting for the request or just receiving the request in LIMS.

One project can have multiple requests going on at the same time. In these cases, the communication is considered continuous throughout the whole process, see Figure 19. The test initiator becomes more involved in cases when there are deviations during testing and uncertainties in how to proceed. However, the final lab report in general becomes one-way communication from the lab representative to the test initiator.

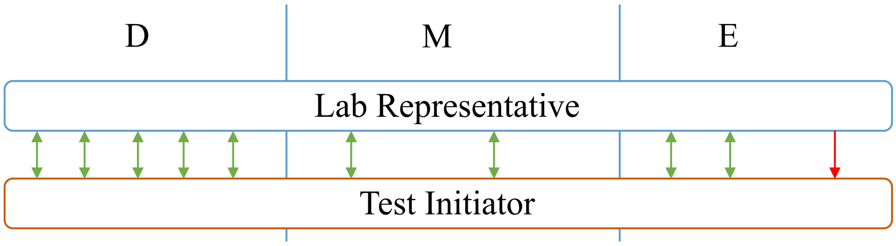

Figure 19 - Communication during project requests is continuous

When working with independent requests, the communication is sometimes perceived as less continuous with little two-way communication. In cases where there is a meeting between the lab representative and test initiator, seen in Figure 20, this usually takes place in Define and Evaluate-phase.

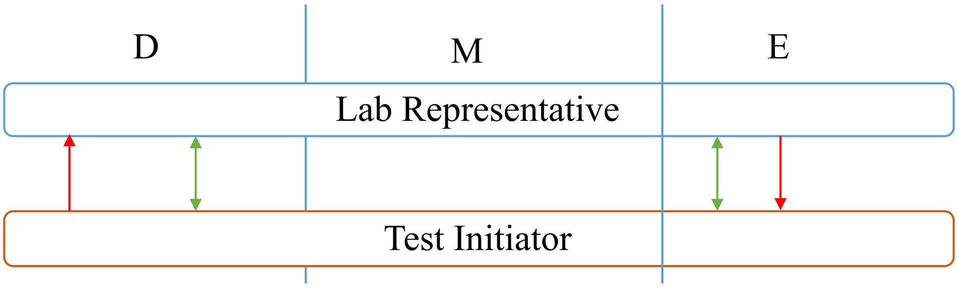

Figure 20 - Independent request with some communication in the Define and Evaluate-phase

In other cases, there is only one-way communication between the lab representative and the test initiator, seen in Figure 21, where the only communication points are when the request is received and the final lab report is sent.

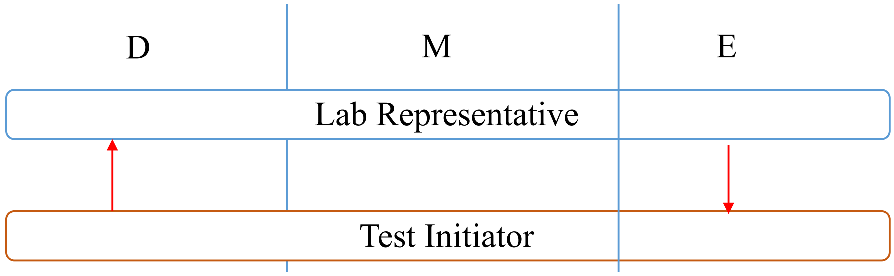

Figure 21 - Independent request with only one-way communication in the Define and Evaluate-phase

Independent requests generally regard standard test methods, which therefore lead to little or no involvement during the Measure-phase. If something deviates, it is rather communicated as a conclusion during the Evaluate-phase. Regarding the final lab report, there are similarities between the project and independent requests, as they are generally communicated one way from the lab representative.

Communication When Dividing a Request Among Lab Representatives

Concurrent engineering makes it possible to work in parallel between upstream and downstream groups (Karlsson & Åhlström, 1996). In addition, set-based concurrent engineering allows for work being carried out in parallel between smaller sub-teams as the parameters have been set and the engineers know the limits to work in between (Ward et al., 1995). As previously mentioned, communication is essential in gaining advantages in set-based concurrent engineering, as others rely on receiving the correct information. Another aspect of communication is within Knowledge Management, where waste can occur when a person in charge does not have sufficient information to act upon but still does, called hand-off (Ward & Sobek, 2014).

There are many lab methods that can be carried out for one request and it is difficult for one lab representative to know all of them. Instead, lab representatives are educated in the different methods. Sometimes a request can require multiple methods to be carried out during the Measure-phase, which leads to more than one lab representative being involved with the request. This was described as difficult, as the 'secondary' lab representatives do not possess the project background or the purpose of the tests in the same extent that the 'ordinary' lab representative.

When dividing the responsibility for a request among multiple lab representatives, the DME-process is carried out concurrently. It can be interpreted as set-based concurrent engineering as the request has a scope and the lab methods are set based on that scope, creating the limits. However, there is a risk of knowledge waste as the 'secondary' lab representatives act on the information given by the 'ordinary' representative or on what is written in the request. As previously mentioned in Findings, there have been situations where information has been insufficient which requires continuous retrieving of information. The person relies on information from someone else which creates a risk for hand-off knowledge waste, as he or she does not possess enough information to question, therefore just continues the assignment, which can cause waste at a later stage.

5.1.2 Deadlines and KPIs

One topic of which many interviewees thought differently, was the deadlines of the request. As mentioned, there were three frequently occurring scenarios concerning the deadlines: how the deadlines are decided upon, expectations of the deadlines and changes related to the deadline.

How Deadlines are Decided

Deadlines depend on numerous factors such as meetings, stakeholders and available resources. In cases where a deadline is needed in further decision making, e.g. for a meeting, the test initiator often bases the 'wished deadline' on the date of the meeting. When the 'wished deadline' does not depend on a meeting, the test initiator might choose a date based on how long he or she believes the process will take or select a random date. However, it is not always clear for the lab representative if the deadline is sharp, meaning that a decision will be made by the time of the deadline or not. Additionally, the test initiator does not always take into consideration that the time needed to finish a request and the associated lab report exceeds the time needed for gathering the data. Therefore, the 'wished deadline' seldom matches the time needed for the lab representative.

The DME-process is conceptually presented and therefore difficult to update with real time changes. As Lindlöf (2014) suggests that by showing the process with only the information which is needed, the employees can easier communicate when and why the deadline is chosen. One tool to handle uncertainties, such as the deadlines in the process, is visual management. As mentioned by Lindlöf (2014), task communication is used to communicate areas of responsibility and how the execution of tasks should be done. As the DME-process is affected by delays and changes, but the communication about the request is on an individual level between a test initiator and a lab representative, communication should not create problems regarding deadlines. A greater focus on communication between the parties could contribute to more flow in the process. This means that it can be clear when a deadline is sharp and not. Additionally, it makes it possible to communicate how the measurements and the evaluation are going.

Expectations

The differences in the perception of the duration also relies on the different expectations of what should be ready at the deadline. The lab representatives say in a higher degree than the test initiators that the whole lab report should be ready before the deadline. For many test initiators it is enough to get the lab result, therefore the final report is not an expectation from them at this point.

The varying expectations can be connected to the theory about insufficient customer empathy (Radeka, 2016), where the customer in this case is the test initiator. In the case where the deadline is sharp, but this is not communicated, the test initiator might not get what is needed because the lab representative does not know that the deadline is sharp. When the lab representative cannot differentiate a sharp deadline from a regular 'wished deadline' in the system, waste is created.

A final aspect regarding deadlines is what the set-based communication theory describes (Ward et al., 1995). When information is needed to a certain time in the work process, people are less likely to delay the work. Therefore, if the expectations of both lab representative and test initiator are clear, it is easier to relate to the deadline. In addition, design loopbacks (Radeka, 2016) can be avoided by providing the decision makers with the right information at the right time, which additionally increases the importance of keeping the deadlines.

Changing the Deadline

The last aspect is the KPI which measures whether the final deadline is on time or not. Due to different expectations, there are many cases where the test initiators do not care about the final lab report because they have already got their result. This means that the incentives for finishing the lab report are low for the lab representative. Hence, the KPI of the final deadline measures something which does not seem important for the performance of the employees. According to Lean, it is waste to measure something which does not add value to the process (Liker & Hoseus, 2008).

Theory states that it is important to measure the right KPIs in order to improve the business, i.e. the KPIs should be based on factors which are important to the company (Liker & Hoseus, 2008). As many of the employees who work in the DME-process change the final deadline and state that the final deadline is not important to their daily work, the purpose of the KPI does not relate to what the theory describes. Therefore, the current KPI alone is not a good measure to improve business. By giving the 'wished deadline' more value in the process, this deadline can become more important for both parties. According to theory, a project is more likely to be successful if pressure is put on it (Karlsson & Åhlström, 1996).

5.1.3 Selection of the Lab Method

The findings show that decision of the lab method can depend on factors such as experience, knowledge, type of request and if it is clearly stated in the requests what factors which should be tested. There is a common understanding that the parameters should be stated by the test initiator and that the lab representative should give suggestions on the lab method, but sometimes the test initiator decides the method by him or herself.

Theory about Lean Product Development techniques describe that by using cross-functional teams, several competences are brought to the table, making the products better (Karlsson and Åhlström, 1996). This means that by involving both test initiators and lab representatives in an early stage of the Define-phase, both the product development and the DME-process can be improved.

The lab representative is supposed to be the expert regarding the methods, including the amount of samples which should be tested. This can be connected to the theory about excess requirements and specifications in the common wastes of traditional product development (Radeka, 2016). When the expertise of the lab representative regarding amount of test samples is not used, the company risks exceeding the expectations of the customer's needs, which in this case is the test initiator or the management leading the project. Additionally, a large amount of samples can exceed the capacity of resources the project has, while too few samples can result in that the whole Measure-phase must be repeated, which according to Lean theory is waste (Liker & Hoseus, 2008).

When excessive tests are carried out because test initiators do not want to miss anything and therefore do not use the expertise of the lab representative, the empathy for the lab representative's job is not present. The theory about Resourceful Sensemaking states that the parties should adopt the perspective of their colleague, in order to understand their point of view (Beverland et al., 2016). Many lab representatives have stated that they do not believe the test initiators fully understand the comprehensiveness of the tests and that they therefore do not understand the timespan of each measurement. This supports the theory about Resourceful Sensemaking, stating that different departments do have different ways of thinking and that conflicts can occur when the differences are not discussed.

5.2 Knowledge Management Aspects in the Process

To answer the second research question, *"What are the aspects of Knowledge Management in the DME-process?",* the analysis will focus on how the knowledge is captured, reused and transferred in the DME-process.

5.2.1 Capturing Knowledge in the DME-Process

In the interviews, 30% stated that they capture their knowledge, however this knowledge does not become accessible to others. Almost 40% stated that they would work more with capturing knowledge if they knew it would be accessible to others. The DME-process mainly captures explicit knowledge in the final lab reports that are published when a request has been finalized. However, throughout the interviews it was found that observations during the Measure-phase can help test initiators to transform explicit knowledge into tacit knowledge.

Observations During the Measure-Phase

The Knowledge Hierarchy explains that data with a defined purpose turns into information, the information later becomes knowledge when it is applied and can be acted upon (Becerra-Fernandez & Leidner, 2014). The explicit knowledge is easy to communicate through documentation whereas tacit knowledge is rather personal and based on experience (Nonaka et al., 1994). The knowledge can be transferred from explicitly written knowledge to tacit knowledge through an internalization process, also known as "learning by doing". Socialization is another mode of knowledge transfer, referring to when tacit knowledge is transferred to tacit knowledge, which commonly happens during observations.

Throughout the DME-process, the lab representative is responsible for carrying out the lab method in the Measure-phase. In the description of the processes, there are no instructions stating that the test initiator should be involved in this phase. In the interviews, it was found that in cases where new methods, products or materials are tested, the test initiators are interested in observing during the Measure-phase. From the test initiator's perspective, it is to learn how the product performs during tests and from the lab representative's perspective it is both how the method works as well as the performance of the product. One test initiator stated that involvement makes it easier to discuss the results and how to proceed with the results. Even if the interviewees were not asked about involvement during the Measure-phase, both test initiators and lab representatives mentioned that they wish to have more involvement as it can increase the learning.

Comparing the Knowledge Hierarchy to the aspect of carrying out a method in the Measure-phase, the written lab method description can be seen as data. The lab method becomes information when it has been assigned to a certain request and thereafter turns into knowledge when it is applied to a sample during testing, summarized in Figure 22. This can be seen as the knowledge transfer mode of internalization, where the lab representative turns explicit knowledge into tacit knowledge. The internalization occurs every time a lab representative conducts a method based on a lab method description.

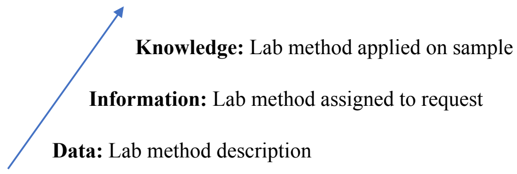

Figure 22 - The transformation from data to knowledge for a lab method description

Another knowledge transfer which occurs during an observation is the one between a lab representative and an observing test initiator, which is socialization. The lab representative explains to the test initiator what has occurred during testing and therefore the knowledge transferred is tacit-to-tacit, see Figure 23.

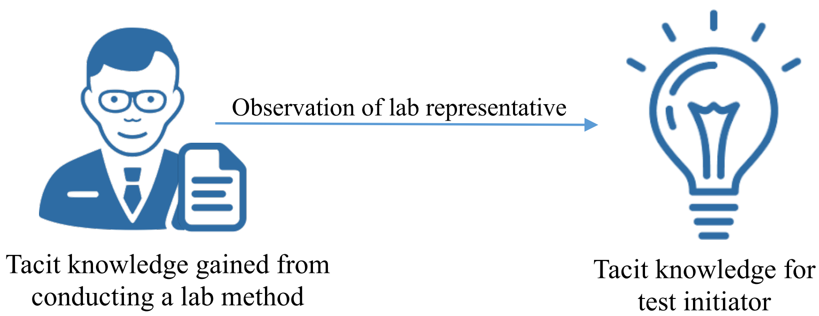

Figure 23 - Knowledge transfer from tacit-to-tacit knowledge between lab representative and test initiator

The socialization process will enable the test initiator to learn by observing. This leads to the top of the Knowledge Hierarchy being reached by both the lab representative and the test initiator, concluding in them creating and capturing tacit knowledge.

Transferring Knowledge to a Lab Report

Theory states that explicit knowledge is easily transferred as it is formal documentation, compared to tacit knowledge which can be difficult to transfer as it is grounded in personal experience (Nonaka et al., 1994). Externalization, the transfer of tacit-to-explicit knowledge, can be difficult to handle as it requires expressing information which can be difficult to explain (Nonaka, 1994). When trying to capture knowledge which is tacit, the learning needs to be continuous and the learner needs to have a shared understanding of the topic.

The structure of how LIMS presents the requests can be interpreted as dividing the final lab report into two parts. The first part, including background, assignment, deadline and samples, is mainly written by the test initiator when initiating the request. The second part of the final lab report includes information of how the method was carried out, data, results and conclusions, which is written by the lab representative. It is the responsibility of the lab representative to finalize the documentation of a request in the DME-process and the lab representative is therefore indirectly responsible for both the first and second part of the final report.

Comparing the theory with findings from interviews, the final lab reports conclude in explicit knowledge, which should be easy to transfer to others. However, it can sometimes be difficult to express what has been seen during the lab process, which sometimes is supported by pictures. To capture the knowledge from the final lab reports, the lab representative needs to consider who the recipients of the report are in order to express the information in an understandable way. In addition, the person reading the final lab report needs to have some previous knowledge or understanding of the product or method in order to fully understand what has been conducted.

Overloading Resources

Overloading resources is one of the wastes in traditional product development and can become an issue when employees have too many projects or activities ongoing in parallel (Radeka, 2016). One way to save time throughout a process or development project is through one advantage of set-based concurrent engineering, which promotes organizational learning (Ward et al, 1995). By using learnings from previous experiences, employees can gain information from a large perspective of the organization and gain a head start in some cases of development.

Lab representatives and test initiators have multiple requests ongoing at the same time and lab representatives can struggle to find time after the results have been presented to finalize the report, as the next request is waiting to be carried out. Currently, the lab representatives consider writing the report as waste, as LIMS does not work sufficiently or smoothly for the user.

There is a relation between overloading resources and the DME-process. A first factor is the lab representatives not having sufficient time to finalize the lab reports, as they describe it to be time consuming because of how LIMS works. A second aspect is the previously mentioned issue in communication, when there is insufficient information from the test initiator, creating time waste as it has to be added at a later stage. A third aspect of writing the final lab report is that it is not prioritized from the lab representative as the results have been delivered to the test initiator at an earlier stage and that the test initiator no longer is interested in the lab report.

Another issue of overloading resources is connected to the project learnings that are written at the end of a project. These learnings are outside of the scope for the DME-process but share many similarities to writing the final lab report. The purpose of writing project learnings is to be able to consider them when starting a new project or when a project is facing a problem. Writing the project learnings is not included when setting the schedule for a project, it is rather an activity which is planned after the project is done. However, after a project has been finalized, the project group has been split up and many of the resources have already moved on to the next assignment and therefore the project learnings are not always captured. Considering set-based engineering, the project learnings are not accessible in a way which gives the next projects an advantage, compared to the Toyota's lessons-learned book (Ward et al., 1995) that is accessible to everyone. This provides employees with a head start in the next project as they have a better picture of what parameters can affect the work and shorten the development time, visualized in Figure 24.

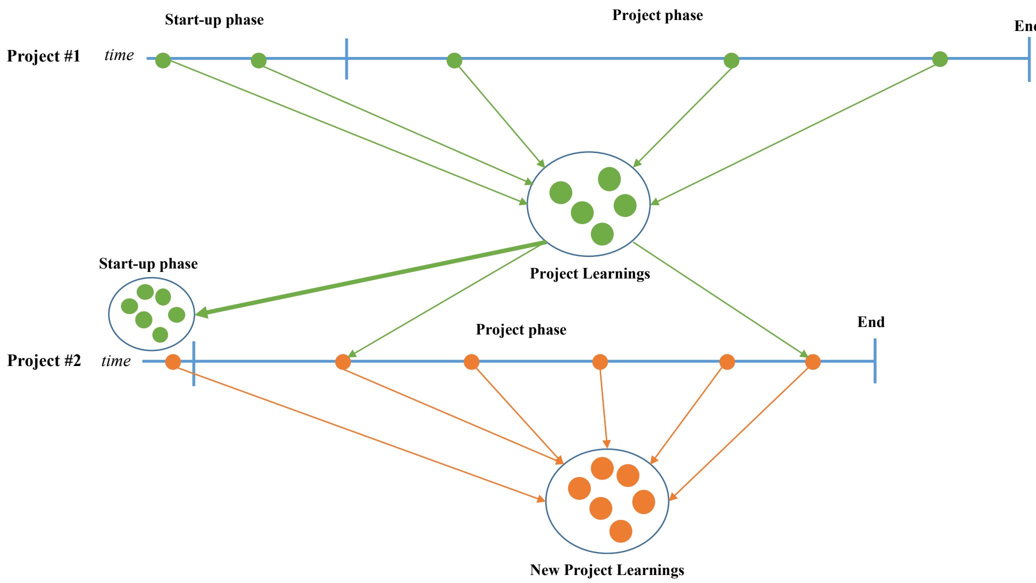

Figure 24 - Project learnings from project #1 gives a head start for project #2 at Toyota and therefore the total time for project #2 is shorter than project #1

The project learnings at the company are accessible to those who have been involved in a project, since they are stored in the project's SharePoint. At Toyota, learnings can provide employees with knowledge from multiple departments which they can rely on when starting a new project or facing problems in an existing project, to learn from what previously have been done. This makes the process more efficient and shortens the overall process time. The uncertainties regarding access to project learnings, make the writing of them less motivating since the issue to gain access to learnings remains. Additionally, this is in line with the theory about ease of knowledge access by Watson and Hewett (2006). Although learnings are captured, the time for conducting the next project does not become shorter as the learnings are not accessible for all, visualized in Figure 25.

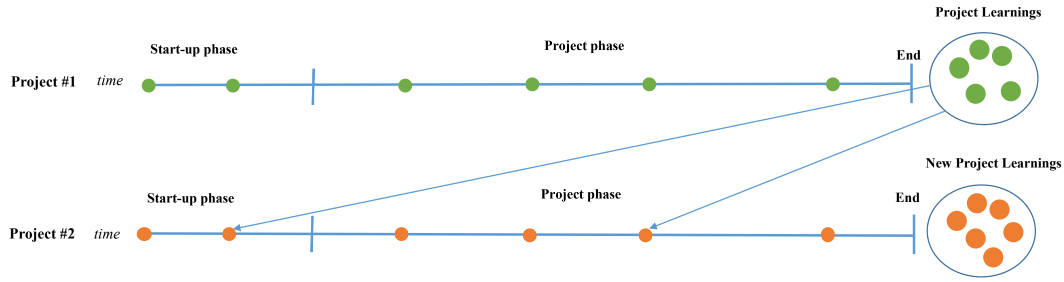

Figure 25 - Project learning at the company take place after a project has been conducted and does not always make the development for the next project more efficient as it is not accessible to all

Standard Structure of LIMS

Alavi and Leidner (2001) describe one alternative perspective of knowledge as the access to information, implying that structure is needed in order to effectively search for the knowledge. The company's main source of knowledge during the DME-process is supposed to be older lab reports. Another important reason for writing the lab reports is due to traceability, as documentation regarding how a product is developed is checked during external audits.

The final lab reports in LIMS are standardized in terms of the content of the reports, as there is a fixed structure in the system. The structure of LIMS should ensure that certain information is included in the final lab reports, which facilitates the search of information as the employees should know what to expect when they look for a report. However, in some cases when the test initiator asks for raw data only and does the analysis of the data by him or herself, the final lab report risks lacking the analysis and conclusion. This is counterproductive in regards to the purpose of the traceable lab reports. When the lab representative is not included in the analysis, this part might be absent in the final lab report, as it is the responsibility of the lab representative to add an analysis in the report. This results in the knowledge not being captured, which creates a vicious cycle when someone in a later stage wants to reuse the knowledge.

Additionally, theory about computer self-efficacy shows the importance of feeling capable of using computer applications in order to more frequently reuse knowledge and contribute to new knowledge (Watson & Hewett, 2006). In cases where the test initiator does not know how to handle the request writing or sends the request by e-mail, asking the lab representative to insert the information in LIMS, the computer self-efficacy is not sufficient to increase frequency of knowledge capturing.

5.2.2 Reusing Knowledge in the DME-process

The findings show that there are three factors which affect how knowledge in the DME-process is reused. These are reinvention, scatter and time for evaluation. By focusing on these factors and analyzing how they affect the firm, the level of knowledge reuse can increase.

Reinvention

One factor mentioned by the interviewees regarding why knowledge is not reused often enough is that the employees get thrown into the Define-phase and that there is not enough time to search for old knowledge. Theory states that the best way to make people search for knowledge is to make it accessible (Alavi & Leidner, 2001). Almost half of the interviewees said that they would reuse knowledge more if it was more accessible and easier to find. When employees do not look for old knowledge because they do not know where to look for it, the knowledge is not accessible which can lead to reinvention and waste. Theory states that the structure of the knowledge should be facilitated by a KMS, which should provide the user with mechanisms to effectively search for suitable information (Alavi & Leidner, 2001). Additionally, ease of knowledge access increases the frequency of knowledge reuse (Watson & Hewett, 2006). Since the company has several locations for saving knowledge from the DME-process, as shown in the Knowledge Source Map, it is not clear where to look for the knowledge.

Scatter

The lack of accessible information contributes to that people in a higher degree ask colleagues for help. In the interviews, 6 of 16 interviewees stated that they rely on asking their colleagues when they are looking for old knowledge. This can be interpreted as contradicting since all interviewees stated that they know where to find old knowledge. According to Lindlöf (2017) it is not enough that employees know where to find knowledge, it must also be easy to understand and use.

To have employees working in the process frequently ask each other for help, can both be positive and negative. It contributes to more communication, which can be positive. Communication between coworkers, such as openness and trusting colleagues' opinions, is positive for a company. Nonaka et al. (1994) state that problem solving happens during information processing and that both new learnings and the understanding of how to use the new learnings are developed during communication. In a culture where it is OK to ask questions, problems are more likely to come to the surface.

Even if theory states how communication is good in most cases, there are times when communication creates more scatter than needed. According to theory, scatter occurs when people are interrupted in their daily work because something unexpected happens, such as a colleague asking about an old project (Ward & Sobek, 2014). Because of the lack of information about where to look for certain knowledge, the company is in high degree exposed to scatter. One typical example is that employees say that they have a big network of colleagues to ask when they want to reuse knowledge, which means that the employees frequently interrupt each other.

Additionally, there is a risk that the knowledge which is communicated from one colleague to another is supposed to be transferred from tacit-to-explicit knowledge (Nonaka, 1994). In cases where one colleague has hands-on experiences of the knowledge, while the other colleague does not, this can be difficult. As the externalization mode is explained as "expressing what cannot be expressed", the communication between colleagues might be problematic if it cannot be written down.

Learning Cycle

One important part with Knowledge Management is the ability to reuse information from previous experiences in new projects. This is presented as knowledge as a capability in the theory about knowledge perspectives (Alavi & Leidner, 2001). In order to use previous created knowledge, it is important to evaluate what has been done at the end of every project or "sub project-activities", such as a request, e.g. by using a learning cycle. Many of the interviewees stated that the information in the requests is not sufficient or thoroughly written, and that it becomes problematic to reuse the requests later. In many cases, this could have been avoided by adding more time in the Define-phase, but as both test initiators and lab representatives often rush through this phase, reuse of knowledge in form of old reports is hindered. Additionally, the final reports are often not read, which makes it even more difficult to reuse knowledge, as reading reports is one way of reusing knowledge.

5.3 Analysis Conclusion

Concluding the analysis, the current situation regarding the DME-process could be explained by Figure 26, illustrating that efficiency can only be reached if the waste is eliminated. In order to achieve efficiency, it is of importance to understand how Lean Product Development affects Knowledge Management and vice versa.

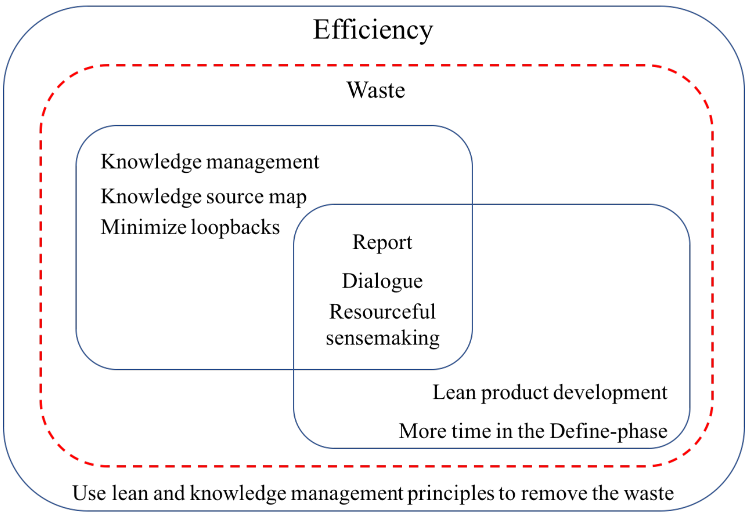

Figure 26 – Efficiency in the DME-process is currently hindered by waste and by using Lean and Knowledge Management, this could be reduced

In terms of making the process Leaner and increase the reuse of knowledge, the users of the DME-process need to set aside more time throughout the Define-phase. There is a need to ensure communication and that important aspects, such as parameters and purpose, are clearly defined in order to avoid late loopbacks (Radeka, 2016). In addition, the information communicated needs to be taken care of during the Define-phase, assuring that the rest of the process is moving smoothly.

Knowledge Management aspects require more time spent in the Define-phase. This is to ensure that lab representatives and test initiators have enough time to find the previous knowledge which could help carrying out the new requests. However, it requires the knowledge to be accessible and that the final lab reports are written in a standardized way, providing the reader with a holistic and informative picture of the request. This means that enough time needs to be set aside for the final lab reports to be finalized and for the project learnings to be considered when setting a time plan. Otherwise, the final lab reports and learnings become wasteful for the company.

6. The Future-State DME-Process

Based on what has been brought up in Analysis, this Chapter will focus on how the future-state VSM of the DME-process can be carried out, by integrating Lean Product Development and Knowledge Management aspects. Hence, this section will answer the third research question "*How can Lean Product Development and Knowledge Management be integrated in the DME-process?*".

By applying four VS loops to the current-state VSM in Section 4.9.2, improvement suggestions to the process has been compiled. These improvements were later presented during a workshop which was carried out in May 2018. The findings from the workshop are presented under each section. There were six participants present, some which previously had been interviewed. The other participants were recommended to include by the management, as they possess knowledge about the process. The participants represented both test initiators and lab representatives. Based on the suggested improvements, this Chapter concludes in the future-state VSM of the DME-process.

6.1 One Process to Reach Standardization

Considering the current-state VSM, the DME-process is unconsciously divided into two different branches, the project request and the independent request which represent the first VS loop, see Figure 27.

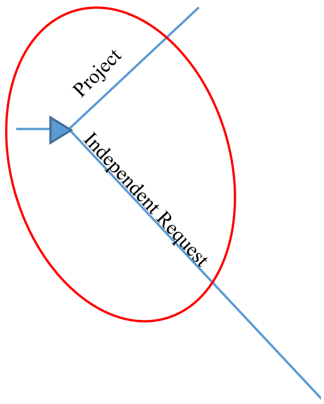

Figure 27 – The first VS loop showing the DME-process branching into two processes, depending on if it is a project or an independent request

When developing a future-state map, the aim is to have one common process. As Lean theory states, it is only possible to make improvements when a process is standardized and does not deviate from time to time. By having one way of working, the employees can focus on learning one process, which can increase the understanding of the process as all requests will be handled in a coherent, standardized way. It can make the roles and responsibilities clearer as they would stay the same. Additionally, by only having one process the individual ways of working can be eliminated.

However, a negative aspect can be that employees consider the process to have a low level of flexibility as the requests may vary in how they are written and carried out. This might require the requests to deviate slightly from the process and can become a difficulty in cases where time pressure or other factors are influencing a request. On the other hand, this issue can be overcome through communication between the parties.

6.2 Communication

Based on the current-state VSM in Figure 11 and the Analysis in Section 5, communication has been found as an aspect that can be improved in the future-state process. As work can proceed throughout the DME-process without having the facts in detail from the beginning, the future state will strive to eliminate the errors in the later stages of the process by focusing on the Define-phase.

6.2.1 Standardized Meeting Agenda and Checklist

After receiving a request, the lab representative needs to have the required information in order to proceed to the Measure-phase. Aspects of uncertainty has been regarding the background information, such as defining why the request is carried out, to whom, and what the purpose of the request is. This leads to the second VS loop creating waste in the Define-phase, see Figure 28.

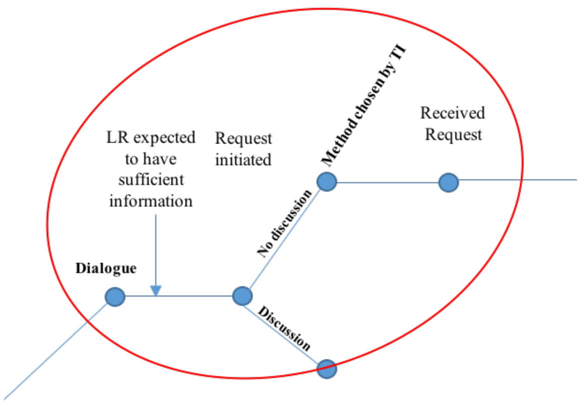

Figure 28 – The second VS loop focusing on the lack of information in the Define-phase which can create late loopbacks in the process

In some cases, this information is provided by the test initiator and sometimes it is not. In order to avoid late loopbacks and retesting, the future-state Define-phase is suggested to have a greater focus on defining the following aspects:

Who: Who is the lab representative with the expertise to solve the request? Who is the test initiator? Who does the results aim for?

What: What should be tested? What has been tested before within the area? What will the results be used for?

Why: Why is the request carried out? Why are there X number of sample products/materials requested?

When: When will the samples be received? When will the tests be carried out? When is the results required to be presented?

How: How should the tests be carried out? How should the results be presented? How should the findings be documented in order to later reuse the results?

These aspects can cover the issues that currently arise in the later stages of the process. One proposal is to construct a standardized meeting agenda in order to know what the discussions should be about. This could make it easier for the lab representative and test initiator, both experienced and newer employees, as it covers the important aspects of what needs to be included to proceed with the process and what can avoid making it an unproductive meeting. Since there currently is a possibility for individuals to work as they prefer, this could allow the DME-process to become more standardized in the future. The meeting agenda could act as a checklist for lab representatives, to ensure that the test initiator has provided necessary information to proceed, in cases where no meeting is held. The checklist resembles the way of working in a development funnel with stage-gates as there are certain deliverables to achieve before proceeding.

The meeting agenda or checklist could be integrated to LIMS, making it visible to the one that fills out the request or as a working instruction that easily can be printed and brought to the meeting. One of the most important aspects to consider when the meeting is held, is that the discussion and result of the meetings are documented. The responsibility when needing to clarify the information of the request should be the test initiator's, as he or she is the one who wants the request to be carried out. The request needs to be described in a way which makes it easy for the lab representative to connect the second part of the final lab report to the first part, as the results should be aligned with what initially was requested.

As the process becomes more standardized, it still allows employees to work concurrently. For example, the lab equipment can be booked whenever the lab method has been defined. The samples can be prepared when it is known which method to use as well as when the tests will be carried out. In addition, when the WHY's and WHAT's have been defined, the lab representative can investigate what previously has been done. As Lean philosophy states that a standard must be present in order to make improvements, the standardization of the meeting agenda can make the process more efficient as the people involved know what information is expected from them. Either that information is generated by discussion between the two parties, or immediately provided to the other party.

Workshop findings
During the workshop, the standardized meeting agenda was discussed and participants were positive to the suggestion. The wish was to integrate the meeting agenda into the IT-system, so that when the test initiator writes the request, the agenda/checklist is visible to them. It was emphasized to focus on WHY and HOW, as they were considered most important. The HOW should be defined after the other information has been added. To ensure that there is an agreement regarding the added information, there should be a point of communication, e.g. an e-mail or a short meeting, to avoid having assumptions in the request. In summary, the standardized meeting agenda was verified by the participants with reservation for discussing HOW at a later stage.

6.2.2 Sample Communication

Another aspect of communication is regarding the samples that are supposed to be tested. It is important for the lab to be aware of when they will be available in order to book equipment in the lab and to prepare the samples that will be tested. There can be external factors that affect the waste seen in the current-state map, especially when the samples are ordered from another country and there might be delays in delivery or in the production. The delays need to be communicated to the lab representatives in order for them to take action in the planning. The third VS loop circles the issue of waste because of the samples not being ready, see Figure 29.

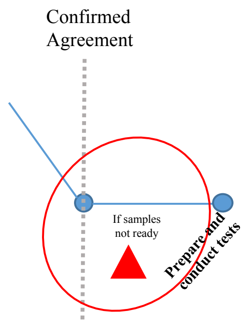

Figure 29 – The third VS loop presenting waste due to insufficient sample information before entering the Measure-phase

As mentioned in Findings, sometimes information about the samples is lacking in LIMS. An internal factor that can be improved in the future-state DME-process is to ensure that test initiators take their responsibility and fill out the sample information. If the test initiator does not fill it out, it generally ends up being the lab representatives who must do it. The lab representative might not have the right details or information of the samples. This could affect the data that is collected and analyzed, but is easily avoided if the information already has been filled out by the test initiator.

Workshop Findings

When discussing the samples during the workshop, it was found that test initiators sometimes leave the sample information in the request's background instead of adding it under Sample Information. Discussions at the workshop regarded that some do not know where or how to add the information. Another aspect discussed was lack of education. This started a discussion, as there is e-learnings about how to insert sample information. Issues with LIMS were brought up as test initiators state that they insert information which later disappears. Furthermore, it was discussed that lab representatives should question the number of samples and not arbitrary test what the test initiators wish. It was verified that it is the responsibility of the test initiators to fill out the sample information. However, more education is required for this to happen.

The participants of the workshop suggested one way to solve this issue. By having the system open the page for the Sample Information directly after filling out the initial request, the test initiators would always find where to insert the sample information. Another wish was to make it mandatory to fill out the sample information in order to submit a request.

The test initiators mentioned that it can be difficult to enter the information in LIMS, because they do not always have it and it takes time to find. This could cause that information is missing, making the final lab reports harder to understand. It was emphasized that it is very important that the right sample information is included for the purpose of traceability and reuse. One test initiator stated that it helps to have the perspective of traceability in mind when writing the request and the sample information, as it can help to remember that the information should be understood by someone else in the future and that necessary information is included. Additionally, the workshop discussed that the sample information is even more difficult to find for a lab representative who has not been involved in selecting the samples. In conclusion, the participants stated that it is the responsibility of each individual to ensure that they have the knowledge they need to insert the information of the samples.

6.3 Selection of Lab Method

During the interviews it became clear that the test initiator quite often decides the lab method without consultation with the lab representative and without explaining why. This happens even if it is the lab representative who has the expertise to recommend the lab method. This relates back to the second VS loop, Figure 28, where the selection of lab method by the test initiator makes it more common to have an additional dialogue in the Define-phase. In some cases, the two parties discuss the selection of lab method, which makes them share experiences and knowledge with each other. In the future-state VSM, it is recommended that the test initiator only can suggest the lab method if it is a standard test or a repetitive test, which requires a certain method to be carried out for comparative purposes e.g. benchmark requests. However, if the test initiator has not explained why a certain method should be carried out in the background and assignment of the request, the lab representative should question the method and ask for more information before proceeding. This is to avoid the late loopbacks in case the information has been insufficient and the test initiator has selected the method. In all other requests, there should be recommendations or discussions regarding what method to use or if there is a need to develop a new method.

It is of importance to respect the roles and responsibilities throughout the DME-process. When it comes to selection of lab method, it is according to the DME-process instructions both the lab representative and the test initiator who decide what lab method to use. What needs to be considered is that the role of the other party should not be neglected in this part of the process. As an example, if a lab representative might have less experience within a certain area in the request, the test initiator needs to teach the less experienced instead of doing the job for him or her. It is important for the test initiator to let the lab representative learn by trying, which is what internalization suggests in knowledge transfer theory (Nonaka, 1994). The internalization should go both ways, using the experience present and sharing it with the less experienced. By being able to transfer knowledge to another employee, one might feel a larger responsibility and feel motivated.

Another aspect which relies on experience and the purpose described in the request is the discussion regarding how many samples which should be tested. It is suggested that in the future-state VSM, the lab representative suggests a number of samples which need to be tested to answer the purpose of the request. It can either be based on what the method states is needed, or it can be what the lab representative feels is necessary to get a significant result. This can prevent testing too many samples, which currently results in waste.

In conclusion, the lab method and the amount of samples must be discussed to reach a satisfactory result with the request. This is important to define already in the Define-phase, and is considered an advantage from set-based concurrent engineering, as critical decisions further into the process will be based on what is early defined (Ward et al., 1995). By assuring that the roles and responsibilities are respected, the test initiators and lab representatives can learn from each other based on experiences from socialization in knowledge transfer theory (Nonaka, 1994).

Workshop Findings

It was found that it is very important for both parties to know the background in order to take initiative when selecting the lab method. As suggested, when conducting standard or repetitive tests for comparative purposes, it is OK for the test initiator to fill out the lab method. Hence, the suggestion was verified. However, the importance of the meeting checklist to include the WHY's and which parameters to test, was verified by the participants. It was added that it easily happens that the test initiators suggest a method, because they are used to do so.

The workshop further discussed that information of all methods should not be available for the test initiators, as this could encourage them to add the method. The test initiators wished to get more feedback regarding the selected lab method as they sometimes are unaware of which method is carried out. This was connected to the meeting agenda/checklist, stating that if HOW is defined and a confirmation is made, the test initiators will know the procedure in the Measure-phase.

6.4 Deadlines and KPIs

Even though the purpose of having both deadlines and KPIs is clear and something the employees agree with, there are some aspects which could be made more clear. In the analysis, three aspects were found which can contribute to more respect for the deadlines among the employees and better use of the KPIs for the company. The aspects concern changing the first KPI and the status 'Received request', the final lab report and the 'wished deadline', and the KPI which measures the final deadline.

6.4.1 The Received Status

One aspect regards the status 'Received' and the KPI connected to the status. Even though several of the statuses are not thoroughly used by the employees, setting the request in 'Received' fulfills an important role. Many lab representatives stated that they do not like to set unfinished requests in 'Received' but feel obligated to do so due to the first KPI, which measures if the request is set in 'Received' within one week. This KPI could be adjusted. One suggestion is that only requests with a completed background and assignment should be set in 'Received' and measured with the KPI as it is today. Furthermore, requests which are not completed could be set in new statuses called 'Received but not completed' and 'Received, meeting in progress', seen in Table 2.

Table 2 – Overview of the possible Received-statuses which can be implemented in order to avoid setting requests as 'Received' in cases where there is insufficient information

Received Request	The request is received and all needed information is included. The process can continue.
Received, meeting in progress	The request is received and the rest of the information will be added during a meeting. No need to further update the request.
Received but not completed	The request is received, but information is lacking. Please add more information in "part" before the process can continue.

The status 'Received but not completed' could generate an email to the test initiator, implying what the test initiator should clarify. If the request is incomplete, but the parties will have a meeting to define the missing parts, the lab representative can use the status 'Received, meeting in progress'. Independent of which Received-status is chosen, the lab representative should always answer within one week. This makes it possible to measure how many requests with unfinished background and purpose that are sent to the lab representatives and later set in 'Received but not completed'. If there is a pattern on which test initiators who do not write the reports sufficiently, this can be brought up to the surface. Additionally, it can measure how long time it takes for the test initiator to update the incomplete requests. One possible result of this is that the test initiators get more motivated to write the background and assignment more thoroughly and that the KPI does not only measure the lab representative's ability to set the request in 'Received'. By measuring this, the current amount of incomplete and late requests in the system can be calculated. Furthermore, it makes it possible to improve the quality of the requests, which affects the efficiency of the process. By doing this, more Lean aspects are incorporated in the process. Independent of which Received-status that has been used, the status 'Confirmed Agreement' should be set before moving to the Measure-phase. Thereby, it is always clear when a request is agreed upon and no misunderstandings regarding the measurements should appear.

Workshop Findings

The discussion of the first KPI in the DME-process concluded in removing it, as it does not measure anything valuable. For example, when a request is assigned to an employee who is out of office, the KPI is affected.

The lab representatives stated that 'Received' means that it has been received, but not read. Another aspect of the initial stages of the request is that when a lab representative sets the status to 'Received' the test initiator gets an e-mail. However, when a lab representative is assigned a request, no e-mail is sent to them. From the company's point of view, the reason is that the lab representatives are expected to be working continuously in LIMS to notice the request assigned to them, but there is a wish to receive an e-mail when a request has been assigned.

Regarding the suggestion to add more options for the status 'Received' the participants stated that in theory it would work well, if the KPI was removed. With the removal of the KPI, the suggested improvement was verified. One test initiator states that it would be good to have a 'bounce-back' to know if the information is insufficient. However, the suggestion of adding more statuses was based on having the lab representatives read the requests before changing the status, which does not seem to be the case today. Without the time pressure from the KPI to be set as 'Received' within one week, the additional statuses could work.

6.4.2 Wished Deadline

Currently, the test initiator sets a 'wished deadline' which can be based on an important meeting, knowledge about how long time the measurements take or it can be taken out of the blue. There are also different expectations on what should be ready to this deadline. The fourth VS loop circles the area from 'Concluded' to 'Final Report', since the result presented in 'Concluded' usually ends up in the final lab report, see Figure 30. As previously mentioned, the time span between the results delivered and having the final lab report finished can be long.

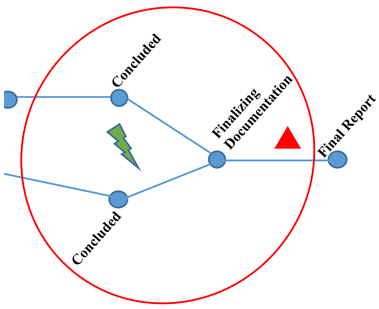

Figure 30 – The fourth VS loop focusing on the late work in the Evaluate-phase delaying the final lab report extensively

One suggestion regarding the 'wished deadline' is that the results from the measurements should be presented at this date. The test initiator should still add this date in the request, but it is up to the lab representative to decide if it is a reasonable deadline for the results or not. If any changes are needed, the lab representative must take responsibility to change it. It is important to specify that the final lab report does not have to be ready at this date, only a draft of the final lab report containing the information which can be found in the top-line is required. By presenting the results to the test initiator before the final lab report is finalized, new information can be added and the connection between the purpose and the results can be clarified. If anything is unclear or problems have occurred, the parties can discuss the confusions and add the right information. One outcome of this change is that the purpose and the result of the request will be more connected. By sending the draft and using it as a point for discussion, the quality of the reports could increase as both parties read it, creating a discussion which later can be added to the report itself.

Workshop Findings

The workshop concluded that 'wished deadline' implies when the results are wanted from the test initiators. At 'wished deadline', the results should be presented in a format which is easy to understand and not in a lab report format. When discussing the possibility of having the lab report draft done by wished deadline, it was found that drafts are not allowed to be sent due to requirements regarding Medical Devices. Therefore, the suggested draft was discarded as a solution. However, the test initiator can see a preview of the report in LIMS. Currently, it is stated that it is difficult to have the lab report almost completed by the time of the wished deadline, as there are many issues regarding LIMS which are time consuming. There was also a discussion of the name 'wished deadline' as it is used as a wish for the results to be delivered. Instead, it was suggested to call it 'Result Deadline'.

Once again, it was emphasized that it is important to understand the responsibility of ensuring that the information in the final lab report is traceable, implying that it is the responsibility of both parties.

6.4.3 KPI of the Final Lab Report

One issue with the KPI measuring the final lab report as it is today, is that it is seen as unimportant to the employees and that it easily can be changed. During the master thesis, the researchers have been informed that the company is planning to make changes regarding the final deadline so it cannot be changed without a delay code. Due to this, the researchers have not used much time on this matter, but believe that the changes will make an improvement to the process since reasons for delays will be known, making it difficult to move the deadline without a justifiable reason. Additionally, this can increase management involvement in the process. By involving management more, employees who keep the deadlines might feel that their work is appreciated by the firm, which is positive for the motivation according to theory. However, it is unfortunate that the final deadline is seen as unimportant, as it is the foundation for the business in terms of traceability. The researchers additionally state that the lab reports are a base for further knowledge capture and reuse and that the changes with the KPI and final deadline will benefit the company in this matter.

6.5 Knowledge Management Integration

The DME-process both captures and reuses knowledge. Based on Analysis, the capturing of knowledge is mainly in the Measure and Evaluate-phases, whereas reusing knowledge could be used in a larger extent in the Define-phase. As the final lab reports are of various quality and the organization experiences knowledge waste, the future-state VSM of the DME-process will focus on integrating reuse of knowledge and increase the motivation to write the final lab report, making it possible to reuse them in the future. The workshop findings for Knowledge Management, both capture and reuse, will be summarized in the same workshop box.

6.5.1 Reuse

Starting with the Define-phase, both the test initiators and the lab representatives have a responsibility to do some research before continuing with a request, to assure that it has not been done before. One example of the knowledge which needs to be researched, is if similar methods have been carried out on similar products and in those cases find out how they performed. This can be compared to the request currently being completed. In order to do the background research, the knowledge has to be accessible and there has to be sufficient time.

Watson and Hewett (2006) describe that knowledge will be reused more frequently if it is easy to access. At the company, there are multiple locations of the knowledge which according to the findings, can confuse the employees. It can be difficult to only have one KMS, as it is a global organization with large amounts of documentation, which is required to be traceable because of external factors. However, SharePoints containing valuable information which are not accessible to people outside the project, can create complexity as previously visualized in the Knowledge Source Map in section 4.9.3. In order to increase the possibility to reuse knowledge, it is suggested to make the knowledge more accessible for employees by keeping e.g. project learnings from projects in one common folder and have the possibility to 'Read Only' for the documentation in SharePoints. In addition, it needs to be clearly stated where information can be found. Regarding old final lab reports, it has been described that they can be difficult to search for in LIMS, therefore a suggested improvement is to have a 'free text search' which can search for specific words in reports. Another suggestion is to have a standardized way of naming the requests. Currently, each request receives a request number which is generated by LIMS, but there are no standards for how the title of the request should be set. This can make the requests difficult to find, unless the employee knows who were involved or what they named the request. In addition, when initiating a request within a project, there should be a drop-down menu with project names, to filter search results.

Relating to the issue from the current-state VSM regarding communication, the lab representative might not have sufficient information to look for knowledge as the scope of the request has not been explained in such detail. This demonstrates the importance of having the information documented, not only for the purpose of Lean Product Development but in addition to enable more reuse of knowledge.

Another aspect brought up regarding reusing knowledge, is that there is insufficient time to do the background research, as requests sometimes arise on short notice or the resources are overloaded. Relating to accessibility, it is difficult to quickly access the information as it is spread out, which makes it time consuming. By solving the accessibility issue, employees might become more motivated to look for knowledge (Watson & Hewett, 2006). A second aspect previously mentioned in Analysis, is that having overloaded resources, can affect the time both test initiators and lab representatives have for research. If an employee has too many projects during the same time and they are all in the Define-phase, it can be difficult to find the time to search for knowledge. It is suggested that in the future-state DME-process, more time to do background research should be given as this has shown a positive outcome in another process at the company.

6.5.2 Capture

According to Watson and Hewett (2006) the interest to provide others with knowledge will increase if the employees know that it will be reused. The Findings show that employees seldom read the final lab report, which decreases their motivation to capture knowledge. By using the suggestions previously mentioned in Section 6.5.1 regarding reusing knowledge, there should be an increase in writing comprehensive final lab reports. For the test initiator this implies taking the responsibility to document the necessary information in the Define-phase. For the lab representative it will be to ensure that the information from the Measure-phase, such as pictures and instructions of the lab method, is included in the report. The lab representative is responsible for conducting the analysis and evaluating the data in the Evaluate-phase and therefore needs to include it in the final lab report. This part needs to capture the findings and learnings from the request that has been carried out.

During the interviews it was stated both from lab representatives and test initiators that it is helpful when test initiators have knowledge of the methods and how products perform, which is knowledge that is gained from observations during the Measure-phase. In the future, it is suggested that the test initiator is more present in the lab when new methods or products are tested. This is an important step to capture knowledge, mainly tacit, which must be gathered for each individual by him or herself. By being more present during observation, a better discussion can be held afterwards. In addition, the knowledge is helpful when discussing the lab method, as both parties gain sufficient information.

Overloaded resources affect both the reuse of knowledge and the capturing of the knowledge. Since the employees have many projects going on at the same time, it can be difficult to find the time to finalize the report, especially when the results have been delivered and the frequency of reading the final lab reports is low. The deadline considers the date for when the report should be published in LIMS. When initially setting the deadline, the time to write the report needs to be taken in consideration to ensure that sufficient time has been set aside to finish the report. Additional factors to take into consideration are how long time the method takes and the number of samples.

As the results most likely have been presented at the unspoken deadline, there is a risk that the lab representative receives a new request before the ongoing request is finished. In the future state, the employees need to respect their own time and others, as it is important for the lab representative to have the time needed to finalize documentation and not accepting new requests which make the previous requests suffer. In this situation, management can be involved to distribute work among the employees and support the lab representative. In addition, the test initiator needs to gain understanding for the importance of the final lab report and the purpose for capturing and later reuse the knowledge by allowing the lab representative to finish the work before handing over the next assignment.

Workshop Findings for Knowledge Management

The workshop discussed the implementation of knowledge briefs and their purpose to increase accessibility of knowledge. With this implementation, the participants believe that the project learnings will be stored in one location, which is aligned with the suggested solutions for increasing the use of learnings.

When searching for a report, it is necessary to know exactly what to look for. However, it was brought up that the requests cover many areas, which makes it difficult to invent a standardized way to name a request. Hence, this suggested improvement was discarded. Instead, the suggested improvement of using the project name as a basis to search and filter was brought up and verified as a good solution. Today, employees rely on asking colleagues to find the information. This was discussed during the workshop as time consuming, but still less time consuming than searching for the information. Bringing up the suggestion to have project folders as 'Read Only' was stated as helpful for searching and retrieving information and a verified solution. The participants reflected upon if it should be possible to do so only after the project has been completed instead of throughout the project, which was considered a good solution.

To finalize documentation for a request before moving on to the next request was stated to be difficult as the new request is prioritized due to pressure from stakeholders. Hence, the suggested improvement to ensure that a request is done before starting a new one, was discarded. Still, the authors believe it is of importance to finish what has been started and avoid waiting several weeks or months as somebody might find the information from a request useful.

6.6 Future-state DME-process VSM

The VS loops and suggested improvements lead to the future-state DME-process, seen in Figure 31. The process should be more efficient and less wasteful, as it assures that information is collected and added in the system, hindering late loopbacks. Before reaching 'Confirmed Agreement' the lab representative should set the request in one of the 'Received' statuses, suggest a lab method and make an agreement with the test initiator. More emphasis should be put on using 'Confirmed Agreement', as its purpose is to approve that all required information has been acquired. It should allow for more time for research of previous requests. The Measure-phase will be unchanged, but test initiators are encouraged to be more involved in this phase. At 'Concluded', the results should be delivered to the test initiator in the agreed format. In addition, a preview of the lab report should have been looked at by the test initiator, which makes it possible to discuss if any documentation needs to be added during the activity Finalizing Documentation. The final lab report should then be set as 'Final Report' before the Final Deadline.

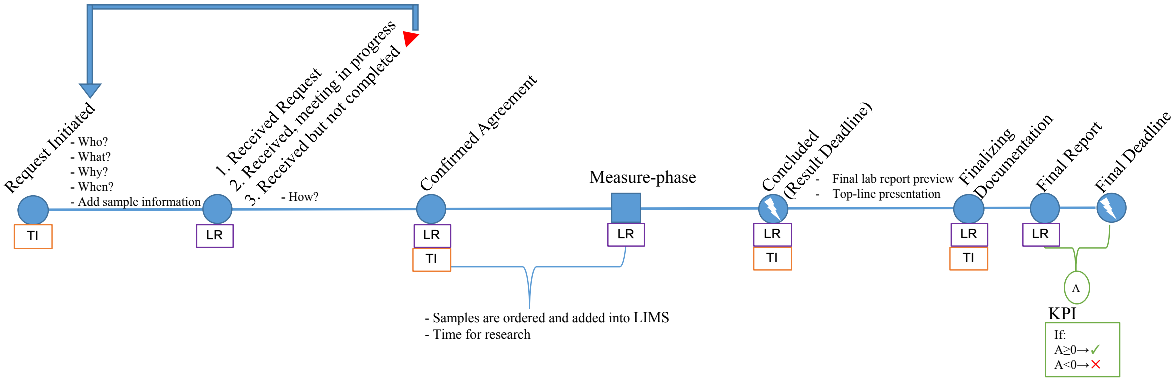

Figure 31 – The future-state VSM of the DME-process showing how the process can look after implementing the suggested improvements

The limitations of this thesis is to provide the company with recommendations regarding the DME-process and not conduct the implementation itself. In the final stage of the VSM, a work plan and implementation should be defined. For the future-state VSM above, a work plan adapted for the DME-process can be found in Appendix 2.

6.6.1 Flexibility in the Process

As the company works in an industry where it is required to work in a fast pace, one employee mentioned that flexibility is necessary or else the process becomes wasteful in terms of time. It needs to be taken in consideration when suggesting a future-state map, as requests sometimes arise on short notice and quickly need to be proceeded with. What needs to be considered is that the quality of the output should not get affected by people working in a rush and that if the standard of the process is followed, it can still be efficient. One example of flexibility is if a lab representative agrees with a test initiator that the roles and responsibilities throughout the request might deviate from the standard process. However, this decision should be mutually agreed upon, without having one or the other compromising their roles and neglecting their responsibilities. In addition, the information still needs to meet the requirements of the meeting agenda, as leaving the Define-phase should only be done when all required information has been documented.

7. Conclusion

The purpose of the master thesis was to investigate how Lean Product Development and Knowledge Management can be integrated in the DME-process. This has been investigated by conducting literature research, observations and 16 interviews based on how work is carried out in the process. The perspectives of Lean Product Development and Knowledge Management were found through literature research and put into relation to the findings of the interviews.

Answering the first research question *"What are the aspects of Lean Product Development in the DME-process?"*, it was found that the DME-process has some techniques that are considered Lean, such as concurrent engineering and cross-functional teams. However, the essence of the techniques is lost when not allowing the roles to do what is expected from them. As mentioned by Karlsson and Åhlström (1996), this is why it is important to not consider something as Lean, only because a Lean technique has been implemented. From the interview findings, a current-state VSM visualizing the waste in the DME-process has been drawn. One suggested improvement is to implement a standardized meeting agenda in order to ensure that information is captured to avoid late loopbacks.

The second research question "*What are the aspects of Knowledge Management in the DME-process?"* made it possible to detect knowledge waste. During the interviews it was found that the DME-process has aspects related to both knowledge capture and reuse. At the company, there are many locations to store the knowledge which has been summarized in a Knowledge Source Map based on the interview answers. One suggestion is to ensure that information becomes more accessible as this can increase both knowledge capture and reuse.

The third research question "*How can Lean Product Development and Knowledge Management be integrated in the DME-process?"* had the purpose to combine the two management theories. Suggested improvements are to make the DME-process more standardized and ensure that information is collected before proceeding, which can avoid late loopbacks. More time should be allowed for research, avoiding to potentially invent the wheel twice. A higher degree of involvement from both test initiators and lab representatives can improve the discussions and the knowledge captured in the process. By having Lean principles and Knowledge Management aspects integrated into the future-state DME-process, both knowledge and product development waste can be reduced.

8. Recommendations and Discussion

The recommendation for the company is to implement the improvements proposed in this master thesis. By standardizing the DME-process and to a higher degree focus on areas of responsibility, the process will become easier to understand. By clearly distinguish the roles of the test initiator and the lab representative, while at the same time allow for flexibility when it is agreed upon, the employees will feel a greater connection to the process. One result of this can be that the employees take more responsibility in the process. Another focus area regarding responsibility is to encourage the test initiators and the lab representatives to question the process, especially for the lab representatives to question the information in the requests. Knowledge sharing and reuse can prevent waste, such as rework, but this demands more focus on communication in an early phase of the process. Topics such as why a request is written and how tests should be conducted, are in need of more discussion.

The implementation of the improvements is not within the scope of this master thesis. In order to make sure the recommendations will be useful for the company, it is important to give the responsibility of implementing the improvements to a manager with great knowledge of the DME-process. One recommendation is to give the responsibility to the DME-process owner, the process leader and the managers of the R&D department. The process leader should make sure the employees are informed about the improvements, ensure that trainings in LIMS are conducted and give opportunities for education about the process-phases, roles and responsibilities, and how to capture and reuse knowledge.

Even though it was not in the scope of this master thesis to focus on LIMS, it has been a topic frequently mentioned in interviews, in the workshop and during the everyday work. There are many issues regarding this area, such as how to add samples in requests, how to communicate the progress of a request through statuses and writing the reports in LIMS. One recommendation is to prioritize improving LIMS. This is because of the possibilities to facilitate everyday work for many employees. Small changes, such as sending a notification to the lab representative when a new request has arrived, can make the daily work easier. Additionally, with the help of education, LIMS can be used more in knowledge contribution, sharing and reuse. An implication for further research could be to see how LIMS can make the communication between lab representatives and test initiators easier.

The company should for now continue to focus on the improvement and learning culture. Through fully exploring Lean and Knowledge Management, the efficiency of the product development process will increase. As the VSM conducted with the DME-process has shown a positive outcome, one recommendation is to continue to use the tool on other processes to find more areas where waste can be decreased. Finally, Lean should never be seen as fully implemented, because improvements can always be made. This is how the company can reach their goal of embracing a Lean innovative culture.

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Appendix 1 – Interview Guide

This part of appendix contains the interview guide, which was used when informing and carrying out the semi-structured interviews in this thesis.

We are currently writing our master thesis for Chalmers University of Technology. The thesis regards the DME-process and the work related to it. Because of this, we have invited you to participate in an interview for us to get a deeper understanding of your work with and within the process.

Purpose

The purpose of the interview is to gain understanding of how the DME-process works and interacts with the different departments in the organization and how you work with the process. Additionally, one part of the interview will focus on how knowledge is captured and reused in relation to the DME-process. The departments we wish to interview are product development, laboratory and the management of these groups.

Interview material

The interview material collected will only be used in this master thesis and no other research. Only material which can be connected to the research questions of the study will be published. Material connected to areas outside of the delimitations will not be used.

The interviewee's rights during and after the interview

The interviewee has the right to stop the interview if he or she does not want to finish it. The interviewee can withdraw answers and refrain from answering questions. The interviewee will have the opportunity to read through the gathered interview material and approve it before use.

Anonymity

In order to talk openly about the topic, all interviewees will be anonymous. This will be done by coding the interviewee, which will be based on if he or she works as a lab representative or test initiator when handling the information.

Practical information

The interviews will be semi-structured, which means that the interviewers on beforehand have prepared some questions, but can ask questions which appear during the interview. We wish to record the interviews to facilitate the transcription work and to make sure the interview material is only used in the right context.

The interview is estimated to take 60-90 minutes.

Introduction

Before we start, please tell us about yourself, your education and your background at the company.

1. How were you introduced to the DME-process?
2. What do you believe is the purpose of the DME-process?
3. Do you work with both requests in projects and requests connected to single products, such as benchmarking?

DEFINE

1) What initiates that a request is written?
   a) In which cases do you write the request by yourself
   b) In which cases do you not write the request yourself?

Deadline

1) How do you decide upon the deadline for a request?
   a) Who decides?
   b) What is the reason behind the deadline(s)?
      i) If they work with different types of requests: Are there different approaches when deciding upon the deadline for a project request and a "single product" request?
2) What do you expect to be delivered at deadline?
3) What happens if a deadline is not met?
   a) At what occasions are you unable to meet the deadline?

Laboratory method

1) How do you decide upon the laboratory method for a request?
   a) Who decides the final lab method?
   b) How often do you have discussions regarding how many samples and replicates you should test?

<u>Questions for non-laboratory</u>

   a) How often do you give proposals for the laboratory method?

<u>Questions for laboratory</u>

   b) How often do you get counterproposals on the laboratory method?

Way of working

1) How does the communication between the test initiator and the lab engineer work during the define phase?

<u>Questions for laboratory</u>

2) Are there occasions when information in the request is lacking?

MEASURE

<u>Questions for laboratory</u>

1) What factors affect how long time the measure phase takes?
      a. When do you get samples?
      b. Who is responsible for ordering the samples?
      c. Does it happen that requests are late because of queues/booked equipment?
      d. How do you work with planning your time regarding being in the laboratory and writing laboratory reports?

2) How does the communication between the test initiator and the laboratory engineer work during the measure phase?

Questions for non-laboratory
3) To what degree are you involved in the measure phase?
4) When do you have the samples available for the laboratory engineer?
All
5) Is there anything which could facilitate the work in the measure phase?

EVALUATE
1) What decides how the test data should be analyzed?
2) What decides how the test data should be presented?
   a) Is it clear from the beginning in which format the results of the laboratory report should be presented?
   b) How is the result of the final laboratory report aligned and the purpose of the report?

Questions for laboratory
3) Do you add anything extra in the final report which you find important?
4) How long time does it take to write the results in the final report?

Questions for non-laboratory
5) Do you read the final report?

All
6) If you could choose how the results should be presented, how would you want it to look like?
7) Where in the process is most time wasted?

ADDITIONAL QUESTIONS
1) Do you use any of the supporting documents in the DME-process?
2) Do you use the status updates in LIMS?
   a) What is the purpose of having the statuses?

Questions for laboratory
   b) Is there any status that you would want to add or remove?

All
3) What would happen if the DME-process did not exist?
   a) Is there anything you find positive in the DME-process?
   b) Is there anything you find extra problematic in the DME-process?
4) Is there anything you do or the test initiator/lab representative does, that does not have a purpose?

KNOWLEDGE MANAGEMENT
1) How often do you reuse knowledge?
   a) Do you know where to find old knowledge?
   b) What could make you look for old knowledge more often?
2) How do work with capturing your own knowledge?
   a) What do you think would make it easier to store knowledge?

End
If you could make one improvement to the DME-process, what would you change or keep?

Appendix 2 – Work Plan for VSM

This part of Appendix shows the work plan for the future-state VSM with a short description of the different parts.

Date	**May 2018**		**Signatures**			
Facility Manager	Name Lastname		Process owner	Process leader	Test initiator	Lab representative
VS Manager	Erika Danielsson Shari Abrahamsen	**YEARLY VSM PLAN**	Person in charge	Related individuals & depts.	Review Schedule	
					Reviewer	Date

Product Family Business Objectives	VS Loop	VS Objectives	Goal	1	2	3	4	5	6	7	8	9	10	11	12				
Improve efficiency and reduce waste in DME-process	1 Two processes	• One standardized process																	
	2 Meeting Agenda	• Eliminate late loopbacks • Act as support for TI and LR	Reach CA 100% before proceeding																
	3 Sample communic-ation	• To follow the roles • Reduce risk of lack in sample info	90% filled out by TI																
	4 Concluded	• Increase the interest of the final report	Have the TI read final lab report																

The above work plan is an example of how the improvements for the DME-process could be planned and monitored when following the steps of conducting a VSM. This work plan can be adapted to the implementation time (the arrows are examples), who should sign the plan and be the person in charge. The Goals should preferably be measurable and quantifiable. As a VSM generally is carried out in production, the signatures have been adapted to those who are responsible for the DME-process and the users of the DME-process.