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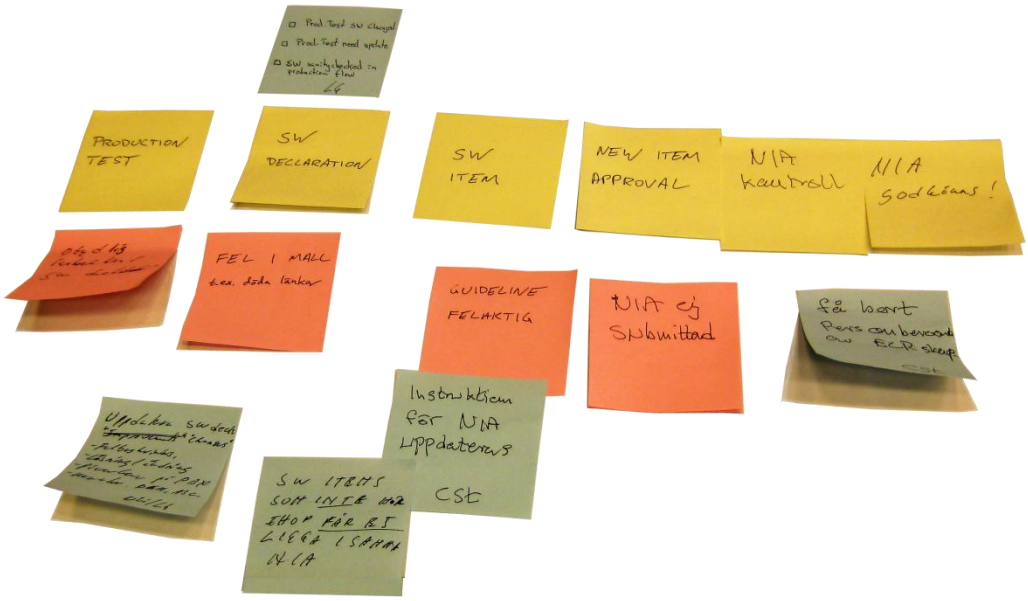

Value stream mapping in product development

Adapting value stream mapping at Ascom Wireless Solutions

Master's Thesis within the Product Development programme

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Gothenburg, Sweden 2012

MASTER'S THESIS

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Cover:
Close-up of a value stream map created during a field test at Ascom Wireless Solutions (Chapter 5).

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Abstract

The purpose of this thesis was to investigate how Ascom Wireless Solutions could use a process modelling method to improve their product development process. It resulted in a method, called Workflow analysis, inspired by the *lean* method value stream mapping.

A literature review and a multiple-case study served as input to the development of the method, which was further improved and evaluated through field tests at Ascom Wireless Solutions. The study indicates an inconsistency between how value stream mapping is described in the literature compared to how it is applied in industry. Whilst researchers have tried to adapt the method to product development by expanding it, the companies in the case study have done the opposite, by simplifying it.

What mainly distinguishes Workflow analysis from product development value stream mapping methods described in the literature are fewer predefined symbols, reduced importance of time metrics and less focus on value-added/non value-added activities. The main emphasis is, through cross-functional integration, instead on creating a shared picture of how the work is done.

An example of a map created during a field test at Ascom Wireless Solutions is presented below.

Key words: value stream mapping, process modelling, lean product development

Sammanfattning

Syftet med detta projekt var att undersöka hur Ascom Wireless Solutions skulle kunna förbättra sin produktutvecklingsprocess genom processkartläggning. Resultatet blev ett förslag på en metod, *flödesanalys*, som är inspirerad av leanmetoden värdeflödesanalys.

En litteraturstudie och en fallstudie låg till grund för metoden som förbättrades och utvärderades genom praktiska tester på Ascom Wireless Solutions. Studien antyder att det finns en skillnad mellan hur värdeflödesanalys beskrivs i litteraturen jämfört med hur den tillämpas i industrin. Medan forskare har försökt att anpassa metoden till produktutveckling genom att utöka den har företagen i fallstudien gjort tvärtom och förenklat den.

Det som huvudsakligen skiljer flödesanalys från de metoder som beskrivs i litteraturen är färre symboler, mindre mätning av tid och ett mer indirekt fokus på värdeskapande respektive icke värdeskapande aktiviteter. Istället ligger tyngdpunkten på att med hjälp av tvärfunktionella diskussioner skapa en gemensam bild över hur man jobbar.

Ett exempel på en kartläggning som gjordes under ett test på Ascom Wireless Solutions kan ses nedan.

Nyckelord: värdeflödesanalys, processkartläggning, lean produktutveckling

Acknowledgements

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Finally, we would like to thank the employees at Ascom Wireless Solutions who participated committedly during workshops and interviews.

Gothenburg, April 2012

Ingrid Fritzell Gustav Göransson

Contents

1 Introduction

This chapter provides a background to the thesis, a description of Ascom Wireless Solutions and finally the purpose and limitations of the study.

1.1.1 Ascom Wireless Solutions

AB Telekontroll was founded in 1955 in Gothenburg, Sweden, but is now known as Ascom Wireless Solutions. Ascom Wireless Solutions is a division within the Swiss telecommunication company Ascom Group. The division has 1155 employees worldwide, of which approximately 200 are stationed at the headquarters in Gothenburg where the majority of the R&D takes place. Ascom Wireless Solutions also has production facilities in Herrljunga, Sweden, with about 200 employees.

Traditionally Ascom has been working with paging technology, but today provides a range of customized wireless solutions like purpose-built handsets, wireless voice- and message transmission systems, customized alarm and positioning applications. The products are targeted exclusively to professional use and customers range from hospitals, elderly care and industry to retail and hotels. In total, more than 75 000 systems have been installed worldwide.

The technology department at Ascom

Technology is one of several departments at Ascom and consists of R&D, Project management and Project office. R&D is divided into smaller sub-functions such as hardware design, mechanical design and integration & verification. Project management contains all project leaders and Project office handles resource planning, project reporting as well as scenario planning.

The product creation process at Ascom

Product development work is carried out in projects at Ascom. These are based on a stage gate process, internally called Product creation process (PCP). Before a project is allowed to enter PCP, it has to be ensured that the project fits the road map and release plan of the company and that required resources are available. This procedure is called Pipeline planning. The subsequent PCP process consists of five basic steps (Figure 1). Each phase ends with a tollgate where a steering committee makes the decision whether a project is allowed to continue on to the next phase or not.

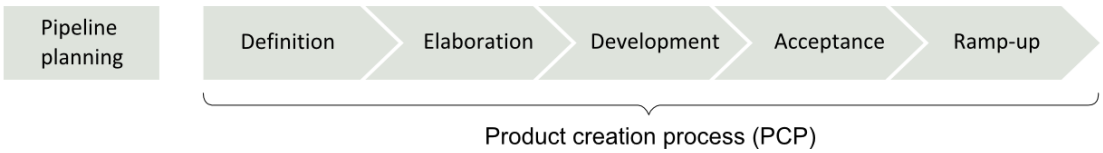

Figure 1: Ascom's product development process

Lean initiative at Ascom

Ascom began its lean journey in the middle of the nineties in production at their Herrljunga plant, using for example lean concepts like 5S, one-piece production flow and visual planning. Early efforts were made in 2006 to implement lean concepts into the R&D department and visual planning was introduced widely in 2008. A3 sheets for issues and pulse meeting boards are other examples of lean tools used today.

1.2 Background

The increased global competition during past decades, where quality and short time-to-market has been the key to survival, has forced companies to streamline their processes (Liker, 2004). Since the discovery of Toyota's superiority in quality and lead time in the nineties, many companies have turned to the lean philosophy as a potential solution to their needs (Womack et al., 1990). From having had initial focus on manufacturing, the lean movement has more recently spread to other functions like product development.

Ascom Wireless Solutions has gradually tried to adopt a lean way of working. However, in the trials with continuous improvement teams in product development it became obvious that it is difficult to handle more complex or extensive areas of improvements. The improvement area often becomes too large and it is difficult to break it down into manageable pieces. An alternative way to start improvement activities is to follow a flow and identify sub-parts where the focus of improvements should be.

One lean method, value stream mapping, has successfully been used to revamp manufacturing processes. By visualizing the production flow, value stream mapping helps to identify wasteful activities and processes and serve as an input for continuous improvement (Figure 2) (Rother & Shook, 1998). However, translating value stream mapping directly into a product development environment is not completely straightforward. Product development consists of a flow of information rather than a physical product. Information can exist in different versions and at different places simultaneously which makes mapping of a product development process more complicated. Furthermore, iterations that in manufacturing are considered as waste are in product development a natural part of the information gathering process. Therefore value stream mapping needs to be adapted in order to be applicable in a product development context.

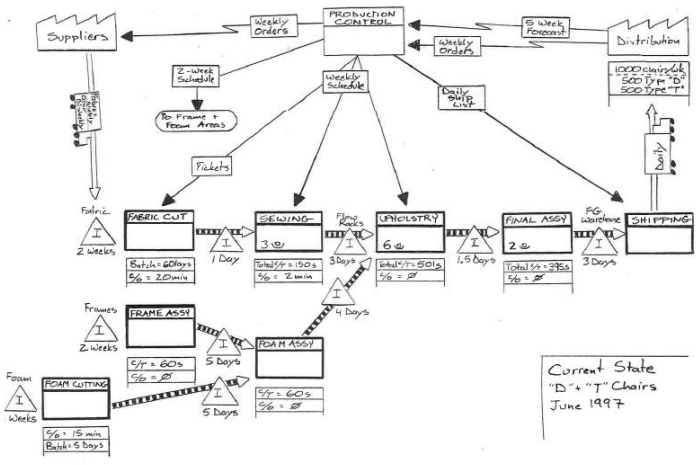

Figure 2: Example of a production value stream map (from Rother & Shook (1998), see section 3.3.1 and Figure 10 for a detailed explanation

Ascom Wireless Solutions wants to investigate value stream mapping and see whether the method has potential to support their improvement work within Research and development (R&D).

1.3 Purpose

The main aim of this thesis is to develop a process modelling method that will support Ascom's improvement work at the R&D department and create a shared vision of their processes.

1.3.1 Problem analysis and research questions

Value and waste are central concepts in lean and in value stream mapping. However, the definitions of value and waste in a product development process are not completely obvious. We would therefore like to put the following question:

- *What is value and what is waste in product development?*

Value stream mapping originates from lean production, but a product development process is not as streamlined as a manufacturing process. Divided opinions exist on how to apply value stream mapping in a product development environment or if it is applicable at all (Locher, 2008) (Morgan, 2002) (Holmdahl, 2010). We therefore wish to investigate how value stream mapping is described in the literature. There is also uncertainness to which extent value stream mapping is used within product development. This leads to our second and third questions:

- *How is value stream mapping described in the literature?*
- *How is value stream mapping used in product development in the Swedish industry?*

Ascom has identified a need for a process modelling method that will support their continuous improvement work. By following a flow and identify sub-parts where the focus should be, Ascom hope to better be able to structure their improvement effort and find more manageable improvement areas (see Figure 3). There is also hope that this tool will involve employees in discussions around their working methods in bringing consensus on how their processes should work. Therefore, our fourth question is:

- *How can Ascom use value stream mapping to support their improvement effort and create a shared vision of their processes?*

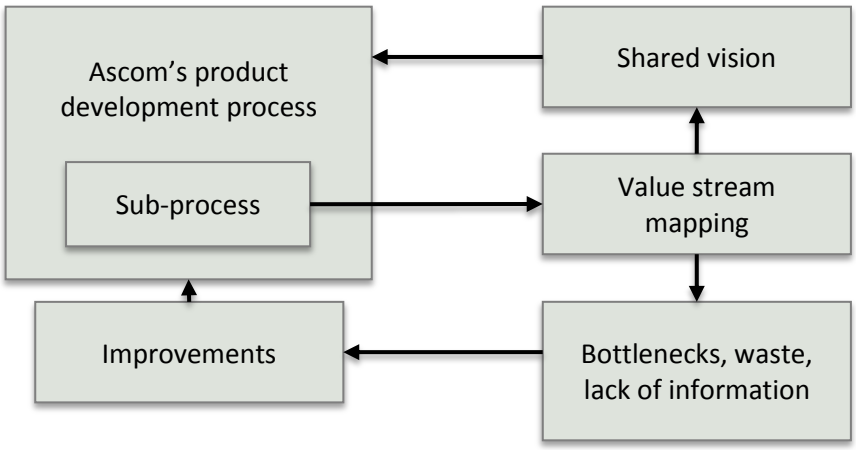

Figure 3: A model of how Ascom hopes to use value stream mapping

1.4 Delimitations

The following delimitations have been defined:

- This thesis will only consider product development. Other processes at Ascom such as production and sales will not be included.
- It is not the intent to develop a method to map the entire development process. The method should be applicable on a specified sub-flow.
- The developed method will not be adapted to manage potential future needs of Ascom. Only the current state will be taken into consideration.
- The reader will be assumed to have basic knowledge of lean concepts. Therefore not all basic lean concepts will be explained.
- The time frame is limited to 20 weeks.

2 Methodology

This chapter describes the research approach and the methods used in the study. The trustworthiness of the approach and the methods are also discussed.

2.1 Research approach

This thesis was conducted using a qualitative research approach. Qualitative research aims to gather in-depth understanding of a focused sample in contrary to quantitative research which relies on large samples and statistical models (Bryman & Bell, 2011) (Wallén, 1996). A qualitative approach has been selected for two reasons. First, it is more suitable to gather in-depth understanding which corresponds to the aim of this thesis. Secondly, value stream mapping in product development is a relatively new phenomenon. Both literature and number of practitioners of the method are limited, which would make a quantitative study difficult.

The thesis consists of three major parts; a literature review covering the existing research done in the field, a case study of companies using value stream mapping in product development and the development of a value stream mapping method suitable for Ascom, see Figure 4. The study began by formulating research questions in order to guide the literature review and case study. The findings from these parts, together with Ascom's needs, formed the basis for an initial value stream mapping method. Tests were conducted at Ascom in order to evaluate and refine the method.

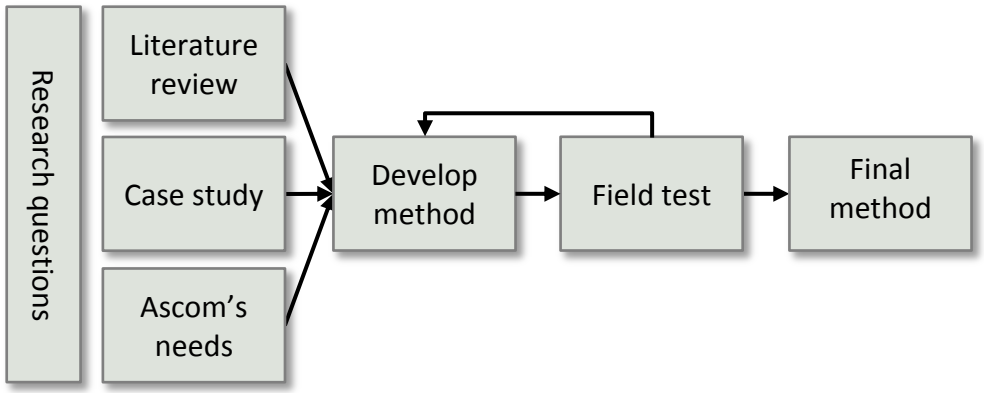

Figure 4: Research approach

The execution of the literature review, the case study and the development of an adapted value stream mapping method through field tests are presented in the following sections.

2.2 Literature review

A literature review can for example be conducted in order to identify already known facts, relevant concepts and theories, important controversies, contradictions in findings and unanswered research questions within the chosen topic (Bryman & Bell, 2011).

For this review, books and scientific articles written by academic authors formed the base. It consisted of a basic study of lean methodology, lean product development, different process modelling methods and of an extensive study of value stream mapping.

2.3 Case study

According to Yin (2009), a case study is useful for explaining present circumstances, e.g. "how" or "why" some social phenomena work. Case study research must not be restricted to only one case, but can instead consist of several cases. Multiple-case studies are often carried out to compare and contrast findings from each case. By doing so, both unique and common aspects can be identified and enable a theoretical reflection on the findings (Bryman & Bell, 2011).

A multiple-case study was selected as a complement to the literature review due to the limited literature covering value stream mapping in product development. The purpose of the study was to find out how and why other companies use value stream mapping and to learn from their experiences.

An initial screening was made to find companies in Sweden that use value stream mapping in product development. This turned out to be a small number of companies operating in different fields. These were contacted and asked to participate in the study. Saab OEG, RUAG Space, Volvo IT and Scania CV accepted the request. Even though these companies operate in other fields than Ascom, it was believed that their mapping approaches were transferable to Ascom since product development processes more or less go through the same phases.

The case study consisted of semi-structured interviews at these companies. All the interviewees have previous experience of using value stream mapping in product development. The interviews were recorded and summarized so no relevant information was left out. These summaries were reconciled with the interviewees and if needed follow-up questions were asked.

The findings from the literature review and case study were used to answer the research questions 1-3:

- *What is value and what is waste in product development?*
- *How is value stream mapping described in the literature?*
- *How is value stream mapping used in product development in the Swedish industry?*

2.4 Field tests

In some situations it is impossible to conduct research without actively participating in the study. This is referred to as action research (Wallén, 1996). According to Greenwood, Whyte & Harkavy (1993), participatory action research encourages continuous learning both on the part of the researchers and the involved members of the organization.

Action research was used in three field tests to gain experience and to develop, test and evaluate the value stream mapping method. The processes were selected by

Ascom and were all in need of improvement. A complementary test was also conducted to gain additional experience and knowledge. The field tests followed the procedure below:

Development of initial value stream mapping method
The initial value stream mapping method was developed by comparing and evaluating the findings from the literature review and the case study.

Selection and preparation
Two of the processes (field test 1 and field test 3) were selected based on suggestion from one of our supervisors at Ascom. The execution of field test 1 attracted attention from other parts of the organization and resulted in field test 2. As preparation, relevant documents were examined and key employees were interviewed. The workshop participants were chosen in co-operation with the responsible for the process. Guidelines for each test were developed (Appendix C to Appendix E).

Execution
The tests were executed in the form of value stream mapping workshops facilitated by the authors.

Analysis
Feedback was collected from the participants after the workshop and follow-up meetings were held with some of the participants. The results from each workshop were discussed, analysed and used to refine the method between each event.

The results from the field tests, along with the results from the literature review and the case study, were used to answer the fourth research question:

- *How can Ascom use value stream mapping to support their improvement effort and create a shared vision of their processes?*

2.5 Trustworthiness

Validity and reliability are commonly used for evaluating the quality of quantitative research. Qualitative research, however, lacks a similar broadly accepted evaluation criterion (Bryman & Bell, 2011). While some suggest that validity and reliability are also applicable in qualitative research, others disagree and have come up with new criteria. For example, Guba and Lincoln (1985) propose trustworthiness instead. Trustworthiness consists of four criteria (Bryman & Bell (2011)):

- *Credibility* – How believable are the findings?
- *Transferability* – Do the findings apply to other contexts?
- *Dependability* – Are the findings likely to apply at other times?
- *Confirmability* – Has the investigator allowed his or her values to intrude to a high degree?

Below follows a discussion regarding the measures that we have taken to ensure the trustworthiness of our findings.

To start with, data has been collected by conducting a literature review, a case study and field tests. Using several methods or sources of data in a study is referred to as triangulation (Bryman & Bell, 2011). If the data is coherent, this will increase the credibility of the results.

2.5.1 Literature review

Multiple sources have been used to increase credibility. The literature was chosen after suggestions from supervisors and by using the Summon database at the Library of Chalmers University of Technology. Keywords like lean, lean product development, value stream mapping and process modelling were used. The reference lists of the studied literature were used to find further relevant work.

2.5.2 Case study

A major concern of case studies is the generalization or transferability (Bryman & Bell, 2011). Yin (2009) states that case studies do not strive to achieve statistical generalization (like quantitative methods), but analytical generalization in which one generalize a particular set of results to some broader theory.

By conducting a multiple-case study with four companies operating in different markets, patterns as well as contradictions in the collected data could easier be distinguished. More accurate conclusions could also be made, hence increasing the transferability of the findings.

Several measures have been taken to increase the credibility of the collected data. All interviews were recorded to ensure that no data was overlooked and summaries of the interviews were made as soon as possible after the interview. This decreased the risk of missing relevant aspects and not understanding the context. The interviewees were also asked to review and comment on the summary, i.e. respondent validation (Bryman & Bell, 2011) was used to confirm the case study data.

Individual experiences and feelings of interviewers affect both questions and interpretations of answers during interviews. These aspects must be made conscious and be dealt with (Wallén, 1996). Therefore, a discussion of the interviewers' perceptions of the interview was carried out shortly after each session to increase confirmability.

2.5.3 Field tests

Action research has been criticized for its lack of repeatability (Bryman & Bell, 2011). Concerns have also been raised regarding confirmability due to involvement of the researchers (Wallén, 1996). Action researchers justify these concerns by saying that the results cannot be gained in any other way.

Greenwood, Whyte & Harkavy (1993) believe participatory action research increases the quality of the research. They say *"democracy in knowledge production gives the participants a stake in the quality of the results, increasing the reliability of information and the likelihood that results will be put into practice"*.

The both authors of this report were present during the workshops. This ensured a higher confirmability of the results compared to if only one author had been present. Moreover, feedback from the participants was collected during and after the workshop.

3 Theoretical framework

The theoretical framework includes background knowledge about lean in general and an investigation of value, waste and value stream mapping. Two other methods for modelling processes, IDEF0 and concept maps, are also presented with the purpose of positioning value stream mapping in a process modelling context.

3.1 Lean

The expression *lean production* was first coined by Krafcik (1988), but the term was introduced to the broader public with the renowned book "*The Machine That Changed the World"* by Womack, Jones and Roos. The basis for lean, the Toyota Production System (TPS), had evolved for almost a century through the hardship of the Japanese economy, but it was the success of the Japanese car manufactures in the US that first spurred the interest among western researchers (Holweg, 2007). They found that management policy, rather than technology and geographical differences, had a large impact on a production plant's performance (Krafcik, 1988).

The background to the notion *lean* stems from a continuously flowing production distinguished by minimized inventory and buffer levels as well as fast detection of quality problems (Krafcik, 1988). To put it short, lean is one way to do *"more and more with less and less"* (Womack & Jones, 2003). It should be mentioned though that the principles underlying lean are not unique. Some can, for example, be derived from the ideas of Henry Ford (Krafcik, 1988).

Since the *discovery* of lean the concept has been developed, mostly by American researches, independently from TPS. Recognized attempts to describe lean have for example been presented by Womack and Jones (2003), Spear and Bowen (1999) and Liker (2004). The lean concept has also spread and been adapted to many different environments and industries like service, healthcare, construction and logistics. The extensive publication on the subject has however led to a fragmentation without a clear definition of lean (Modig & Åhlström, 2011).

3.1.1 Lean product development

A common opinion is that the nature of product development is substantially different compared to production (Reinertsen, 2005) (Morgan & Liker, 2006). In short, production is a repetitive process where the same product is created over and over again whilst in development the main goal is to create single recipes for different products or product variants - there is no point in creating the same recipe twice (Reinertsen, 2005). Moreover, a physical product and its associated parts are the main output in production. In a product development context, Holmdahl (2010) instead defines knowledge as the main output. This opinion is shared by Morgan & Liker (2006) who state that *"knowledge is the fundamental element (material) in product development".*

The differences between production and product development require a transformation and an adaption of the initial lean concepts to fit product development (Reinertsen, 2005) (Morgan & Liker, 2006). For example, Morgan & Liker (2006) propose a lean product development system model including 13 principles. Other adaptions have been made by for example Mascitelli (2007) and Holmdahl (2010).

The Cynefin framework
Product development is a dynamic environment; new demands appear constantly and the market and its customers changes rapidly. In such an environment, the Cynefin framework might provide assistance (Figure 5). The framework can be used *"primarily to consider the dynamics of situations, decisions, perspectives, conflict, and changes in order to come to a consensus for decision-making under uncertainty"* (Kurtz & Snowden, 2003). It consists of five domains:

1. **Simple** – Where a simple and linear relationship between cause and effect exists.
2. **Complicated** – Where a relationship between cause and effect exists, but the relationship is not known or only known by a limited group of people. Thus, *"everything in this domain is capable of movement to the known domain"*.
3. **Complex –** Where cause and effect are only coherent in retrospect and do not repeat.
4. **Chaos –** Where no cause and effect relationship is perceivable.
5. **Disorder** – The space of not knowing which domain you are in.

Product development[1] moves from the complicated domain towards the simple domain. New product development[2] starts in the complex, or sometimes even in chaotic domain, and moves through the complicated domain to the simple domain (Figure 5). (Holmdahl, 2010)

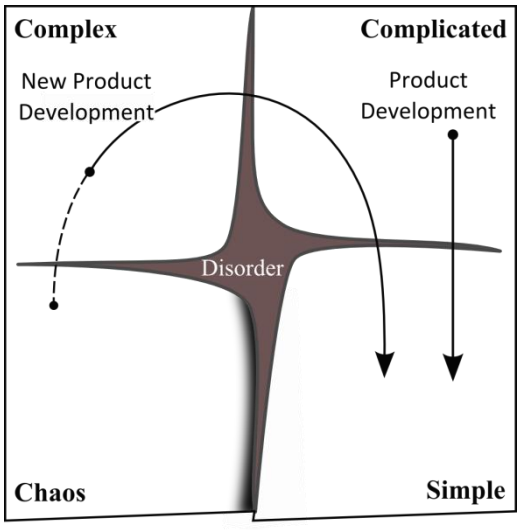

Figure 5: Cynefin framework (after Kurtz & Snowden (2003) and Holmdahl (2010))

3.1.2 Value in lean

The main directive of any true lean system is to establish and deliver customer defined value (Morgan & Liker, 2006). From a customer's point of view this is why a producer exists (Womack & Jones, 2003). Modig and Åhlström (2011) suggest it is the need of the customer that defines value. A similar statement is given by Womack

[1] By product development, Holmdahl (2010) means adjustment and limited reconstruction to existing products.
[2] New product development is the development of completely new products (Holmdahl, 2010).

and Jones (1996): *"Value can only be defined by the ultimate customer"*. However, identifying the customers is sometimes hard and there may be various types of customer with both direct and indirect needs (Modig & Åhlström, 2011). Despite the importance of defining value, one should not to end up in philosophical debate over the details of value (McManus, 2004).

According to Womack and Jones (2003) it is only meaningful to express customer value in terms of a specific product that fulfils the customer needs at a specific time. In production this is relatively easy since it involves flow of material which can be directly related to a product.

However, product development involves flow of information and knowledge. The complexity of the process, the distance to the final customer and uncertainties in market demand, technical performance, cost and schedule make it hard to define the value (Chase, 2001). It is difficult to immediately determine the quality of the information that an activity produces. In other words, value is created and determined at separate occasions (Browning, 2003). This time gap is bigger in product development than in production.

Definitions of value in product development

There are many different definitions of value in product development. Several are based on the customer's perception of the final product. Slack (1999), for example, defines value in terms of performance, importance, availability and cost. However, this product based value definition can often be hard to relate to in a product development environment (Chase, 2001).

Chase (2001) divides the value concept into product value and process value. Product value is a measure of the product created, often described as a balance of performance, cost and schedule. Process value on the other hand is created by the selection and coordination of resources. It can be thought of as effectiveness of the process in reducing performance, cost, and schedule uncertainty (Chase, 2001).

Another way of expressing value is to define it in terms of information. The purpose of many product development activities is to gather information in order to decrease uncertainty about the capability of the design meeting the requirements (Browning, 2003). Product development can therefore be seen as a process to increase the knowledge in order to reduce the risk. Ward (2007) adopts a similar definition when he defines value in product development as the creation of usable knowledge and manufacturing systems (i.e. descriptions for producing the product).

Usable development knowledge is in return created by three kinds of learnings (Ward, 2007):

- *Integration learning* includes learning about customers, suppliers, partners, the physical environment in which the product will be used, etc. It helps us understand how to integrate our designs with the needs of others – most importantly, our customers.
- *Innovation learning* creates new possible solutions.
- *Feasibility learning* enables better decisions among the possible new solutions, avoiding cost and quality problems or cost overruns.

3.1.3 Waste

According to Womack and Jones (2003) all activities can be divided into three categories; those which create value (value adding activities), those which do not create value but are required for the process to function (necessary waste activities) and those activities which are pure waste and can be eliminated (pure waste activities). The father of the Toyota Production System, Taiichi Ohno, identified seven types of waste in production (Ward, 2007) (Womack & Jones, 2003);

1. Waiting
2. Inventory
3. Excess processing
4. Over production
5. Transportation
6. Unnecessary motion
7. Defects

Waste in product development

Several attempts have been made to classify waste in product development. Millard (2001) and McManus (2005) have directly re-interpreted Toyota's seven wastes into product development (Table 1). A similar effort was made by Slack (1998) who expanded the seven wastes with complexity and time lag.

Table 1: The seven types of waste in product development (McManus, 2005)

Waste	Description
Waiting	Idle time due to unavailable information
Inventory	Information that is unused or is "work in progress"
Excess processing	Information processing beyond requirements
Over production	Producing and distributing more information than needed
Transportation	Unnecessary movement of information between people, organizations or systems
Unnecessary motion	Unnecessary human movement (physical or user movement between tools or systems)
Defects	Erroneous data, information, reports

By analysing car body development, Morgan (2002) identified 13 waste categories, which all except waiting were different from the seven wastes. However, these waste categories are to a great extent underlying causes of the seven wastes in product development defined by McManus (Kato, 2005). Bauch (2004) combined earlier definitions of value to formulate ten main waste categories. In addition to the seven wastes he added re-invention, lack of system discipline and limited IT resources. Another notable effort was made by Ward (2007) who used useable knowledge as a starting point for defining three main waste categories (scatter, hand-off and discard of knowledge) with two sub-categories in each. A compilation of the waste categories can be found in Appendix F.

Kato (2005) found it easier to measure the effect of waste rather than the cause. By analysing cause and effects of various wastes he identified nine waste indicators that can be used for measuring waste (see Appendix F).

It should be noted that most waste categories are not mutually exclusive and that a relation exists between them. Defects could for example be caused by over-processing (Chase, 2001).

3.1.4 Criticism of value and waste

Identification and removal of waste have almost become synonymous with lean (Browning, 2003). Several concerns have been raised against this approach, especially in product development.

According to Holmdahl (2010) it is difficult to remove waste in product development since the relationship between cause and effect is visible first afterwards. However, Holmdahl (2010) still suggests it is meaningful to use the waste terminology if it is defined as *"consumption of resources without creating value"*.

Browning (2003) further says that by focusing only on value-adding activities you *"fail to address wastes caused by the structure of the process"*. For example, even if an activity is completely value adding it is still unable to produce high quality results if it is fed with poor quality input.

Furthermore, the classification of activities as value adding, necessary waste and pure waste depends on which level of detail the activities are defined at. From an overall perspective everything is value adding, but as you go deeper down the hierarchy the other category will appear. Go too deep and there will be no value adding activities left at all (Browning, 2003).

3.1.5 The value stream

Rother & Shook (1998) defines a value stream as all the activities, both value adding and necessary waste, needed to be able to create a product. In *Lean thinking*, Womack & Jones (2003) define a value stream as all the specific activities required to bring a specific product through the three management tasks of any business:

- the *problem-solving task,* going from concept development, detailed design and engineering to production launch
- the *information management task,* going from order taking and detailed scheduling to delivery
- *the physical transformation task,* going from raw materials to a finished product in the hands of the customer

The value stream in product development

Kennedy, Harmon & Minnock (2008) divide product development into two value streams; a product value stream and a knowledge value stream (Figure 6). The product value stream consists of the flow of tasks, people and equipment needed for creating for example drawings, bill of materials and manufacturing systems, i.e. "the recipe" of the product. Thus, the product value stream is specific for each project. The knowledge value stream on the other hand represents the capture and reuse of knowledge about markets, customers, technologies, products and manufacturing

capabilities. This knowledge is general across projects and organizations. For each product development project, knowledge is gained and re-used in the coming projects. This accumulation and reuse of knowledge is visualized by the ascending arrow in Figure 6.

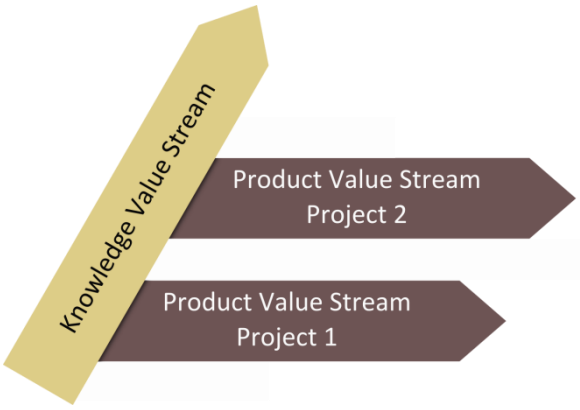

Figure 6: The product development value streams (after Kennedy, Harmon & Minnock (2008))

3.2 Value stream mapping

Value stream mapping is a visual, lean method for modelling and improving processes. As the name indicates, the method is about making a map of a value stream. For an example, see Figure 7.

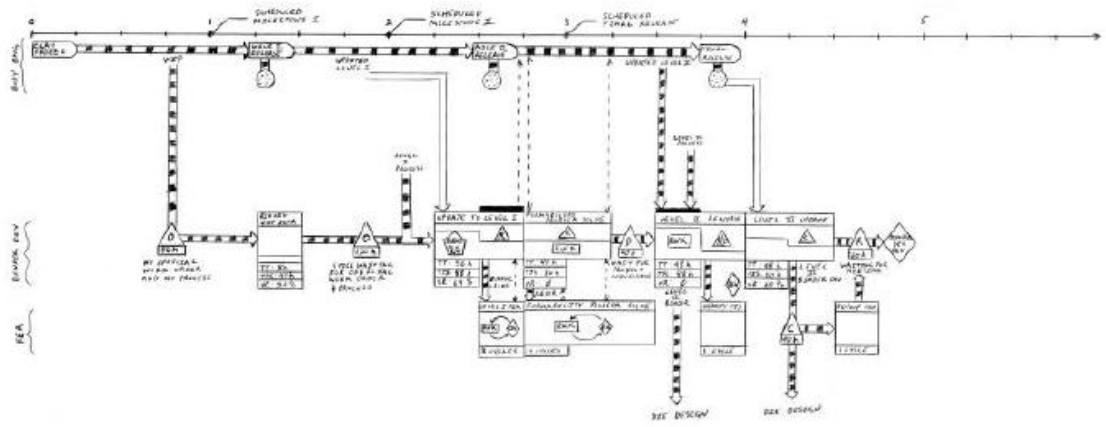

Figure 7: Example of a product development value stream map (from Morgan (2002)), further explanations are given in section 3.3.2

3.2.1 Process modelling in general

The Oxford dictionary defines a process as *"a series of things that are done in order to achieve a particular result"* and modelling as *"the work of making a simple description of a system or a process that can be used to explain it"* (Hornby, 2010). During the recent decades, a myriad of different ways to model processes have appeared, for example phase/stage-based models, activity networks, IDEF0 and DSM. To this group belongs also value stream mapping. However, modelling processes is nothing new. The first method for this, the flow process chart, was developed already in the early 1900's by Frank Gilbreth (Graham, 2004).

A number of different reasons drive the need for using process models, for example to provide a base for how to plan, execute and manage projects (Browning et al., 2006), serve as a support for continuous improvement efforts or for creation of a coherent picture of how the work is done (Galloway, 1994) (Ulrich & Eppinger, 2008) (Damelio, 1996). The demand for a process model can also be derived from requirements from standards such as ISO or internal policies within a company (Browning et al., 2006).

3.2.2 What is value stream mapping?

Value stream mapping has evolved from what Toyota calls the *material and information flow diagram*, which was used to teach TPS to suppliers (Liker, 2004). Rother & Shook (1998) were the first to convert Toyota's way of working with value stream mapping to a practical guide, called *Learning to see*. Learning to see focuses on mapping in production but the method has later been adapted and used in other disciplines such as administration, office processes, healthcare and supply chain (Tapping & Shuker, 2003) (Keyte & Locher, 2004) (Graban, 2009).

Value stream mapping provides support for understanding the flow of material and information required to make the final product and for analysing how that flow can be improved by using lean principles. By focusing on the customer, on value creation and on the removal of waste, an effective and efficient flow in the process can be accomplished (Rother & Shook, 1998).

Moreover, by looking at an entire value stream instead of isolated tasks, the focus will be on improving the wholeness and not individual parts which can result in sub-optimization. Value stream mapping is the only tool that shows the linkage between information flow and material flow (Rother & Shook, 1998). It can be used as a tool for communication, planning and/or continuous improvement efforts (Rother & Shook, 1998) (Morgan, 2002) (Millard, 2001).

Value stream mapping is a visual method using predefined notations and symbols, for example to indicate movement and storage of material. Accurate metrics are also collected to assess the value or identify bottlenecks of the process. The method basically consists of four steps; (1) set the scope, (2) identify the current state of the chosen process, (3) draw a future, desired state and finally (4) make a work plan to ensure implementation of identified improvement areas (Rother & Shook, 1998). A more detailed description will be provided in the following sections.

Focusing on value and removing waste is not exclusive for the concept of lean and value stream mapping. Galloway (1994) and Trischler (1996) both include that approach in their business process modelling methods. Similar to value stream mapping, Trischler (1996) also uses time and cost metrics to assess the value. What primarily differentiates value stream mapping from these two methods is the creation of a future state map. Besides, symbols to indicate storage, inspection and transportation were already a part of Frank Gilbreth's flow process chart method from 1921 (Figure 8) (Graham, 2004).

Figure 8: Symbols for storage/delay, inspection and transportation (after Graham (2004))

3.2.3 Value stream mapping in product development

As already mentioned in section 3.1.5, Womack & Jones (2003) have identified three core tasks needed in any business. Value stream mapping has been used a lot, and successfully, for two of them: the information management task and the physical transformation task. As for the problem-solving task, or product development, value stream mapping has not been applied to a great extent.

It is difficult to use the successful value stream mapping method from production outright in a complex product development environment. Since information can be at several different places at the same time, the mapping of a product development process needs to be different compared to production where a physical part is dealt with (Morgan, 2002). Furthermore, product development is generally characterized by long cycle times, which makes it difficult and time-wasting to collect accurate metrics (Locher, 2008). Extensive cross-functional integration is also often required and consequently puts different demands on how to visualize such a process (Morgan, 2002). However, these should not be reasons for not trying to adapt the method to fit product development (Mascitelli, 2007). There is more to value stream mapping in product development than mapping and improving the current state. Morgan (2002), for example, stresses the organizational learning aspects which alone can justify the time spent.

Criticism of using value stream mapping at all in a product development context has been addressed by Holmdahl (2010), who argues that value stream mapping should stay in production since it is too difficult to decide what is effective in creative, non-repetitive work such as product development. Instead, he proposes process modelling using concept maps. Concept maps as a process modelling method will be further explained in section 3.4.2.

Adaption of the value stream mapping method to product development

One of the first value stream mapping adaptions for product development was made by Morgan (2002), who used the production method *Learning to see* as a basis to a significant extent. Another early effort of adapting value stream mapping to product development was made by Millard (2001). His method consists of a Gantt chart (Figure 13) or a Ward/LEI map (Figure 14) for mapping on a high level combined with a process flow map and a design structure matrix for mapping (Figure 16) on a detailed level. McManus (2005) developed an extension of Millard's work resulting in a product development value stream mapping manual within the Lean Aerospace Initiative (LAI).

Other adaptions of value stream mapping have for example been made by Locher (2008) and Mascitelli (2007). Both are strongly influenced by Rother and Shook's original method, but Mascitelli further expands the method by mapping on several hierarchical levels.

3.3 Description of value stream mapping methods

This section describes the value stream mapping methods *Learning to see*, *Product development value stream mapping* (PDVSM) and *Value stream analysis and mapping* (VSA/M).

3.3.1 Learning to see

Learning to see by Rother & Shook (1998) was the first book which described the concept of value stream mapping in production in detail. The actual mapping is carried out in four steps:

Procedure

1. Preparation

Before starting the value stream mapping it is important to select a product family since mapping the whole production flow would be too complicated. One should also appoint a value stream manager who is responsible for the mapping and the improvement of the value stream.

2. Current-state drawing

The first step is to collect information about the current state. This is done by walking the same path as the product and gathering data of how the product travels through the factory. The mapping is done on door-to-door level, i.e. from the delivery of materials to the shipping of the products. By starting from the end of the flow and move upstream, the customer will be the starting point. It is preferred that the same person maps the whole stream because someone needs to see the entire picture. Several people need to be involved to collect the required information, though.

To avoid delays, the mapping should be drawn by hand. Rother & Shook (1998) propose a couple of predefined symbols and special notations (Figure 9). Boxes are used to indicate processes. A process is defined as one area of material flow, i.e. a process box stops wherever processes are disconnected and the material flow stops. Information flow like order scheduling and production control is also drawn on the map. Data like cycle time, lead time, value-creating time, number of operators etc. is collected for each process. It is important to obtain this data in person in order to get accurate information and understanding of what is happening in the flow. See Figure 10 for an example of a current state map.

3. Future state drawing

The next step is to improve the current state map by applying lean principles. By using the current state map and the data collected as a basis, a future state map is created (Figure 11). To assist the creation of a future state, Rother & Shook (1998) present both lean guidelines (e.g. *"Develop continuous flow wherever possible"*) and key question to answer (e.g. *"What is the takt time?"*).

4. Work plan & implementation

A work plan is created to achieve the future state. It can for example consist of a yearly updated value stream plan including when and where to start the improvements along with responsibilities. Rother & Shook (1998) advise to start the implementation where the likelihood of success is high. The responsibility for achieving the future state lies within management.

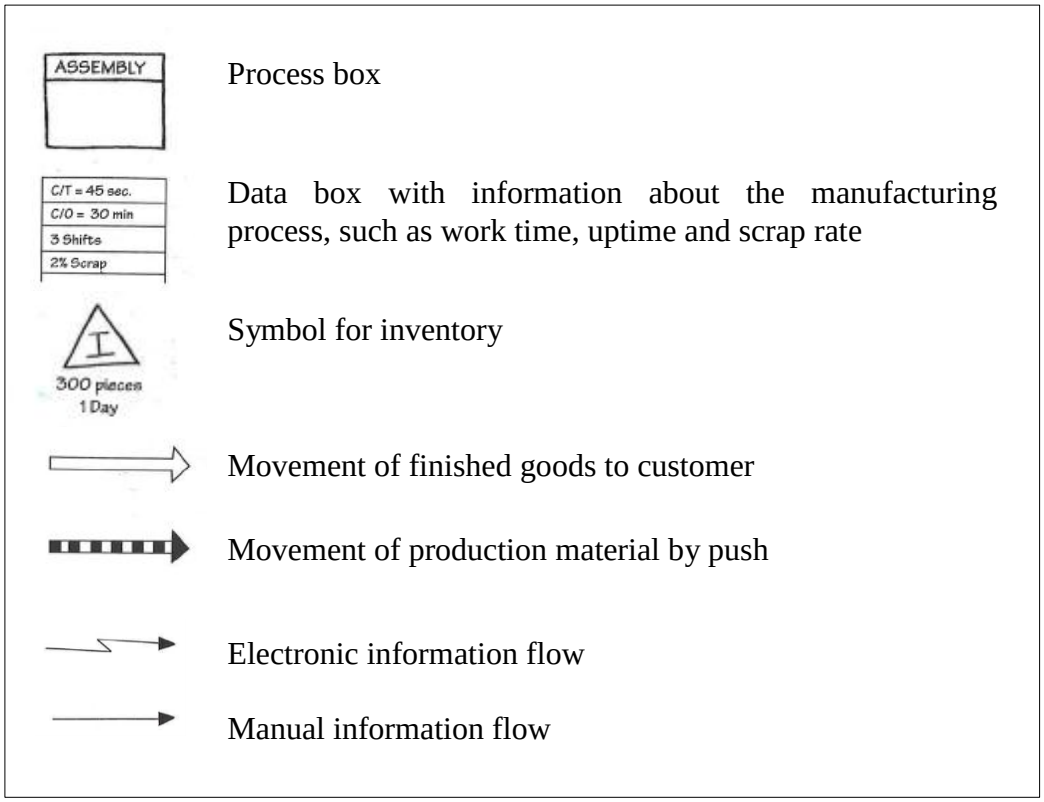

Figure 9: Example of notations (from Rother & Shook (1998))

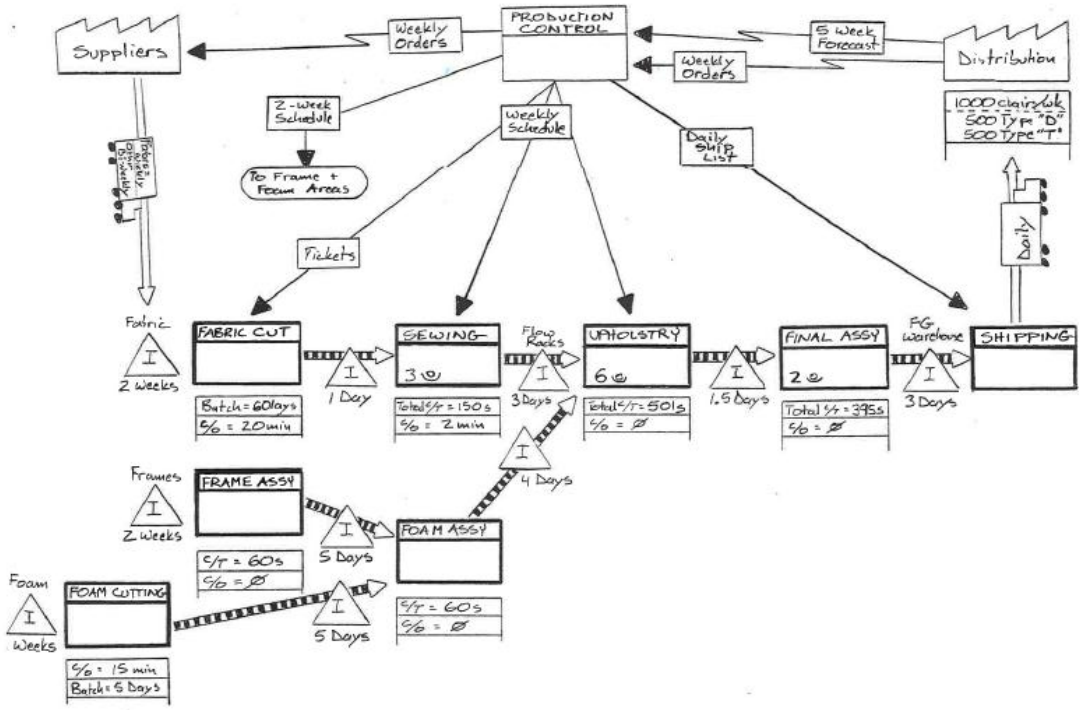

Figure 10: A current state map (from Rother & Shook (1998))

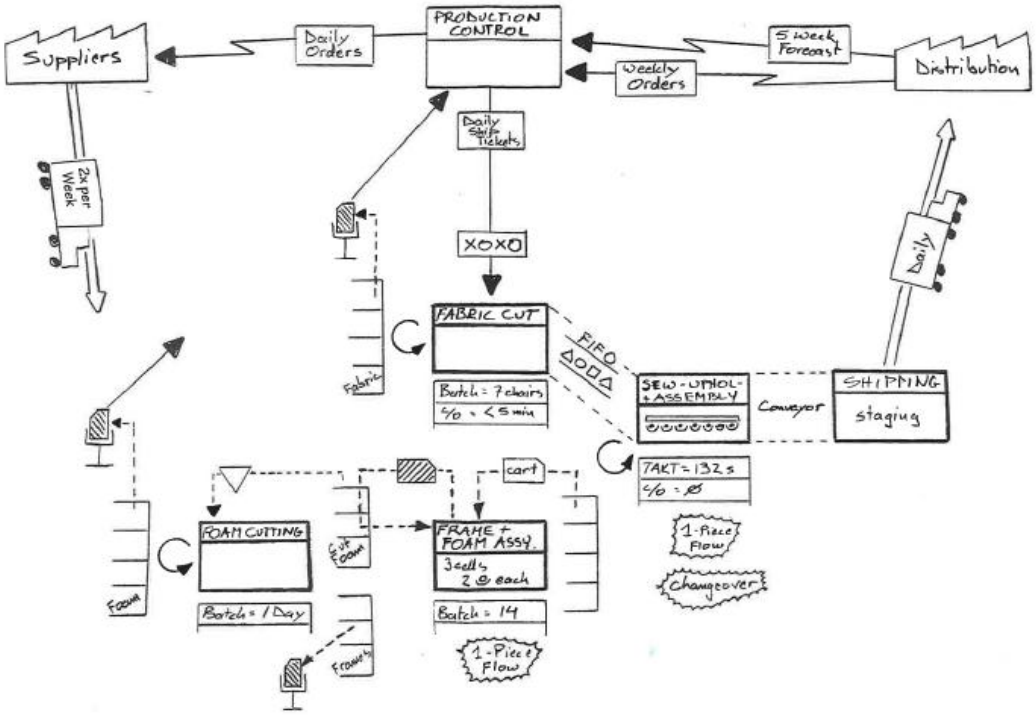

Figure 11: A future state map of the process in Figure 10 (from Rother & Shook (1998)). The process has been improved by implementing for example kanban systems and one piece flow.

3.3.2 Product development value stream mapping (PDVSM)

The first method for value stream mapping in product development was created by Morgan (2002) while studying the product development systems of two large automotive companies. The methodology in *Learning to see* functioned as a basis to a significant extent (Morgan, 2002). Below follows the procedure of the method.

Procedure

1. Preparation

The first step is to create an understanding of what value means to the customer(s) of the company. Therefore, the mapping shall be executed by a team who together possesses the expert knowledge needed to truly understand the value stream chosen for analysis. Boundaries of the process, level of detail of the mapping and goals of the mapping effort are also decided in this step. To get power behind the anticipated change, strong support from management is crucial.

A rough process model, later to be used as a template for the mapping, is created by using information collected from interviews, existing documentation and historical data. Accurate information (for example work time, value added time and reasons for delays) needed for the concrete mapping is collected by using activity logs filled out by the employees.

2. Create a current state map

As the data is collected, the team starts to create the current state map. This means that the current state map is created gradually as the development project progresses. Just as in the production variant *Learning to see*, it could be useful for the team to walk the actual flow.

Symbols and special notations are used, similar to *Learning to see*. Though, the map is not the goal itself and it is therefore not critical to follow these icons as long as the mapping can be communicated and provide new insight into the product development process. In addition to *Learning to see*, a timeline and horizontal layers (swim lanes) are introduced to accentuate simultaneous activities in the mapped process (Figure 12).

3. Create a future state map

The next step is to evaluate the current state map by asking a set of questions based on Morgan's 13 wastes (Appendix F), for example *"Where are the queues?"*, *"How are the value ratios?"* and *"Are there too many reviews or hand-offs?"*. The identified opportunities for improvement are then analysed and their root causes are found. Countermeasures are developed and their locations are marked in the current state map. The final task in this step is to incorporate the countermeasures in a future state map.

Where to apply the method?

Morgan (2002) believes it can be beneficial to use value stream mapping at practically all levels in product development; process level (e.g. stamping a die), single function (e.g. stamping engineering), multiple functions or the entire product development value stream. Though, he advises to start mapping on the single function level. Mapping on the single level is similar to "door-to-door" mapping of a single plant in *Learning to see* (Morgan, 2002) (Rother & Shook, 1998).

Workshop variant

Collecting very accurate data by using for example activity logs is time consuming since product development project cycle times can be rather long (Morgan & Liker, 2006). If data accuracy is not critical, Morgan & Liker (2006) propose a three day PDVSM workshop where the data is estimated. An advantage of a workshop is the cross-functional dialogue that activity logs do not permit. During the workshop, the maps can preferably be created by using large sticky notes and by drawing information flow by hand (Morgan & Liker, 2006).

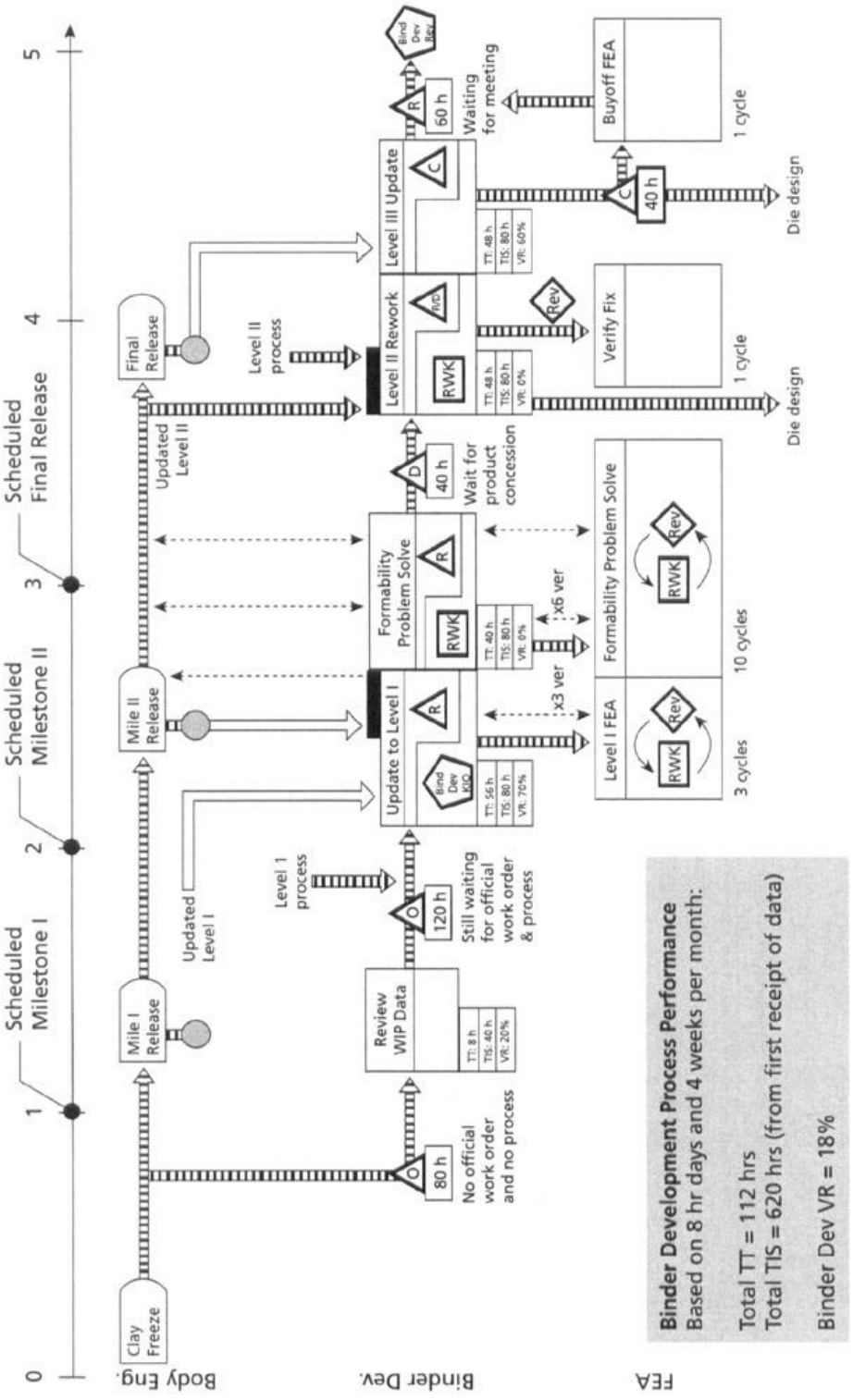

Figure 12: Example of a current state map in product development (from Morgan & Liker (2006))

3.3.3 Value stream analysis and mapping (VSA/M)

Millard (2001) used information gathered from site visits in the US aerospace industry as input to his method, called *Value stream analysis and mapping* (VSA/M). He defines VSA/M as *"a method by which managers and engineers seek to increase the understanding of their company's development efforts for the sake of improving such efforts"*. Below follows the procedure of the method.

Procedure

1. Assemble and train VSA/M team

A value stream mapping team who together possesses a balance of enterprise perspectives is assembled. It shall consist of lean experts, process owners/users, system thinkers and customers/suppliers. The team is trained in lean business philosophy and the tools chosen for the VSA/M.

2. Select value stream to improve

A value stream is selected for improvement by using a scatter plot of relative risk and potential benefits, by finding bottleneck processes or by finding critical pacing processes.

3. Define value stream elements

Boundaries, owner, product, customer(s), inputs and constraints of the value stream are defined by the team.

4. Analyse and map current state

With a draft of the current process as starting point, the process is analysed by the team until an accurate map exists. For this Millard (2001) proposes three categories of mapping tools with different level of detail.

1. A high level mapping method for defining the value stream and its context, for example a *Gantt chart* (Figure 13) or a *Ward/LEI map* (Figure 14)
2. A detailed-level process flow map for determining flow and value, for example *Process flow map*, *Learning to see* (Figure 10) or *System dynamics* (Figure 15*)*
3. A detailed-level *Design structure matrix* (Figure 16) for illustrating process structure, groupings and concurrency.

Data for the maps, such as elapsed time, in-process time and core task work time is collected by using special sheets. This is done as close to the process as possible, for example by speaking to employees (Millard, 2001). The value of the activities in relation to the process as a whole is determined by the team.

5 a) Analyse and map future state

A future state map is created by analysing the current state map. Millard presents seven value stream improvement heuristics with linkage to lean practice to find improvement areas. Examples of such heuristics are *Flow continuity*, *Balanced review & responsibility* and *Concurrent processing*. Similar to the current state map, the future state map is created and analysed through iterations and refinement. The future state map is the blueprint for improving the process.

5 b) Analyse and map ideal state
The next step is to map the ideal state of the process, i.e. the perfect implementation of lean business ideals. This ideal state map functions as the vision and a reference towards which improvements are made.

6. Implement new process
In this step, the future state map is implemented. It is important to be aware of the risk of sub-optimization and the motivation behind the improvement effort.

7. Continuous improvements
For future improvement of the map, Millard (2001) believes it is important to really understand the map and not only how to use the value stream mapping tools technically.

A brief description of the proposed tools is provided below.

Gantt chart
A Gantt chart is a traditional tool for representing the timing of tasks (Ulrich & Eppinger, 2008). Different tasks are listed in the left column (Figure 13). Their duration is illustrated in the right pane by utilizing a timeline.

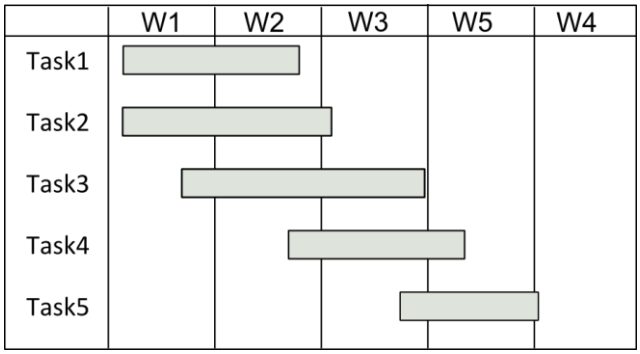

Figure 13: Gantt chart (after Ulrich & Eppinger (2008))

Ward/LEI map
A Ward/LEI map illustrates time and resources needed for different activities in a process. Each curve shows the duration of an activity and the distance from the horizontal axis represents the required resources (Figure 14). Tasks with a high degree of iteration are marked with a circle arrow.

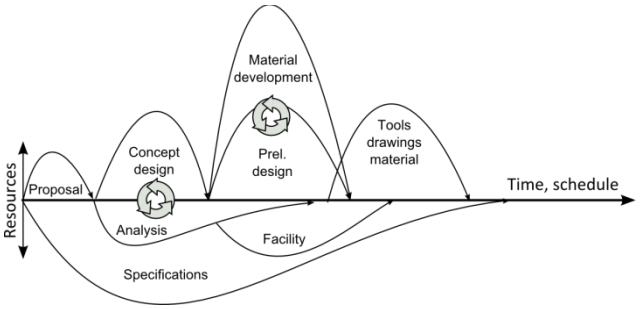

Figure 14: Ward/LEI map (after Millard (2001))

Process flow map
A process flow map is a traditional process mapping tool. It consists of standardized symbols such as work, review and decision. These are connected with arrows to describe the flow. One process flow map method is described by Trischler (1996).

Learning to see
See section 3.3.1.

System dynamics
System dynamics is an approach for understanding the dynamics of complex systems by modelling how changes in one part of the system affect other parts. It captures feedback processes, stocks, flows and time delays, see Figure 15 (Sterman, 2001).

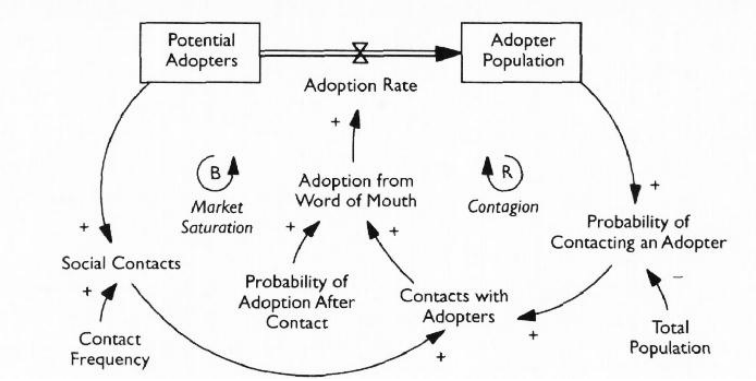

Figure 15: An example of a System dynamics model (from Sterman (2001))

Design structure matrix
A design structure matrix (DSM) is a tool for representing and analysing task dependencies (Ulrich & Eppinger, 2008). In such a matrix, each task is assigned one row and also a corresponding column (Figure 16). For each row (task), a cross represents a dependence of that task on the task in the corresponding column. For example, in Figure 16 task 3 depends on task 1.

	Task 1	Task 2	Task 3	Task 4
Task 1				
Task 2				X
Task 3	X			
Task 4	X	X		

Figure 16: Design structure matrix (after Ulrich & Eppinger (2008))

3.4 Other process modelling methods

IDEF0 and Concept maps are presented below in order to put value stream mapping in a process modelling context.

3.4.1 IDEF0

IDEF0 (*Integration definition for function modelling)* is a function modelling method developed by the U.S. Air Force in the 1980's for improving manufacturing productivity. Today the method is used to model decisions, actions and activities in organizations or systems. IDEF0 contains both a definition of a graphical modelling language and a methodology for developing models. (Li & Chen, 2009)

Syntax

IDEF0 consists of a hierarchical series of diagrammes. It uses a simple syntax based on boxes which represent functions and arrows which represent data and objects. Each side of the box has a unique function (Figure 17). Inputs enter from the left while outputs exit to the right. Controls enter at the top of the box and mechanisms (persons or automated systems) which perform the operation enter at the bottom of the box. IDEF0 also defines rules for naming and numbering of functions and arrows. (U.S. Air Force, 1981) (Li & Chen, 2009)

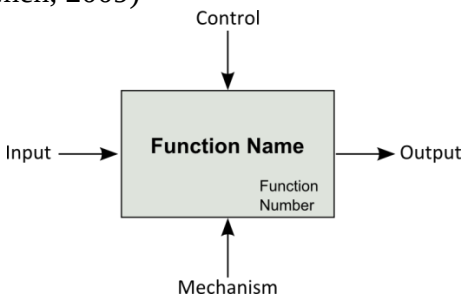

Figure 17: IDEF0 notation (after Li & Chen (2009))

Procedure

The IDEF0 process starts by identifying the main function which is represented in a top level context diagram. This sets the scope of the IDEF0 analysis (U.S. Air Force, 1981). The main function is decomposed into sub-functions on another diagram using boxes and arrows. Each sub-function may also be decomposed to achieve the required level of detail (Figure 18) (Li & Chen, 2009). Drafts of IDEF0 models are called kits. The U.S. Air Force (1981) presents a comprehensive manual for how these kits shall be compiled, reviewed and released.

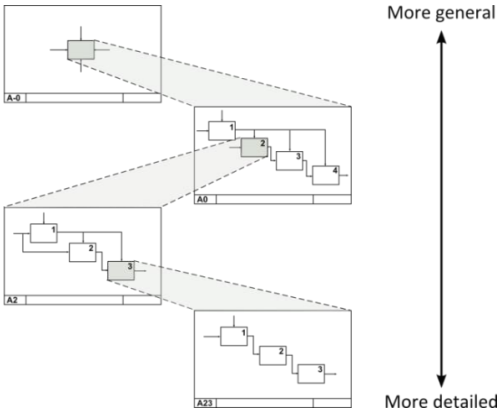

Figure 18: Decomposition of IDEF0 (after Li & Chen (2009))

3.4.2 Concept maps

Concept maps is a graphical tool for organizing and representing knowledge. It was developed in the 1970s by Joseph D. Novak for representing children's conceptual understanding. According to Holmdahl (2010), concept maps is a useful tool for creating common understanding, capture knowledge in development projects and for mapping processes.

Syntax

A concept is an object or event, designated by a label, for example "radiator" or "heat". In a concept map the concepts, represented by boxes, are connected by labelled arrows in a branching, hierarchical structure. The arrows represent the relationship between the concepts which together form a meaningful statement, for example "radiator produces heat". For an example of a process description in the form of a concept map, see Figure 19.

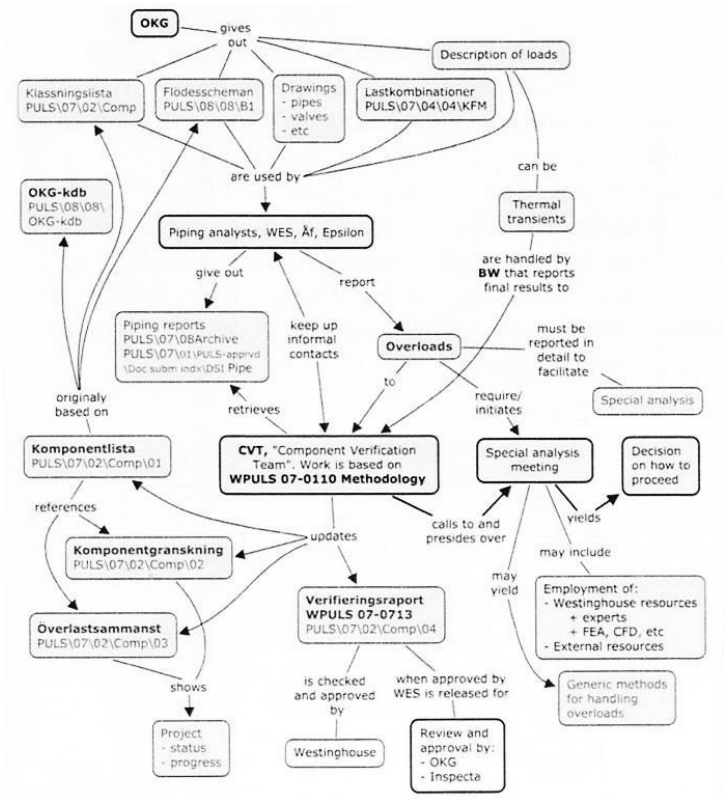

Figure 19: Example of a concept map (from Holmdahl (2010))

Procedure

Novak and Cañas (2008) suggest the following approach for creating concept maps:

1. Select a domain of knowledge to map
2. Define the context by constructing a focus question (i.e. a question that specifies the problem that the concept map should resolve)
3. Identify key concepts that apply to the domain
4. Rank the concepts from most general and inclusive (top) to the most specific (bottom)

5. Construct a preliminary concept map
6. Seek linkages between concepts in different segments or domain of the map
7. Revisit the map and re-position concepts to get clarity and better overall structure

3.5 Comparison of the presented process modelling methods

A comparison of the process modelling methods from the previous sections is described below and a compilation is presented in Table 2.

3.5.1 Value and waste

The three value stream mapping methods focus on measuring value and identifying waste. IDEF0 and concept maps on the other hand have no matching counterpart. Instead, their emphases are on describing systems and organize knowledge, respectively.

3.5.2 Lead time

Lead time is of great importance in all presented value stream mapping methods. Metrics are collected by using either a clock or data sheets/tool tags and then evaluated thoroughly. In addition, PDVSM also utilizes a timeline. This stands in contrast to IDEF0 and concept maps where the focus on time is non-existing.

3.5.3 Number of symbols

The number of symbols used differs remarkably between the value stream mapping methods and IDEF0 and concept maps. For example, PDVSM consists of 29 different symbols compared to IDEF0's 5 (one box and four types of arrows).

3.5.4 Use of hierarchy

In Learning to see, PDVSM and concepts maps, the processes are described on one single level. In VFM/A on the other hand three different levels of tools are used to map the process and in IDEF0 the decomposition can last until the required level is achieved.

Table 2: Comparison of the presented process modelling methods

	Learning to see	PDVSM	VFM/A	IDEF0	Concept maps
Focus on value/waste	Yes	Yes	Yes	No	No
Focus on lead time	Yes	Yes	Yes	No	No
Number of symbols	24	29	-*	5	2
Use of hierarchy	No	No	Yes	Yes	No

* Millard proposes several tools, which makes the comparison meaningless

4 Case study

This chapter presents the findings from the case study along with a comparison between the methods used at the companies.

The study consists of interviews at four companies in Sweden with varying experience of lean and value stream mapping. One interview with one interviewee at each company was conducted. All interviewees work with process improvement and have practical experience of value stream mapping in a product development context.

4.1 Saab OEG

Saab Electronic Defence System Operations Gothenburg (OEG) is a part of the defence company Saab's business unit Electronic Defence System. Saab OEG develops and produces radar systems for different applications. The engineering work is primarily concentred to electronics and software, but also involves mechanical engineering.

4.1.1 Lean background

The lean effort at Saab OEG started in an unsystematic manner within small parts of the organization a few years ago. Lean methods are now about to be widely implemented in the organization. For example, improvement groups have been used for half a years' time. Each group has an improvement board where everyone can add improvement suggestions. These suggestions are evaluated and, if accepted, implemented by the group members using a PDCA cycle.

4.1.2 Value stream mapping at Saab OEG

Trials with value stream mapping started one year ago at Saab OEG. The method was seen as a structured way of finding improvement areas and at the same time share knowledge among functions. Initially, the value stream mapping method for production was used as a reference but was soon found to be too theoretical. The method have since then undergone heavy modification in order to fit into the product development environment. So far, 15 value stream mapping sessions have been conducted at the company.

4.1.3 Value stream mapping procedure

Today value stream mapping is carried out in groups of 5-10 people as a workshop lead by a facilitator with lean experience. The role of the facilitator is to help the team to move forward and challenge them to think outside the box, for example by asking questions like *"Why do like this?"* and *"Are you not stuck in the same routines?"*.

The workshop is run for two consecutive days; one day for mapping the current state and one for creating a future state. The group consists of the actual people working in the processes, and not people who *think* they know how the process works. Adjacent functions are also included if possible. Groups of more than 10 people are considered to be too large and are divided into smaller groups that perform the exact same value stream mapping. This makes it possible to compare the results and discuss the differences.

The depth and the size of the value stream map are usually based on the time available. If the chosen process is big, the analysis will not be that deep. The

interviewee believes that the deeper you go, the more improvement ideas you will find. This trade-off is made depending on the process.

Day 1 - Current state
The workshop starts with a basic introduction to value stream mapping and the typical types of waste in product development. The introduction is held by the facilitator. The next step is to specify the start and end point and the inputs and outputs of the process. This is important in order to bring consensus. If possible, the group follows the real flow by walking around in the department(s). The process is then mapped using sticky notes with different colours like activities, information, obstacles, inputs/outputs and delivery (Figure 20). These notes are put on a big piece of paper on a table and connected with arrows to visualize the flow. There are often issues with the inputs to an activity and therefore it is suitable to discuss the activity that generated the faulty input immediately afterwards. Consequently, the mapping starts at the end of the process and moves backwards towards the beginning. Lead times and effective times are roughly estimated in chunks of activities.

When the process is complete the group discusses, activity by activity, what kind of disturbances, obstacles and frustrations they experience. These are written down on red sticky notes. The facilitator also notes improvement ideas that arise during discussions in the group. The mapping of the process and the following discussion usually take between 4 and 6 hours.

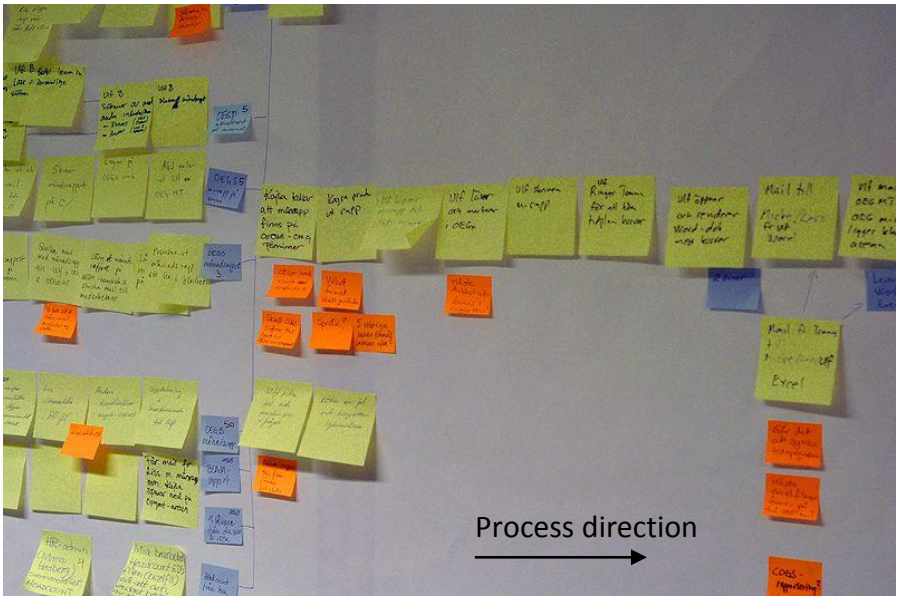

Figure 20: Detail of a current state map at Saab OEG

Day 2 - Future state & action plan
The second day starts with a short reflection on the previous day. Then the creation of a future state map begins with the focus on improving the workflow. The current state map from the previous day has been put away not to obstruct the minds of the group, but first the most important activities are copied to form a skeleton for the future state map. The goal is to create a map of how the employees would like to work in half a year's time. A longer timespan would result in more advanced improvement ideas which could be difficult to implement.

The group will have a number of improvement suggestions when the future state has been completed; the improvement suggestions from the future state map, the improvement suggestions noted by the facilitator, red sticky notes (disturbances) converted to improvements as well as other suggestions that the group members might have written down during the workshop.

All improvement ideas are now organized and prioritized using a pick chart (Figure 21). Each idea is placed in the chart depending on its benefit and effort. This will reveal which ideas are worth pursuing. It is now decided whether the improvement ideas shall be implemented as a project or be transferred to the improvement boards' inboxes of appropriate groups in the organisation. If the latter is chosen, each department is from now on responsible for the improvement suggestions and possible implementation.

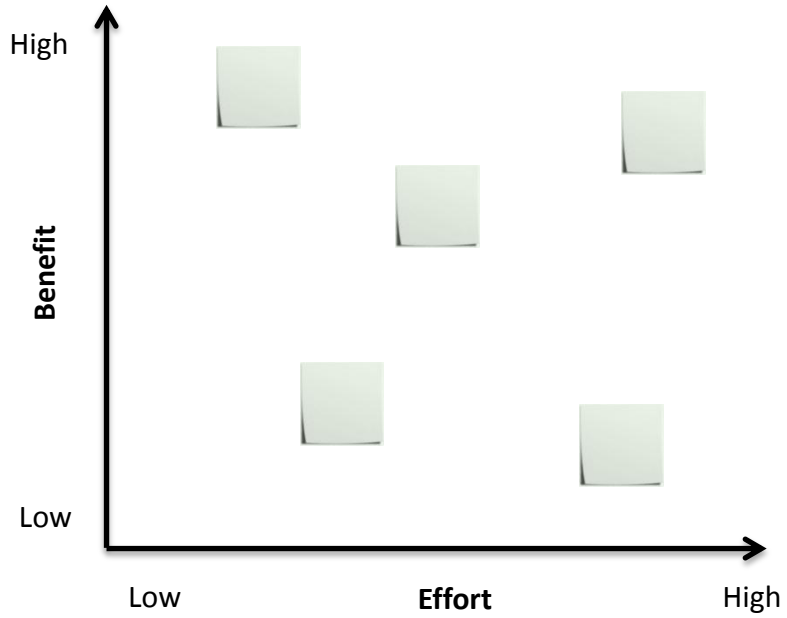

Figure 21: Pick chart

After the workshop
After the workshop, the maps shall be put up in the workplace in order to spread knowledge. There has been some resistance to this since the maps are considered ugly and the groups do not want to show their "bad working methods". Today however, this is a prerequisite for doing value stream mapping.

The response from the participants has so far been mostly positive, although a few of the participants regard the workshop as silly and not worth the time spent.

4.1.4 Lessons learned

Out of the 15 conducted value stream maps, one was less successful. That team struggled for months with a particular process. One issue was that the value stream mapping session was spread out on smaller two-hour-sessions with a week in-between. This resulted in a lot of start-up time, especially since the group participants varied from time to time. The group also had trouble in defining what they actually did in their process.

Putting too much focus on the final customer was another lesson learned from the early efforts. The discussions ended up being too theoretical and the employees found it difficult to relate it to their daily work. The motivation for performing the mapping session also decreased. Instead, focus is now on the employees and on removing obstacles and frustrations in their workflow.

During the first value stream mapping efforts Saab OEG measured lead time for each activity which resulted in long discussions in order to agree on a figure. The participants felt that this was unnecessary since the estimates were not exact anyway. Instead, Saab OEG now estimates time in chunks of activities. By doing so, they also capture the waiting time in-between activities.

4.1.5 Future ideas

Saab OEG hopes to be able to use value stream mapping in a more structured manner in the future. Today the processes have been chosen in an ad-hoc manner. One idea could be to use value stream mapping on a larger part of the company by starting from the top with a general analysis and then break it down and do more detailed value stream maps on smaller parts. These detailed mappings could preferably be repeated twice a year to continuously improve the processes.

4.2 RUAG Space

RUAG Space in Gothenburg is a medium sized company active in the space industry. They design and manufacture digital electronics, microwave electronics and antennas. The company works exclusively in projects, both within development and production.

4.2.1 Lean background

Lean tools were introduced in production in 2004/2005 at RUAG. Among the reasons were increased competition and encouragement to implement lean from customers and other companies. Inspired by the efforts in production, lean concepts were introduced in development in 2007/2008. The company started off by using improvements boards, followed by visual planning. RUAG does not explicitly say that they "work with lean", but use and modify lean methods as a means to improve their business.

4.2.2 Improvement efforts

Each resource group at RUAG has an improvement board. Improvements suggestions are written on so called "blue notes" by the employees. These are put on a suitable resource group's board and taken care of by that group.

Value stream mapping has been used at RUAG for about a year within development and 8-10 sessions have been carried out.

4.2.3 Value stream mapping at RUAG

Value stream mapping has been used on different types of processes, for example how new components are tested, how a testing procedure can be out-sourced and how requirements are traced. The approach differs depending on the problems in the process. If lead time is the issue, time is mapped in detail. In other cases, lead time is not dealt with at all. What usually triggers a value stream mapping session is cost overruns in projects.

4.2.4 Value stream mapping procedure

At RUAG, a value stream mapping event is performed in a group, consisting of 5-7 people working in the chosen process. The session is led by a coach working in the operations management department. The role of the coach is to ask "stupid" questions, challenge the participants to think outside the box, keep the session on track and the participants active. Among the participants is also a problem owner appointed by the coach. The problem owner is usually the one who identified the problem in the first place. One of the tasks of the problem owner is to keep records during the session.

The value stream mapping event consists of three separate meetings, each 1,5-2 hours long, spread out over a three week period. It is critical that the same people are present at all three meetings. This can be ensured by booking all the meetings initially.

Meeting 1

At the start of the first meeting the coach makes a short presentation. The concept of value adding activities, necessary waste and pure waste is explained. Typical wastes in production translated to a development context and examples of earlier value stream maps done at RUAG are also presented. A brainstorming session around the

problem(s) in the process is then held during the remaining time of the meeting. The problems are written on sticky notes. It is important to question the purpose of the investigated process; "*Why are we doing this in the first place and can it be linked to a customer requirement?*".

Meeting 2
The purpose of meeting 2 is to map the process flow using the sticky notes from meeting 1. During this meeting, the process is reviewed from the beginning to the end and the sticky notes are put on a big paper on the wall. Documents etc. used in the process are opened and shown to the rest of the group. This will for example make it more obvious if it is difficult and time consuming to find information. An important question that the coach can ask is "*How do you make it easy for the person after you in the process?*".

There is much focus on hand-offs and dependencies when mapping the process, since these are common sources to problems in product development. The level of detail on the map tends to come naturally, but the interviewee believes it to be beneficial to make the map as detailed as possible.

Meeting 1 and meeting 2 often blends together since it is difficult to brainstorm around the problem without putting the sticky notes in order.

Meeting 3
The purpose of meeting 3 is to create a future state map. After meeting 2, the coach has converted the map made of sticky notes to a computer format, where different symbols are used depending on the context (Figure 22). The future state map is then developed with the computer drawn map as a basis. It can, for example, be used for planning future projects since all activities and dependencies are identified.

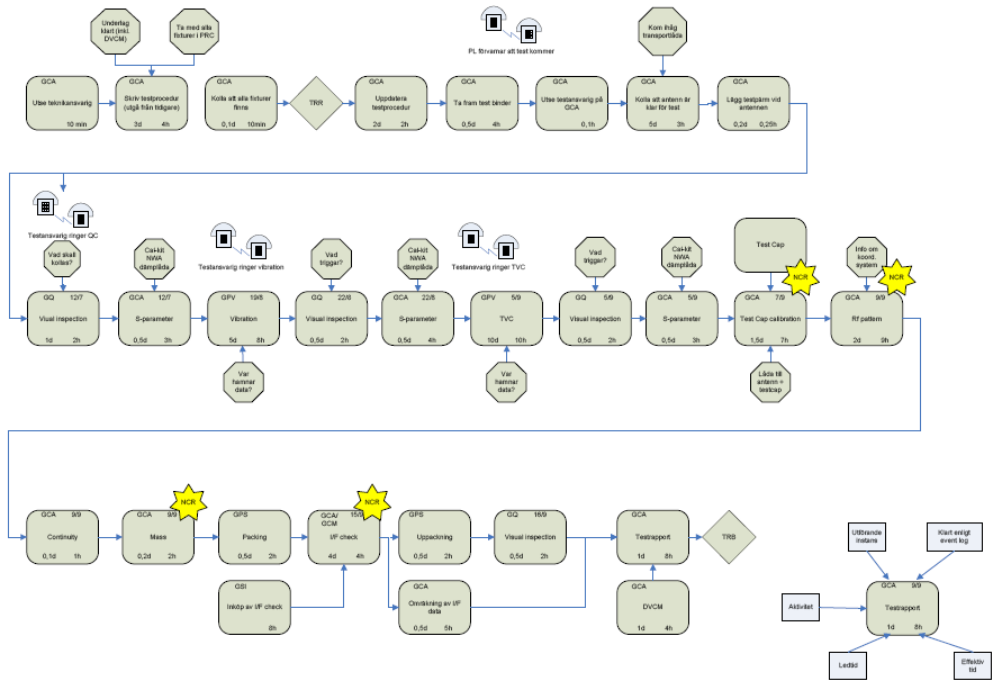

Figure 22: Example of a value stream map at RUAG with symbols for activities (box), communication (phone), customer review (diamond), issues with specification (star) and important reminders (octagon)

A lot of improvements ideas generally pop up during the meetings. These are written by the participants on the blue improvement notes and are the main result of the value stream mapping session. The event ends with the participants completing an evaluation form. People generally appreciate the value stream mapping session. Much is gained simply by putting people in the same room and making them understand each other's problems.

Presentation of result
The coach demands that the value stream map(s) shall be presented to a larger forum, for example during a department meeting.

4.2.5 Lessons learned

Design of the value stream mapping template
In the beginning, a highly simplified template of a production value stream mapping method was used. After performing a number of value stream mapping sessions the interviewee realized that the method must be adapted to fit the problem. For example, apart from mapping workflows, the method has even been used for tracking how an item, that should be kept in a clean room, is moved between floors in the building (Figure 23).

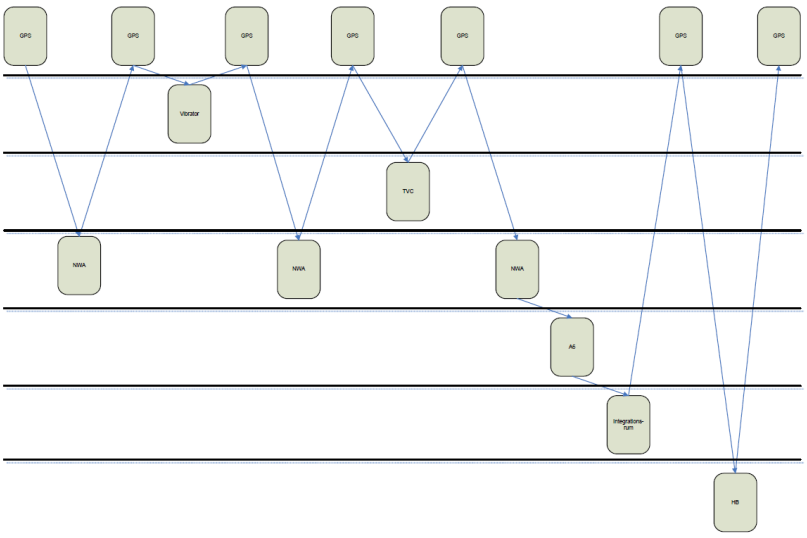

Figure 23: A map of the movement of an item between floors

Select concrete problems
It has also been learnt that it is better to select a concrete problem over a general. Otherwise there will be too many special cases and difficult to keep the discussion focused and on track.

Implementation of improvement suggestions
During the first value stream mapping attempts, the participants assumed that the coach was responsible for implementing the changes. This led to poor rate of implementation of ideas, since the coach does not generally work in the analysed process. The concept of the problem owner was introduced to resolve this problem.

If an improvement note is posted on another group's improvement board, there is a risk that they might not understand the importance of the suggestion and neglect it. To

solve this issue, it has been tested to have an improvement board specifically for results from the value stream mapping events. The problem owner is responsible for that improvement board.

4.2.6 Future ideas

Only some of the value stream maps are today put up on walls in the organization. The interviewee wants the organization to be better at this in the future.

No follow-up of the value stream mapping events have been conducted. RUAG has not yet come to that stage, but a template for evaluating value stream mapping events is being piloted.

4.3 Volvo IT

Volvo IT is a business unit within the Volvo Group. The company provides IT solutions and consulting services to other business units as well as to external customers.

4.3.1 Lean background

In the recent five years the company has been more and more inspired by Toyota's way of working. For example, visual planning and value stream mapping have been used in product development.

4.3.2 Value stream mapping at Volvo IT

In product development value stream mapping has mainly been used to shorten lead time since there is currently a strong focus on this within the company. The interviewee has carried out a couple of such value stream mapping sessions at different business units within the organization.

According to the interviewee, mapping processes is not something new, but what characterizes value stream mapping is the focus on problem solving. Also, a value stream mapping event is a group activity where the actual people working in the process are also the ones who improve it. Such an approach creates more engagement and commitment among the employees compared to outsourcing the task to a consultancy firm.

4.3.3 Value stream mapping procedure

At Volvo IT the actual value stream mapping events are conducted during two consecutive days; one for mapping the current state and one for creating a future state and an action plan. This is preceded by a preparation phase.

Preparation phase

The interviewee and involved parties together start by deciding the scope and setting targets for the event. It is important to define both a clear goal and clear boundaries of the value stream mapping session to achieve good results. The Volvo Group uses key performance indicators (KPI) to measure the performance of the organization. When using value stream mapping, preferably only one KPI, like for example lead time, is chosen for optimisation.

A group of 5-10 people working in the process is selected to conduct the actual mapping. It is important that the process can be mapped on a reasonable level of detail by that number of people. If not, the process is too big to analyse and should be divided into smaller parts.

As a part of the preparations the interviewee conducts interviews with key persons to become familiarized with the process. It is important to be well-informed and have an idea about the outcome, but still be open and flexible to the situation. During the actual event, the interviewee's role is to act as a facilitator. The intent is not to be the expert, but to guide the group during its analysis.

Day 1 - Mapping the current state

The group uses a whiteboard and pens to map the current state. Sticky notes could be used as well. The mapping is done as simple as possible to maintain flexibility, but

special symbols are used for decision points and for waiting. The group maps the flow from the end to the beginning of the process. The interviewee believes that this approach makes it easier to focus on the flow of the process. It is also important to map how the actual work is carried out and not how it is supposed be.

When the whole process has been mapped the group identifies problem areas and, with the selected KPI in mind, prioritizes a couple of them to focus the improvement effort. Metrics are usually estimated by the group since exact data is not available. Estimated metrics are considered to be sufficient enough for identifying problems. Metrics regarding lead time are often on an activity level.

Day 2 - Create a future state map and action list
The creation of the future state map is based on the problem areas found during the first day. A root cause analysis is performed to identify the sources of the selected problems. These are then used to find appropriate countermeasures. The type of countermeasure can vary a lot, for example to add activities to the process, to implement a new tool or to increase the communication between people. Thus, a future state map is not always made since that depends on the problem and type of countermeasure.

An action plan is created for the implementation of the countermeasures at the end of the session and people responsible are appointed.

So far, all value stream mapping events conducted at Volvo IT have been successful and the overall the response from the participants has been very positive.

4.4 Scania CV

Scania CV is a large, global company active in the automotive industry. Scania does not conduct value stream mapping in the same sense as the other companies do, and therefore the interview at Scania was of a different nature.

4.4.1 Lean background

Scania is considered as leading within lean in the Swedish industry. However, the word *lean* is not used internally at Scania, only externally. Scania uses and modifies the parts they find useful from the lean concept with the goal of making the organization more effective and efficient – *"It is about trying to understand what you do and improve it. Defining lean only makes things more complicated"*.

Modularisation is one example of a method that Scania uses successfully. The interviewee points out that other companies perhaps use modularization in other ways; it all depends on what needs the organisation has.

Continuous improvement efforts are a natural part of the work. Scania has improvement coaches whose aim is to support the organization and its different departments.

4.4.2 Why use value stream mapping?

According to the interviewee, value stream mapping should not be viewed as a predefined method performed for example within a week. Such events easily turn into happenings. It is more important to try to understand the actual principles behind the concept of value stream mapping to be able to use it successfully. Value stream mapping could for example be used to better understand how value is created, how lead time can be decreased or how a flow can be identified and improved. It is also essential that the group using the value stream mapping method has an actual need for doing so. The value stream mapping session shall not be the main goal.

The interviewee prefers to have value stream mapping more integrated in the daily work instead of performing it as a happening. It is important that the group controls their work methods. With a happening, chances are that the value stream map becomes the consultant's and is not owned by the group. However, there are cases when such a happening is useful, for example when people need to think outside the box.

4.4.3 Start by identifying the customer

According to the interviewee, the first step should be to focus on the customer. For example, the end user and the one paying for the product do not necessarily have to be the same one and it is important to be aware of this. By identifying the customer it is easier to separate the activities that actually create value from activities that are carried out merely because engineers find them fun and interesting.

4.4.4 Two flows

Essentially there only exist two types of flow in all kinds of processes; repetitive flow (e.g. production, taking out drawing number, handling applicants for a job) and knowledge flow (e.g. the innovation process, when the sales department handles a sale, when production methods are tested and improved). Classifying lean into lean

manufacturing, lean product development, lean services etc. only complicates things more than necessary.

In a production flow you want to eliminate waste and try to reduce the lead time. For knowledge flows you want to optimize the learning and for this, a longer lead time might be acceptable since the knowledge gained could be reused in future projects. Both these flows occur concurrently in product development, which means that you should not focus on only one of them. Many books about value stream mapping for product development only focus on the repetitive flow in product development, according to the interviewee.

4.4.5 Processes also include people

A consequence of value stream mapping could be that employees might find that their work is non-value-adding. It is essential to point out that people are always valuable, but perhaps not their present activities.

One thing not to forget is that processes can be dependent on people. In such cases it is important to look at many different aspects and define the total value, and not only look at the task itself.

4.4.6 Lessons learned

At one occasion the improvement coaches at Scania assisted a department with process mapping. The map was created as a group activity. After the mapping session, the coaches decided to rewrite the map using a computer. At a later meeting, the group expressed satisfaction about the result with comments like "*What a great process map you have made.*" and "*It is really good that you do this.*" to the coaches. The way the group expressed themselves made the coaches realize that they had taken too much control, with the consequence that the group did not really consider the mapping as their work.

4.5 Comparison of the value stream mapping methods

Similarities and differences between the value stream mapping methods used at Saab OEG, RUAG and Volvo IT are described in the following section. Scania is left out due to the different nature of the interview.

On a high level, the value stream mapping procedures are similar and all include the general steps:

1. Selection of process to analyse and definition of the purpose of the session
2. Mapping of the current state
3. Creation of a future state
4. Prioritization of improvement suggestions and implementation plan

The main results from the interviews regarding practical details of value stream mapping are compiled in Table 3.

Table 3: A comparison of the value stream mapping methods

	Saab OEG	RUAG Space	Volvo IT
Purpose of value stream mapping	Find improvements and share knowledge among functions	Mostly to decrease cost in projects	Decrease lead time in projects
Format	Workshop led by a facilitator	Workshop led by a facilitator	Workshop led by a facilitator
Group size	5-10	5-7	5-10
Participants	People active in the process, if possible also people active before and after the process	People active in the process	People active in the process
Duration	2 days	3 meetings, 2 hours each	2 days
Focus	Usually on obstacles that the employees experience in their daily work, but it depends on the process	Focus on hand-offs and dependencies, but it depends on the process	Lead time
Aids	Sticky notes with different colours, pens, paper	Sticky notes, pens, paper, computers	Pens, whiteboard, (sticky notes)
Mapping procedure	From the end to the beginning	From the beginning to the end	From the end to the beginning
Special notation	Yes, different colours on the sticky notes	No	Only for decision points and for waiting

Metrics	Yes, estimated lead times in chunks of activities if suitable	Depends on the situation	Yes, estimated lead time on activity level
Creation of future map	Yes	Depends on type of process	Depends on type of process
Result from session	Improvement suggestions that enter a PDCA cycle	Improvement suggestions that enter a PDCA cycle	Action list with responsible people

5 Field tests

This chapter describes the development of an adapted value stream mapping method for Ascom's R&D department.

5.1 The initial value stream mapping method for Ascom

The initial value stream mapping method for Ascom was developed using identified elements from the literature review and the case study as a basis (Table 4). These were:

Table 4: Elements of the initial method

Element	Reasons
A need to improve the process	A need for improvement among the employees will result in more commitment during the workshop and ease the implementation of improvement ideas
Workshop format	- Time efficient - Enable cross-functional communication - The companies in the case study use this approach
A facilitator	- Neutral part who can control the discussions - Brings outside perspective and enables the group to think differently - Has knowledge in the methodology (participants do not need to be lean experts)
5-8 participants who together possess the knowledge required to cover the process	- Appropriate group size according to the case study - Ensures that nothing will be overlooked
The high level steps from the methods in the literature review and the case study	- It is a systematic way to solve problems, both literature and the companies in the study use these steps

5.1.1 A simplified method

The literature review and the case study indicated that value stream mapping is moving towards a more simplified approach in product development. We believe it is possible to simplify it even more. By doing so many employees, regardless of background and knowledge in lean, could appreciate and find the workshop meaningful and also fast contribute to a useful outcome.

Since the concept of lean is not deeply rooted at Ascom at the moment, it was decided to put no explicit focus on identifying value-added or wasteful activities and to avoid words like *lean* and *value* to prevent confusion. By having the facilitator asking questions like *"In what way does this activity contribute to the end result?"* these matters could hopefully be dealt with in a more natural way. Also, no special symbols or notation for writing the notes were used – the important thing was that the participants understood each other. Finally, to make the content of the workshop match its name, the method was named *Workflow analysis*.

5.1.2 General procedure during the workshop

The high level steps of the value stream mapping method were essentially the same as in the versions from the literature review and the case study:

1. Introduction
2. Definition
3. Mapping of the current state
4. Analysing the current state map
5. Creation of countermeasures and a future state map
6. Prioritizing improvement suggestions and creation of an action plan
7. Evaluation of the workshop

Papers, pens and sticky notes (different colours for activities, problems, countermeasures and information) were chosen as aids. If suitable, computers could be used to show actual documents used in the process, i.e. a variant of "go and see". A guideline for the facilitators was developed to ensure that no relevant aspects were forgotten and that the schedule was followed (Appendix C to Appendix E). For a detailed description of the initial method, see Appendix B.

5.2 Field test 1 - software release process

The software release process was selected as the first process to test the method on, because it is small and clearly defined. There have been complaints from the employees about this process being too slow, so there was a specific need for analysing and improving it.

Field test 1 was performed with the objective of investigating an appropriate level of simplicity of the method as well as getting hands-on experience from facilitating a workshop.

5.2.1 Process description

The purpose of the software release process is mainly to secure the quality of the software before it goes to production or is published as a software update. The process involves a series of steps where different functions at the company have to review and approve the software before release.

5.2.2 Execution

Six participants from four different functions (product configuration & conformity, production engineering, infrastructure software design and supply technology) were present during the workshop. The event was scheduled to 3,5 hours.

The overall results from the workshop were positive. In total, 13 issues were identified along with eight feasible countermeasures. The participants had no problems using the method and the visualization of the workflow triggered a lot of discussion which gave the group a deeper insight into the process. Furthermore, using sticky notes was flexible and useful when the group rearranged the map.

In Figure 24, yellow notes represent activities, pink notes represent problems and blue notes represent countermeasures. The input to the process is represented by the leftmost sticky note and the output is represented by the rightmost. Concurrent activities are represented with yellow sticky notes aligned vertically.

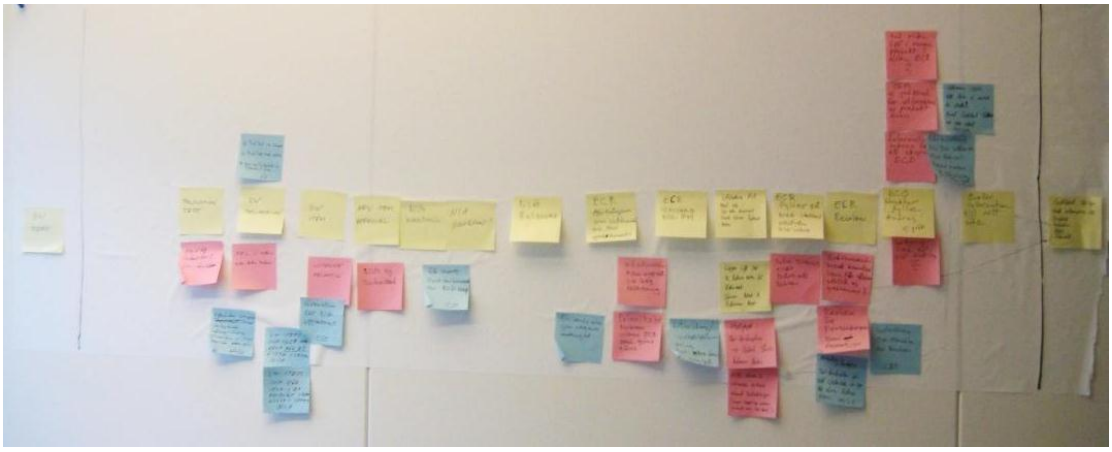

Figure 24: Current state map, field test 1

During the introduction, simplified lean waste categories in product development were presented. However, these were not used later when analysing the current state and identifying problem areas. Perhaps they did not fit in properly and could be revised.

The sticky notes for indicating information from other functions were not used. A possible explanation could be that all people affecting the process were present during the workshop since the process is small and well-defined. Though, both information to and from customers were discussed and could in retrospect have been symbolized with orange information notes.

No future state map, no prioritizing of improvement suggestions and no creation of an action plan were made due to lack of time. People were instead quickly assigned different actions at the end of the workshop. As a substitute, an additional meeting was held four weeks later where the countermeasures were prioritized. Up to that meeting, a couple of countermeasures had already been implemented and some were on their way.

5.3 Field test 2 - critical components

The second workshop was initiated by an employee who had been assigned the responsibility to improve Ascom's way of handling components regulated by law, so called critical components. The employee had heard about the method from the participants in the first field test and thought it could be useful as a starting point for the project.

Field test 2 provided a possibility to investigate how the method worked on a more complicated process compared to the software release process.

5.3.1 Changes made to the initial method

The procedure followed the same basic steps as the first test but with some modifications:

- The initial presentation had been modified slightly with less focus on typical waste
- The duration of the workshop was extended to a whole day's workshop to ensure creation of a future state map and prioritization of countermeasures

5.3.2 Process description

There are a number of electrical safety regulations that Ascom's products need to fulfil in order to, for example, be allowed in an explosive environment. This requires some components to be handled under special procedures which affect the development and manufacturing of the product (R&D, purchasing, production, service etc.). The process for managing these so called "critical components" is at the moment loosely defined.

5.3.3 Execution

Seven participants from six different functions (mechanical engineering, production, purchasing, quality, product configuration & conformity and supply technology) were present during the workshop. One of the participants had participated in field test 1. Not all participants were present during the entire workshop.

The number of participant was appropriate. However, there was no representative from the hardware department which would have been good since the discussions concerned that department as well.

Just as in field test 1, the overall results from the workshop were positive. In total, 37 issues were identified along with 25 countermeasures. Even though the critical component process is vaguely defined, the participants understood how to use the method and the visual workflow generated a lot of discussions along with a consensus around the process. Compared to the previous field test, sticky notes for information were utilized. However, they ended up representing more aspects than information, indicating that the use of those notes was unclear to the participants. The participants also had problems to understand and remember the meaning of some of the notes even after a short lunch break.

A future state map was created extremely quickly (in approximately 15 minutes) and the result was very similar to the current state map.

When prioritizing the countermeasures, each note was given a number. That number was written on a new sticky note and put up on a pick chart. Had the initial notes been removed from the map, it would have been difficult to put them back in their correct places.

Due to the nature of the analysed process, the person assigned to improve the process was given the responsibility of all countermeasures. Consequently, no action plan was created during the workshop.

In Figure 25, yellow notes represent activities, pink represent problems, blue represent countermeasures, orange represent information and green represent the future state. The group also marked the phases of Ascom's PCP process at their own initiative by drawing black vertical lines.

Figure 25: Detail of current state map, field test 2

5.4 Field test 3 - tooling phase

Compared to the processes in previous tests, the tooling phase can be viewed as a pure product development process. The purpose of field test 3 was to investigate how a future state map could be created and investigate how the notes shall be written to ensure enough understanding without hindering the participants.

5.4.1 Changes made to the previous method(s)

- To put more focus on creating a future state map, that map shall be created before creating the countermeasures. The countermeasures are instead developed in order to reach the desired future state, and not vice versa.
- Put more emphasis on writing the notes by adding information about responsible function or person on each.
- Sticky notes representing information were removed.

5.4.2 Process description

Tooling is a part of the mechanical engineering part design procedure and involves tool design, choice of suppliers, design loops to adjust the tool for mass production, and administration work. The main part of the work is done by the mechanical engineering department but in collaboration with the supply department in Herrljunga. Suppliers are most often located in Southeast Asia. Known problems in the process are long lead time, communication issues due to cultural differences.

5.4.3 Execution

Six participants from two different functions (mechanical engineering and purchasing) were present during the workshop. Two of the participants had participated in field test 2. The event was divided in two succeeding days, each session three hours long. Some participants were not present during the entire workshop because they had to attend other meetings etc. as well.

The overall results were good and 45 problems were identified along with 35 countermeasures. The types of countermeasures were mainly minor modifications, but also some which required a change in the flow.

After having mapped the current state, the map was divided into three bigger chunks of activities and lead times were estimated for each. The participants also marked loops and decision points on the map at their own initiative.

In Figure 26 yellow notes represent activities, pink notes represent problems, blue notes represent decision points and green represent countermeasures.

Figure 26: Current state map, field test 3

Despite the intention of creating a future state map, none was made mainly because the participants saw no point in doing so. According to them, the activities would be the same and appear in the same order. The countermeasures were instead created after the problems had been identified, just as in the previous field tests.

A pick chart was used to prioritize the suggestions (Figure 27). The chart was divided into four parts. The countermeasures were discussed and assigned one of the letters (A, B, C, and D) instead of removing them from the map and putting them on the chart. A function/person responsible for each countermeasure was also appointed.

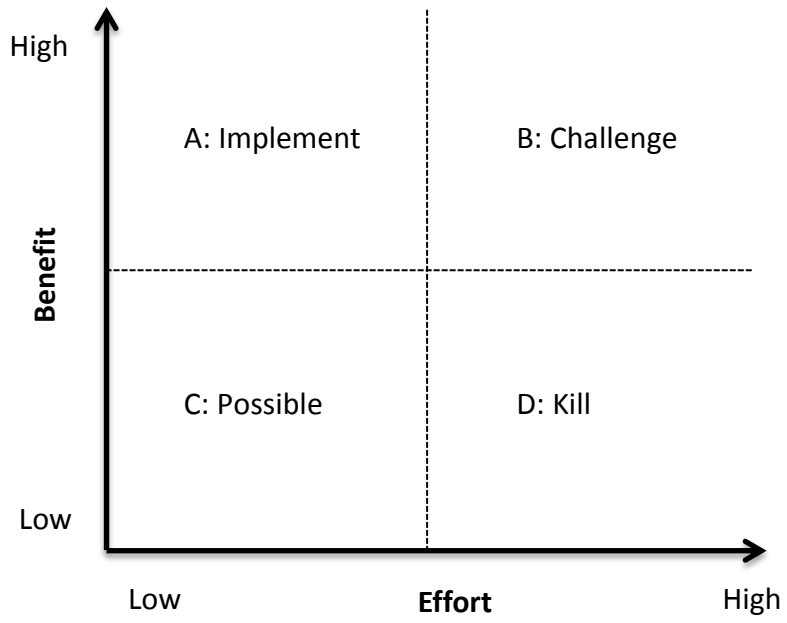

Figure 27: Pick chart, field test 3

The person summoning the workshop was assigned responsibility for compiling the improvement suggestions into an action list and to summon a follow-up meeting where the issues shall be discussed in detail.

After the workshop, the person responsible has on his initiative converted the current state map to computer format, both in the form of a graphical picture and a compilation of the activities, problems, countermeasures and responsible persons in a table.

5.5 Additional test

Since it was difficult to create a future state map in the field tests, an additional test was scheduled in order to try a different approach. A fourth test at Ascom was not feasible due to time and practical limitations, like scheduling participants for two half days. Instead, the process of finding a master's thesis, write a proposal and get it approved was selected.

5.5.1 Changes made to previous method(s)

The obstacle of creating a future state map could perhaps be overcome by selecting the most important activities from the current state map and use them as a starting point to create a future state map. This approach was chosen after consulting the interviewee at Saab OEG.

To force the participants to think differently when creating the future state map, they were asked to decrease the lead time of the process by 50 %.

5.5.2 Process description

To be allowed to carry out a master's thesis, all students must find a suitable thesis project, write a proposal and get it approved by Chalmers University of Technology.

5.5.3 Execution

Two students at Chalmers University of Technology participated in the workshop and mapped how they received approval for their master thesis proposal.

Seven problems were identified and a future state map was created to avoid these. This resulted in five countermeasures. The countermeasures required both a change in the flow and minor modifications to the activities.

Just as in field test 3, the process was divided in chunks of activities and lead time and the effective time for each chunk was estimated. In addition, arrows were drawn between the activity boxes (Figure 28).

When the current state map was finished, the participants appointed the most central activities in the process. These were marked and removed from their locations on the map.

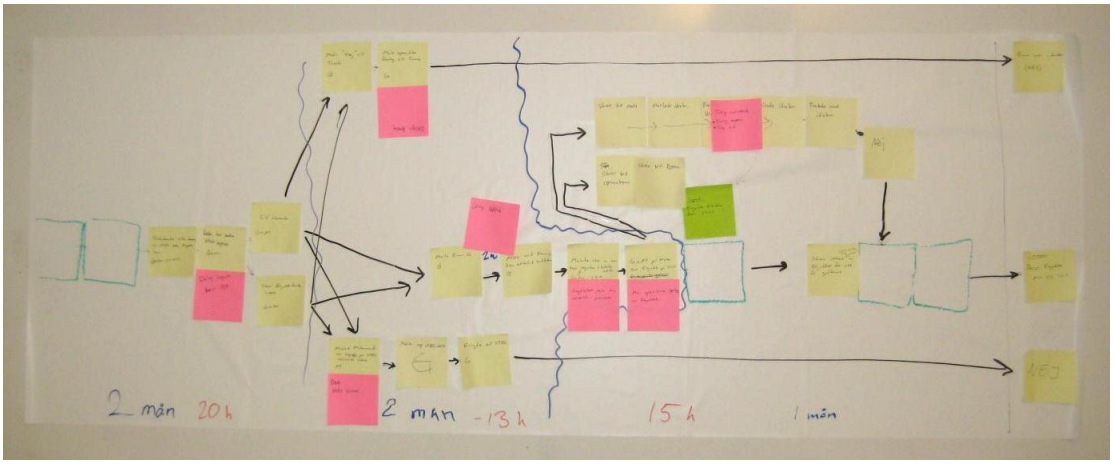

Figure 28: Current state map, additional test. The green squares represent the former locations of the most central activities (which have been moved to the future state map).

The most central activities from the current state map then formed a skeleton for the creation of a future state map. The countermeasures needed to achieve the future state map were written on blue notes and placed on the future state map (Figure 29).

Figure 29: Future state map, additional test. The notes marked with green squares were the most central activities in the current state map.

The problems in the current state map were also revised to ensure that nothing was forgotten. Lastly, all countermeasures were prioritized using a pick chart.

6 Workflow analysis

This chapter describes the adapted value stream mapping method developed for Ascom.

6.1 Step 1 - preparation

The first step is to define the scope of the value stream mapping workshop. This could preferably be done together with key stakeholders in a preparatory meeting.

The following needs to be defined:

6.1.1 Scope

The main requirement is to have a process with a need for improvement. If this need is shared by people working in the process, it will be easier to implement and sustain improvement suggestions.

The purpose of the workshop shall be agreed upon, for example to:

- Create a shared vision
- Reduce lead time
- Improve specific parts of the process

6.1.2 Selection of participants

A recommended group size is 5-8 people (excluding the facilitator). If the group becomes too big there is a risk that too much time is spent on inefficient discussions and that not everyone gets his/her voice heard. In these cases it is better to divide the group into separate teams, map the same process and compare and discuss the results. The process might also be too big to map and has to be divided and mapped in separate workshops.

The following persons need to be selected:

- Facilitator – responsible for guiding the group through the workshop and keeping track of time. The facilitator has knowledge in the method and shall push and challenge the participants to come up with new ideas. The more experience the facilitator has in lean and process improvement, the better (s)he can control and steer the discussions.
- Participants – the ones mapping the process. The participants include:
    - A workshop owner responsible for the implementation of improvement suggestions
    - Employees working in the process (not people who *think* that they know how the work is carried out)
    - Employees working before and after the process (i.e. the person delivering the input to the process and the person using the output)
    - Employees affecting the process without participating in it, for example decision makers
    - Employees necessary to achieve a potential future state, i.e. people with mandates to change the analysed process

6.1.3 Duration
The workshop duration depends on the scope and size of the process. However, two consecutive half-days are deemed to be sufficient for most processes. An all-day event is too exhausting and not recommended. Especially since parts that require focus and creativity like future-state mapping and creation of countermeasures are located at the end of the workshop. Separating the event into two half-days also give time for reflection and could improve the results, though it is important to have the days next to each other in order to lose as little information as possible.

6.1.4 Inform and prepare participants
To achieve a good starting point for the workshop, the participants need to be informed about the workshop, its purpose and the reason why they should participate. Instructions shall be sent to the participant so that they can familiarize themselves with the method and prepare for the improvement effort.

6.1.5 Aids
The following aids are required for the workshop:

- Sticky notes, yellow for activities, pink for problems and blue for countermeasures. Other colours can be useful to have in spare if there is need for visualising for example decisions, iterations etc.
- Pens
- A roll of writing paper (width: minimum 50 cm)
- Relevant documents and computers to show working procedures etc.

6.2 Step 2 - workshop
The workshop consists of the following parts:

6.2.1 Introduction
This step contains a short introduction held by the facilitator including the purpose of doing Workflow analysis and a basic description of the method.

6.2.2 Definition of the process
This step begins with a discussion regarding the purpose of the process. Both the internal and the external customers are discussed in order to create consensus.

The group then defines input and output to the process. These are written down on yellow sticky notes and put on a big piece of paper placed on a table. The borders of the process are marked with black lines and dependencies on other processes are discussed to avoid sub-optimization (Figure 30).

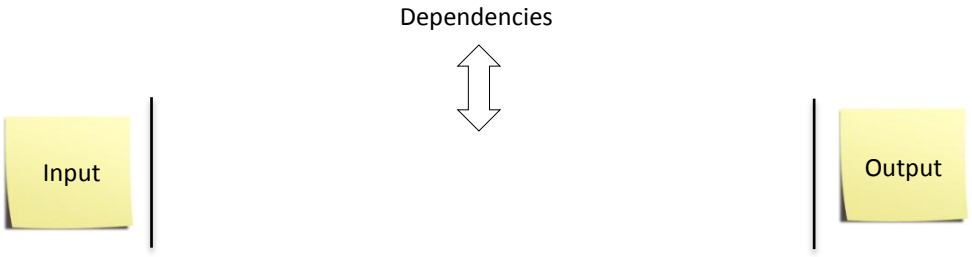

Figure 30: Definition of the process

6.2.3 Creation of the current state map

The mapping of the current state starts at the end of the process and moves towards the starting point (Figure 31). By doing so, the participants are forced to think differently and the customer will always be the starting point.

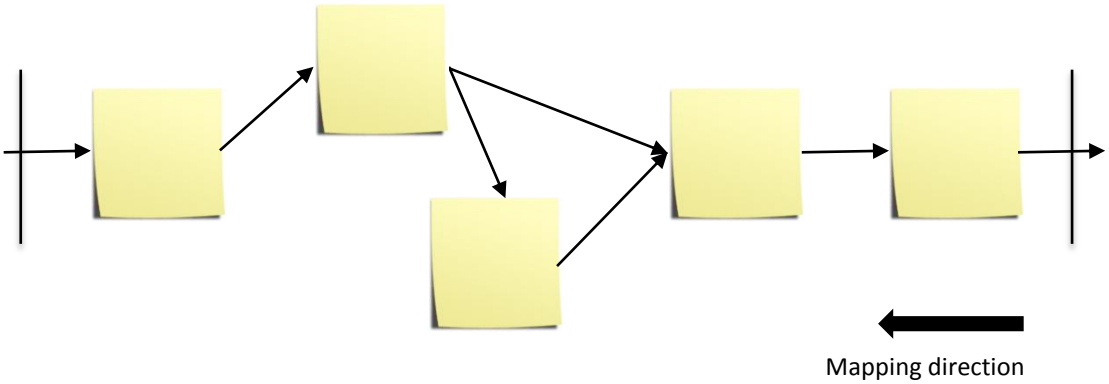

Figure 31: Current state map

During the mapping, each participant explains what (s)he does and writes down the activities on yellow sticky notes. If possible, the participants show each other the documents and tools that they work with. The level of detail of the activity notes depends on the time available, but it is important to write notes in such way that all participants clearly understand each activity and who performs it. Sticky notes in other colours than yellow, pink and blue are also available if the participants want to mark certain events, like loops or milestones.

The participants might have different opinions regarding activities and their internal order in the process. Hence, *one* single current state map might not even exist. However, discovering that employees have different work procedures (and discussing why) can alone be worth the time spent.

It is not allowed to discuss solutions to problems at this stage, since it is important to get a clear picture of the process before solving individual problems.

6.2.4 Analysis of the current state map

The next and last step of the day is to identify problems by discussing the process activity by activity. It is important to find the root causes of the problem and not only the symptoms. The facilitator can for example ask ‘why’ a couple of times. The identified root causes are written down on pink sticky notes and put up at appropriate locations in the flow (Figure 32).

When all problems are identified, the group discusses and summarizes the biggest problem areas that need to be resolved in a future state. Finally, the most important activities in the process are marked with green dots (Figure 32). These activities will be used as a basis for the future state map.

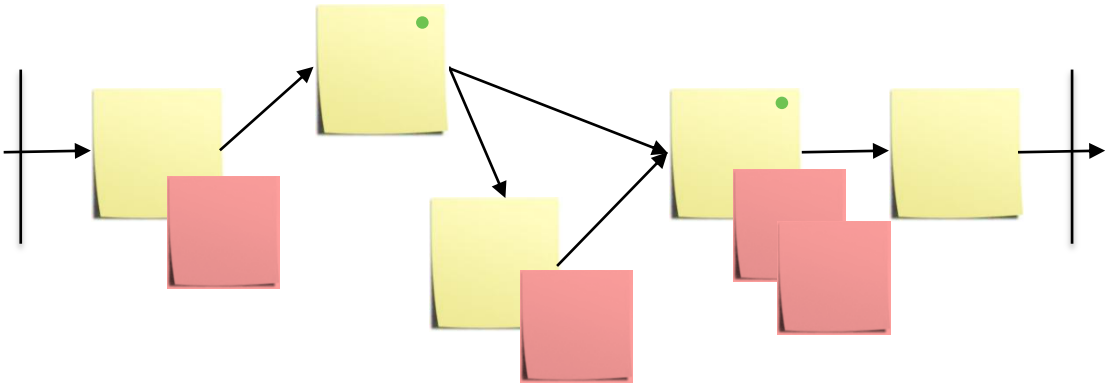

Figure 32: Analysis of current state map

6.2.5 Creation of a future state map

The second day begins with the creation of a future state map where the problem areas shall be eliminated. With the sticky notes marked with green dots as a framework, new sticky notes are written and arranged to form an improved flow (Figure 33). A trick that the facilitator can use to force the group to think differently is to ask them *"How do you achieve this in half the time if you had to?"*.

The changes needed to achieve the future state map are written on blue sticky notes and put up in the flow (Figure 33). It is important that the participants can picture themselves working like this within 3-6 months. Otherwise there is a chance that the group ends up with improvement suggestions that are too difficult to implement.

Finally, the improvement suggestions are synchronized with the identified problems in the current state map so that no relevant issues are left out.

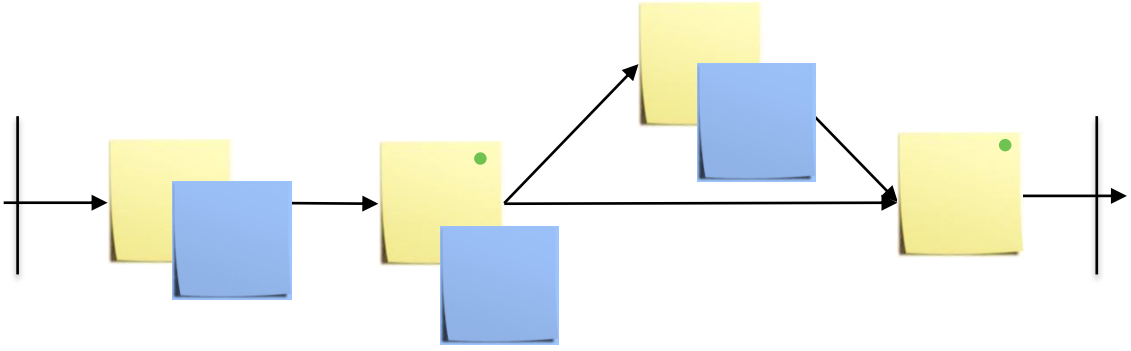

Figure 33: Future state map

6.2.6 Prioritization of countermeasures and creation of action plan

The improvement suggestions shall now be ranked by the group by using a pick chart (Figure 34) and employees responsible for implementing the chosen improvement suggestions shall be appointed. It is the workshop owner's duty to make sure that the workshop is followed up.

The prioritization can preferably be made as in field test 3 (section 5.4.3) if the group does not want to remove the countermeasures from the future state map.

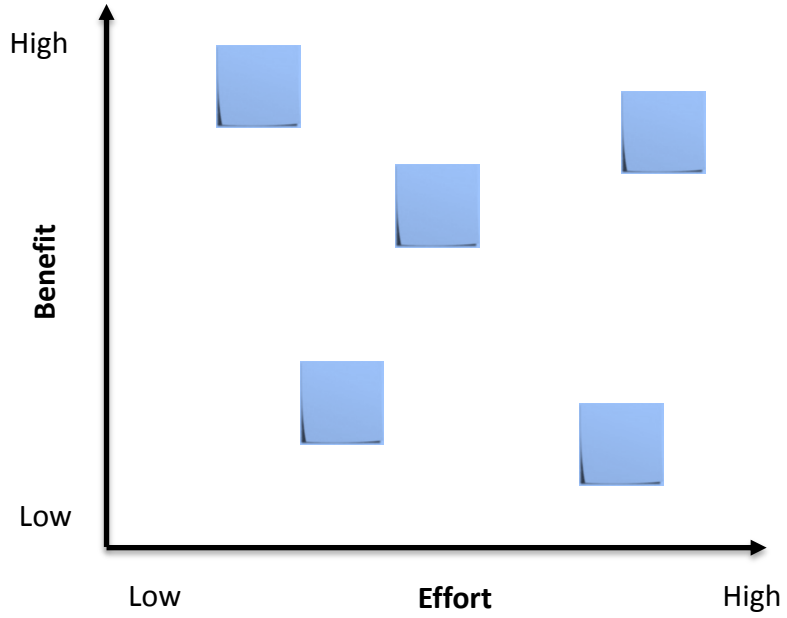

Figure 34: Pick chart

6.3 Step 3 - implementation and follow-up

The end of the workshop is not the end of the value stream mapping. Improvements need to be implemented in order for the event to be a success.

A follow-up meeting, for which the workshop owner is responsible, shall be held to evaluate the improvement effort and to tie up loose ends, for example issues might have arisen during implementation.

All participants shall receive feedback even if they are not involved in the implementation effort. It might cause resistance towards participation in future workshops if the effects of the workshop are not communicated. The result of the workshop can preferably also be communicated at department meetings to create motivation for further improvement efforts.

6.4 Implementing the method at Ascom

- Ascom needs to educate a couple of facilitators at the different functions within R&D. By doing so, an employee from one department can lead sessions in another. Apart from the facilitator being "external", (s)he will also gain valuable knowledge about other functions at Ascom, which can be brought back to her/his home department.

- Appoint a person with responsibility for the method. There are without doubt improvements to be made to the method itself. Having a person responsible for maintaing and refining the method is therefore important.
- Inform employees about the method and its applicability, so that it becomes a known tool within the company.

7 Analysis

This chapter consists of an analysis of the findings from the literature review, the case study, the field tests and the proposed method.

7.1 Adaption of literature to suit industry

The success of value stream mapping in production have resulted in adaptions to other contexts like product development. For example, Millard (2001) and Morgan (2002) have modified the method by introducing more steps and tools or by expanding the notation to cope with product development specific activities like iterations, cross-functional activities and decision points.

While the literature (e.g. Millard (2001) and Morgan (2002)) have adapted value stream mapping to product development by expanding the method the companies in the case study have done the exact opposite, by simplifying it. A majority of the companies started off with the methods described in the literature, but soon found them too complex. The case study revealed that the companies basically follow the same pattern on a high level as the methods proposed in literature, but that a great amount of adaption was required in order for the method to suit the process and participants. Instead, they now use a simplified approach with less strict notation and less or no metrics.

Thus, it seems like the original value stream mapping method for the production environment has undertaken the transformation of going from a strict method in theory to a simplified method in reality in order to fit a product development context. We believe that the simplification makes it is easier to adapt the method to the situation, especially for complex processes like product development.

The field tests conducted at Ascom indicated that value stream mapping could be simplified even more without losing its main function, i.e. to understand and improve product development processes. Focus was on creating a shared picture of the process with indirect emphasis on value and waste.

7.2 Value and waste in value stream mapping

An important part of the production oriented method *Learning to see* is to measure the value adding time for each activity (Rother & Shook, 1998). While it is a matter of measuring time of each operation in production, it poses a problem for product development.

Judging from the literature, there is no good definition of value and waste in product development and it is therefore hard to determine what is value adding or not. Besides, it is uncertain what effect a pure waste-removing focus would have since much is dependent on the sequencing and coordination of activities in product development. Besides the risk of using the wrong metrics, quantifying value on the activity level could draw attention to optimizing specific activities rather than the wholeness with an inherent risk of sub optimization. Furthermore, the case study indicated that attempts to quantify value could result in empty discussions around it. Instead, the companies have more focus on issues closer to the employees.

However, we still believe that it is important to question how activities contribute to the end result. Discussing value-adding and wasteful activities could preferably be handled in an indirect way by the facilitator challenging the group. The extent to which the company has adapted the *lean philosophy* further determines how much effort can be put on direct value discussions. If the mindset is not rooted at the company, less focus shall be put on lean concepts to avoid unnecessary theoretical discussions and confusion. As a company gets more experience from working with value stream mapping, more of the underlying theory can be added to the method. This might even be required since when processes become more efficient it will be more difficult to find improvement areas.

7.3 Mapping the product value stream

Value stream mapping mainly maps the flow of tasks in product development. Using Kennedy, Harmon & Minnock's (2008) model, value stream mapping captures the product value stream and not the knowledge value stream.

A reason could be that the product value stream by nature is more concrete and hence easier to visualise. However, knowledge will still increase due to the exchange of experience among functions during the workshop. Knowledge is for example created through integration learning, i.e. learning about customers, suppliers, partners and the environment in which the product is used (Ward, 2007). Since customers and suppliers can be both external and internal, the proposed method is a good way to increase that type of learning.

7.4 Value stream mapping composition and format

7.4.1 Workshop

The majority of the companies in the case study have adapted the cross-functional workshop format for value stream mapping instead of the project approach described by Millard and Morgan. The benefit of cross-functional workshops is further supported by the field test, where many of the improvement ideas were derived from the interaction between functions. Besides, a three-day workshop variant of Morgan's initial value stream mapping method was later proposed by himself and Liker which further strengthens the choice of such a format.

A reason for the success of the cross-functional workshop format could be the high degree of synchronized activities in product development. For example, Ward (2007) argues that hand-offs are the biggest issue in product development and 70% of the knowledge is lost during transfer. The case study also supports the notion that hand-offs is an issue in product development. Therefore we believe that the method is most effective in processes with a lot of hand-offs and which include many separated functions.

7.4.2 Participants

Many attempts to model processes result in a map not representative of how the work is carried out. In value stream mapping, a more accurate map of the current state is created by involving people working in the process.

The participants will affect the result during the workshop but also the rate of the implementation of countermeasures. From the field tests it was learnt that it is

important to include people with mandate to change the processes. Both Morgan and Millard support this theory by advocating strong management support and process owners as members of the improvement teams. However, management involvement in the workshops could potentially obstruct the mapping of the current state since the participants might tell what they think the boss wants to hear instead of the reality. Therefore, the selection of participants needs to be done depending on the situation.

In general, the selection of participants is a very crucial step in value stream mapping. The right balance between the right people and group size needs to be found to get optimal results.

7.4.3 Facilitator

The advantage of having a neutral facilitator to guide the workshop was a recurring point of view among the participants in the field test. An external facilitator has no ties to the selected process and can view it with fresh eyes and keep the discussions on track. However, the use of a facilitator is not completely without difficulties. The role as a facilitator is demanding and a major part of the outcome depends on his or her performance.

The field tests indicated the difficulty for an outside person to follow the group's discussions and to determine whether the discussions were relevant or if it was better for the group to move on, especially when it got into details. This is probably something that gets easier with more practice, something we felt by comparing our performance in the first and last field test.

The importance of the facilitator not taking over the workshop, for example by writing the sticky notes (and transforming the map to computer format), was pointed out by the interviewee at Scania. By making the participants map their process, the chances of a realisation of the improvement ideas will increase.

7.4.4 Aids

The method developed in this thesis uses a small set of aids. Notation-wise it is more similar to concept maps than the original value stream mapping methods for production and product development.

While an extensive set of symbols would allow more accurate mapping we are of the opinion that the notation should be enabling rather that restricting. It is important to keep in mind that the map is a way to create improvement suggestions - creating an exact map is not the main goal. There might even be cases when it is impossible to create an accurate state map, for example if the analysed process is complex or chaotic (see the Cynefin framework, section 3.1.1). However, we believe that the method must be put in a perspective to its alternatives. Even if the map is not complete, it still provides a basis for discussion.

A complex notation results in a longer learning curve and allow for debate around details of how the notation should be used. The field tests revealed that by providing additional notes, the group could take its own initiatives to add special symbols if needed. As a consequence, the map will probably feel more like the group's map.

Sticky notes increase the flexibility since they are easy to move around. A drawback with them is that all activities will look the same regardless of their duration, effort or

importance due to their format. However, right now we consider this the best alternative until a better one is found.

7.5 Achieving a future state

A reoccurring issue during the field test was the creation of a future state map. In the first test a future state map was excluded due to the limited time. During the second test a future state map with strong resemblance to the current state map was created very quickly and during the third test the participants believed that a future state map would end up looking the same as the current state and hence no one was created at all.

By not creating a future state map, it is probably more difficult to come up with countermeasures that require a change to the flow. Instead the improvements are more likely to be within or between activities. During the additional test it was noted that the creation of a future state map triggered ideas related to sequencing of activities.

However, both minor improvement suggestions and more innovative ideas that require a change in the flow are of interest when making product development processes more efficient and effective. The success of the workshop is therefore not only determined by whether a future state map is created or not, but it is important at least to try.

It was learnt from Saab OEG that it could be easier to achieve a future state map if activities from the current state form a base for the new flow and by forcing the participants to think differently.

8 Discussion

The chapter provides a discussion about the results of the thesis and suggestions for further research.

This study was of a qualitative kind and such an approach could pose problems regarding subjectivity both when collecting data and when analysing it. Though, since three different sources of information were used, i.e. a literature review, a multiple-case study and action research, we do believe the results can be regarded as trustworthy. The proposed method is to a large extent based on the methods used in the case study. The success of these indicates the advantage of such a value stream mapping approach, which is further supported by our field tests.

The case study consisted of companies from the space, the defence and the automotive industry. The fact that they have adapted value stream mapping in a similar way together with the results from the field tests at Ascom, which operates in the telecommunication industry, points towards that our proposed method is applicable to product development in other industries as well.

However, there are aspects that could have affected the outcome and these are discussed below.

In the case study, all interviewees had experience from facilitating value stream mapping workshops. Thus, that data can be regarded as unilateral. It would have been beneficial both to participate as observers during workshops and to interview participants as well in order to receive more comprehensive data.

Moreover, the value stream mapping methods in the existing literature are developed mainly by American researchers investing American companies, whilst the case study consists of companies in Sweden. Thus, cultural differences might affect the comparison.

The process in the additional test was different compared to an actual situation at a company and not all participants active in the process were present. It is therefore difficult to estimate the transferability of the findings.

From a research perspective it is difficult, within the scope of the study, to analyse the quality and applicability of the improvement suggestions created during the field tests and thereby the usefulness of the method. However, the fact that the method generated a lot of improvement suggestions, of which some have already been implemented, along with positive feedback from the participants indicates the advantage of proposed method.

Finally, the purpose of this study was to develop a method suitable for Ascom, and not a generic value stream mapping method. There are probably several ways to achieve a successful value stream mapping in product development, but this method is believed to be one of them. We are convinced that the method is transferable to other contexts and companies, but we leave the task of proving this from a scientific perspective to future research.

8.1.1 Further research

- The time frame of this project is too short to be able to evaluate the usefulness and quality of the process improvements generated by the method. Therefore an extension of our work could be to study the effects of the method at Ascom.
- Investigate the transferability of the method by using it at other companies
- There are almost certainly many other application areas for the method, for example as a part of lessons learned in projects.
- Investigate what types of problem areas and situations that are suitable to resolve by using a workshop format to better target the improvement effort.
- It can be difficult to understand the map, the problems of the process and the countermeasures for those employees who have not participated in the workshop. It is important that the knowledge created during the workshops is transferred to the affected parts of the organization. An extension of the method could be to specify how this knowledge could be transferred.

9 Conclusions

This chapter presents the key results by answering the research questions.

RQ1: What is value and what is waste in product development?
There are no unified definitions of either value or waste in product development judging by the literature. For example, value can be expressed based on the customer's perception of the product (Slack, 1999), as usable knowledge and manufacturing systems (Ward, 2007) and the capability of a product development process to reduce uncertainty (Browning, 2003). As for waste, several different attempts have been made to classify it, among others by Morgan (2002), Kato (2005), Slack (1999) and Bauch (2004), without converging conclusions.

RQ2: How is value stream mapping described in the literature?
The value stream mapping method originally developed for improving manufacturing processes is characterized by identifying value-adding and wasteful activities, and removing the latter. Large emphasis also lies on collecting and evaluating lead time metrics. The methods developed by researchers to make value stream mapping fit a product development environment share these features, but are in addition expanded by extra symbols, tools and more people.

RQ3: How is value stream mapping used in product development in the Swedish industry?
The case study indicated an inconsistency between how value stream mapping is described in the literature compared to how it is applied in industry. While literature has expanded the method, the companies in the case study have simplified it. Value stream mapping is carried out in the form of workshops with people working in the actual process led by a facilitator. The focus is on time metrics. The number of predefined symbols is reduced, and so is the explicit focus on identifying value-adding and wasteful activities.

RQ4: How can Ascom use value stream mapping to support their improvement effort and create a shared vision of their processes?
Workflow analysis is presented as a potential process modelling method for supporting Ascom's continuous improvement efforts. The method consists of the same high-level steps as the value stream mapping methods, but with a simplified procedure. Just as at the companies in the case study, it is carried out in the form of a cross-functional workshop with an external facilitator leading the session. The participants consist both of people working in and adjacent to the process and people with mandate to change it.

The method treats lean concepts like value and waste indirectly. To start with, there is, as explained above, no unified definition of what value and waste are in product development, making it difficult to use the definitions during a workshop and make sure that the participants interpret them in the same way. The case study also indicated that by simplifying the method and removing the explicit focus on value and waste, unnecessary and pointless theoretical discussions were decreased. Instead more emphasis could be put on creating understanding across functions. Finally, the field tests conducted at Ascom showed that by removing emphasis on value and waste, the main function of value stream mapping, i.e. to understand and improve product development processes, was sustained.

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Appendix A Case study questions

1. General questions

Presentation - tell us briefly about yourself and your background

- Duties at the company?

Company

- What does the company work with?
- Number of employees?

How is the company structured?

- The organizational structure?
- Projects? Size?
- Project length?

2. Lean and value stream mapping

When did the company start working with lean/lean product development?

- How?
- Why?

How would you describe value in product development?

- How would you describe waste in product development?

Why did the company start using value stream mapping?

How would you describe value stream mapping?

- Process mapping?

In what ways have the company used value stream mapping in product development?

- For how long?
- Has the tool been modified in any way since you started working with it?

How do you proceed when you use value stream mapping?

- How do you decide where to use value stream mapping?
- Do you prepare the participants in any way? Education?
- Who does the analysis? How many? Leader?
- Group work or individual? Group size?
- Visual aids, computers?
- Scope?
- Do you use any kind of metrics (lead time, etc.)?
- Level of detail?
    - *Do you categorize what you map e.g. resources, activities, events, information?*
    - *How do you mark relations in the map e.g. flow, direction, users, sub-processes?*
    - *Does the level of detail increase/decrease during the mapping?*
- How often?

How do you ensure that the total "value" in the process increases (no sub-optimization)?

How do you deal with variations in the process when making a value stream map?

How do you proceed when you find something to improve?

- Priority?
- Who implements?
- How fast?
- Evaluation/follow-up?

In what processes have you used value stream mapping? (Structured/ad hoc)

- Why did you choose those processes?
- Result?

Can you tell us about an occasion when a value stream mapping event was really successful?

- Why?

Can you tell us about an occasion when a value stream mapping event was unsuccessful?

- Why?

Are there any processes where you should not use value stream mapping?

- Why?

What are the participant’s opinions about value stream mapping? Feedback?

How do you think that value stream mapping will be used in the future at your company?

Can we mention you in the report?

Appendix B Description of the initial method

1. Introduction
2. Definition of the process
3. Creation of the current state map
4. Analysis of the current state map
5. Creation of countermeasures
6. Creation of a future state map
7. Action plan
8. Evaluation of the workshop session

1. Introduction

This step contains a short introduction to the event; the purpose of doing Workflow analysis and a basic description of the procedure. Examples of waste in a product development environment are also presented, with the purpose of making the participants think a bit differently about the process and their work tasks.

2. Definition of the process

Step 2 starts by the facilitators asking the attendants what the purpose is of the process that is going to be analysed. That is followed by a discussion regarding what the participants want to achieve with the session. The group then defines input(s) to and output(s) from the process. These are written down on yellow sticky notes and put on a big piece of paper, which is placed on a table. Dependencies on other processes are also discussed, in order to avoid sub-optimization. See Figure 35.

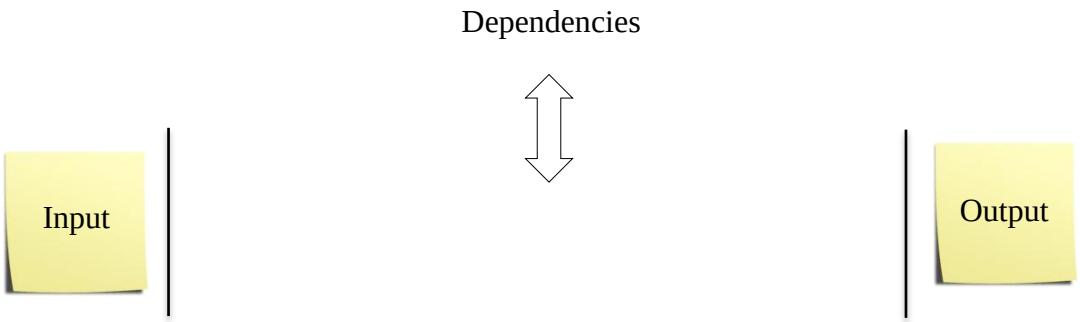

Figure 35: Definition of the analysed process

3. Creation of the current state map

The mapping of the current state starts at the end of the process and moves towards the starting point. By doing so, the participants are forced to think a bit differently and the "customer" will also always be the starting point.

Each participant explains what (s)he does and writes down each activity on a yellow sticky note. If possible, the participants show each other what the documents they are working with look like on a computer. Also, it does not matter exactly how the participants write the notes, the important thing is that they understand each other. Orange sticky notes are used when information is needed from another process/function. See Figure 36.

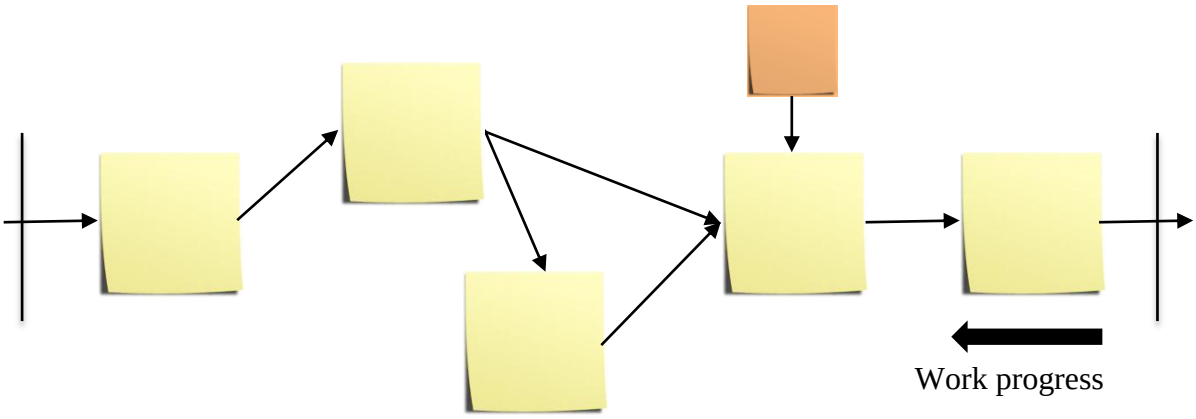

Figure 36: Current state map

4. Analysis of the current state map

When the entire process is mapped and the participants agree on it, the process is gone through activity by activity and problems/improvement areas are discussed. The 5 why's can preferably be used to identify the root causes of the problems and not only the symptoms. Identified problems/root causes are written down on pink sticky notes and put up at the flow on suitable locations. See Figure 37.

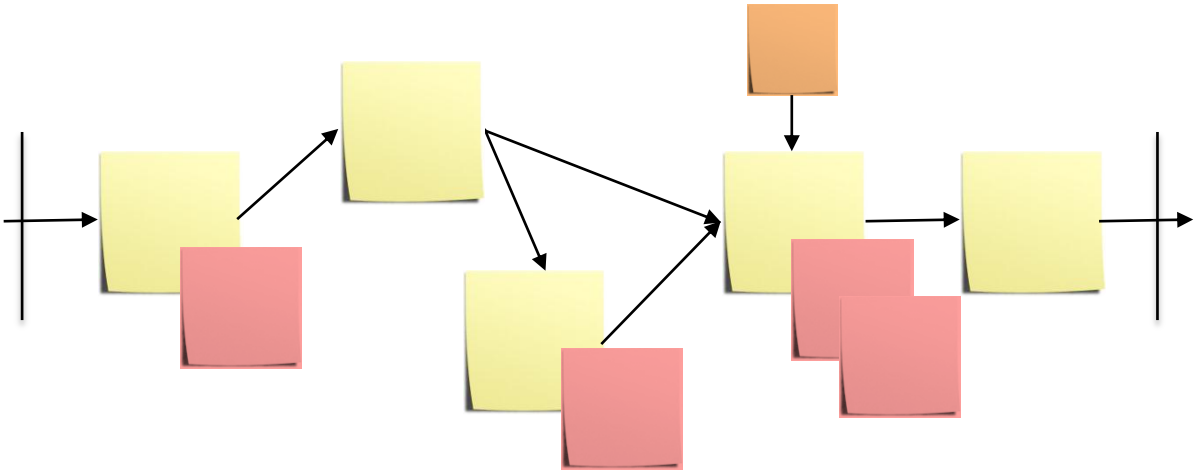

Figure 37: Analysis and problem identification

5. Creation of countermeasures

Each pink note is now discussed and suggestions for how to solve the issue(s) are provided by the participants. The suggestions are written down on blue sticky notes and put up in the flow at suitable locations. It is important that the suggestions are realizable within 3-6 months. See Figure 38.

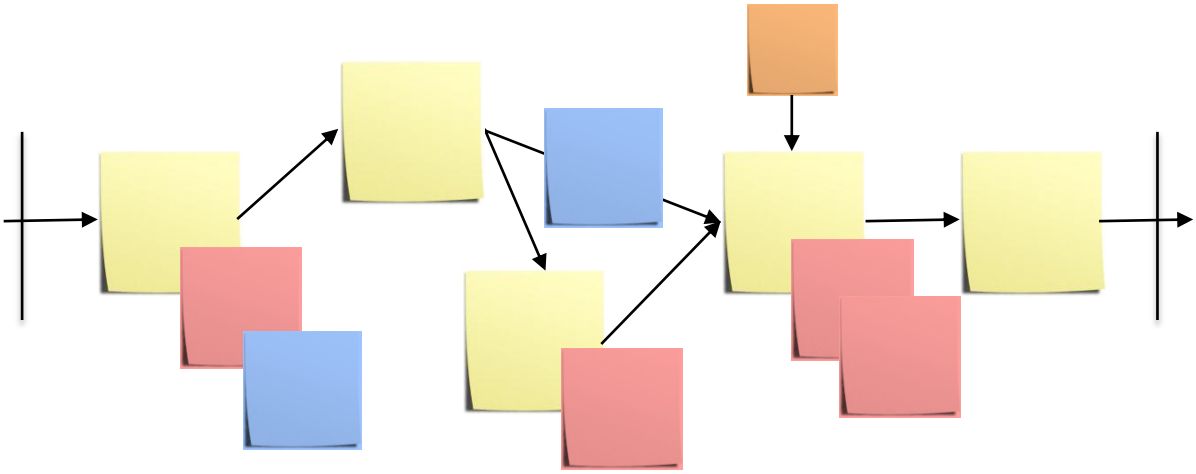

Figure 38: Creation of countermeasures

6. Creation of a future state map

The next step is to create a future state map where the problem areas should be eliminated. This can be done by writing new sticky notes and arranging them in an improved flow (Figure 39). Also here it is important that the participants can picture themselves working like this within 3-6 months.

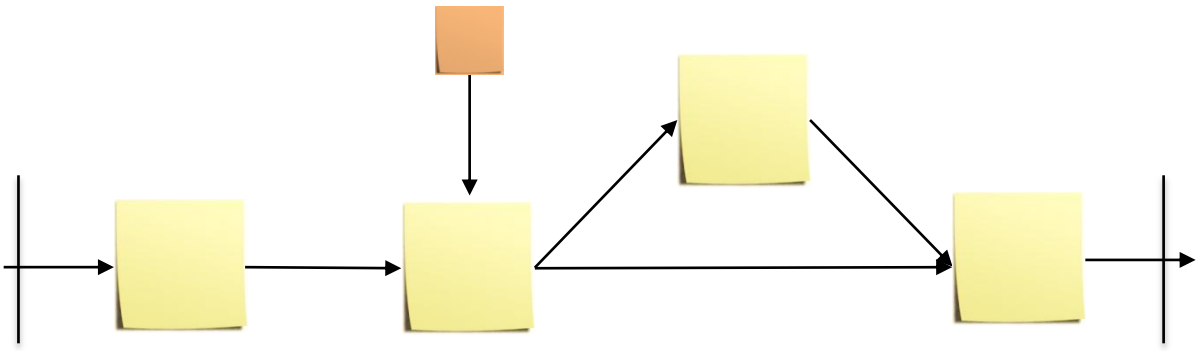

Figure 39: Future state map

7. Prioritization of improvement ideas and creation of an action plan

The blue sticky notes and ideas that have come up during the creation of the future state shall now be ranked by the group by using a so called pick chart (see Figure 40). Depending on the type of improvement suggestion(s) chosen for implementation, responsible persons shall be appointed.

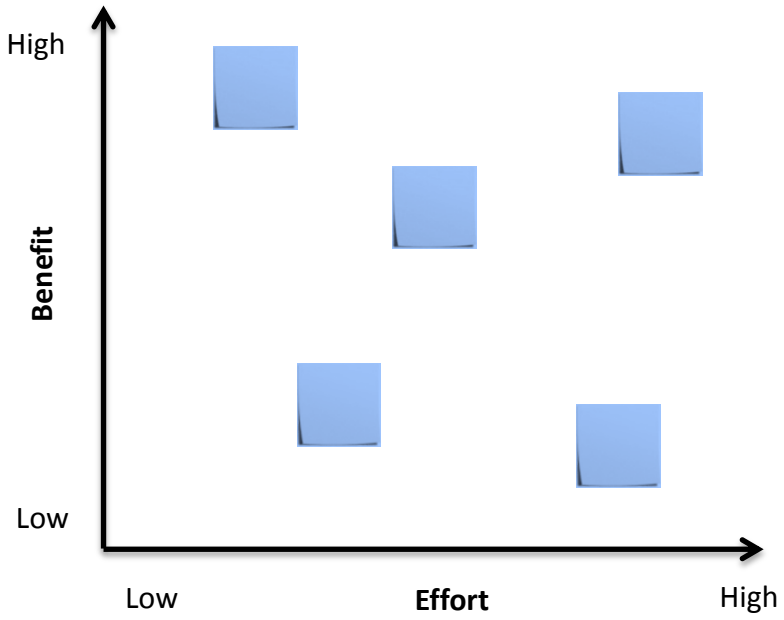

Figure 40: Pick chart

8. Evaluation of the workshop session

The last step is to evaluate the workshop session. The participants write what they think was good and what they think can be improved on sticky notes and put them on a big paper (Figure 41).

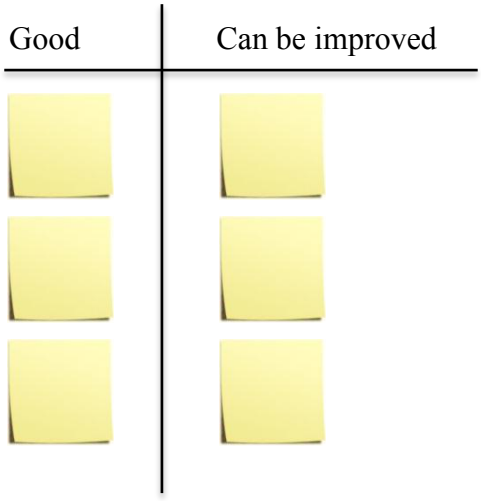

Figure 41: Evaluation of workshop

Appendix C Guideline field test 1, software release

1. Introduction

15 minutes

2. Definition

30 minutes

- Discuss what the group wants to achieve during the session
- Discuss the process (SW), its purpose and dependencies on other processes
- Define input(s) and output(s)

Remember to:

- Make sure that the team has a clear goal with the session and that all agree on that

10 minutes break

3. Creation of current state map

60 minutes

- Begin at the end of the process and make the participants explain and show (computers) to each other what they do, activity by activity
- Write the activities on yellow sticky notes

Remember to:

- Ask stupid questions
- Try to avoid discussion around subjects off topic
- Make sure that the participants understand the notes (but it does not matter exactly how they are written)
- Make sure that the participants do not discuss solutions during this stage. (Write them down and move on.)
- Ask: How can you make it easier for the person after you in the process?
- Who does what? Different roles?
- What resources are used?
- What documents are used?
- Are there any decision points?
- Hand-offs?
- Waiting?

5 minutes break

4. Identify problems and opportunities for improvement

60 minutes

- Discuss activity by activity
- Use the 5 why
- Use the seven wastes for inspiration

- Estimate lead time and effective time
- Try to come up with solutions to the problems, write on sticky notes in another colour and put them in the flow
- Discuss what the group wants to do with all ideas (use a pick chart for prioritizing the ideas)

5. Evaluation

The participants are asked to give feedback regarding what was good and what could be improved.

Appendix D Guideline field test 2, critical comp.

1. Introduction (9:00 - 9:15, 15 min)

Presentation

2. Definition (9:15 – 9:35, 20 min)

- Discuss the goal with the Workflow analysis – write the goal on the whiteboard
- Discuss the purpose of the process – write the purpose on the whiteboard
- Discuss dependencies
- Define input(s) and output(s)

Remember to:

- Make sure that the team has a clear goal with the session and that all agree on it

3. Current state map (9:35 – 11:15, 1h 40 min)

- Begin at the end of the process and make the participants explain and show (computers) to each other what they do, activity by activity
- Write the activities on yellow sticky notes

Remember to:

- Ask stupid questions
- Try to avoid discussion around subjects off topic
- Make sure that the participants understand the notes (but it does not matter exactly how they are written)
- Make sure that the participants do not discuss solutions during this stage. (Write them down and move on.)
- Ask: How can you make it easier for the person after you in the process?
- Who does what? Different roles?
- What resources are used?
- What documents are used?
- Are there any decision points?
- Hand-offs?
- Waiting?

Break 5 minutes

4. Identify problem areas (11:15- 12:00, 45 min)

- Discuss activity by activity
- Question the activities; what do they add?
- Use the 5 why
- Use the seven wastes
- Write the problems/root causes on red sticky notes and put them in the flow
- Finally, identify/discuss the main problem areas.

12:00 – 13:00 Lunch

5. Create countermeasures (13:00-13:45, 45 min)

- Try to come up with solutions to the problems, write the on sticky notes in another colour and put them in the flow

6. Create current state map (13:45-14:45, 1h)

- Try to make the participants question their old routines

7. Prioritization of countermeasures (15:15, 45 min)

- Discuss what the group wants to do with all ideas (use a pick chart for prioritizing the ideas)
- Book a follow-up meeting

8. Evaluation

The participants are asked to give feedback regarding what was good and what could be improved.

Appendix E Guideline field test 3, tooling phase

1. Day 1

Introduction (8:30 - 8:45, 15 min)

Presentation

Definition (8:45 – 9:05, 20 min)

- Discuss the goal with the Workflow analysis – write the goal on the whiteboard
- Discuss the purpose of the process – write the purpose on the whiteboard
- Discuss dependencies
- Define input(s) and output(s)

Remember to:

- Make sure that the team has a clear goal with the session and that all agree on it

Creation of current state map (9:05 – 10:00, 1h 40 min)

(Break 5-10 min, 09:30)

- Begin at the end of the process and make the participants explain and show (computers) to each other what they do, activity by activity
- Write the activities on yellow sticky notes so that all participants understand what they mean. Ask control questions to make sure that everybody has understood.
- When the current map is created, discuss it to ensure that nothing is forgotten and that the notes are on an appropriate level. If suitable, divide the map in bigger chunks and estimate lead time and effective time.

Remember to:

- Ask stupid questions
- Try to avoid discussion around subjects off topic
- Make sure that the participants understand the notes (but it does not matter exactly how they are written)
- Make sure that the participants do not discuss solutions during this stage. (Write them down and move on.)
- Ask: How can you make it easier for the person after you in the process?
- Who does what? Different roles?
- What resources are used?
- What documents are used?
- Are there any decision points?
- Hand-offs?
- Waiting?

Identify problem areas (10:00 - 11:30, 45 min)

- Discuss activity by activity
- Question the activities; what do they add?
- Use the 5 why
- Write the problems on red sticky notes and put them in the flow
- Finally, identify/discuss the main problem areas.

2. Day 2

Create future state map and countermeasures (08:30-09:30, 1h)

- Short reflection regarding yesterday
- Creation of a desired future state map
- Write down countermeasures to achieve the future state (on a new sticky note colour)

Identify further improvement possibilities (08:30-10:30, 1h)

Try to develop countermeasures for the problems on the current state map

Prioritizing of countermeasures (10:30-11:30, 1h)

- Discuss what the group wants to do with all ideas (use a pick chart for prioritizing the ideas)
- Book a follow-up meeting

3. Evaluation

The participants are asked to give feedback regarding what was good and what could be improved.

Appendix F Waste categories in product development

Ohno (1978)	Slack (1998)	Millard (2001)	Morgan (2002)	Bausch (2004)	McManus (2004)	Kato (2007)	Ward (2007)
Transportation	Transport	Transportation		Transport/handoffs	Transportation	Transportation	
Inventory	Inventory	Inventory		Inventory	Inventory		
Motion	Movement	Unnecessary movement		Movement	Unnecessary motion	Motion	
Waiting	Wait time	Waiting	Waiting	Waiting	Waiting	Waiting	Waiting
Over-processing	Over-processing	Processing		Over processing	Excessive processing	Over processing	
Overproduction	Overproduction	Overproduction		Overproduction/ unsynchronized processes	Overproduction	Overproduction	
Defects	Defects/scrap	Defective product		Defects	Defects		
	Complexity						
	Time lag						
			Hand-offs			Hand-off	
			External quality enforcement				
			Transaction				
			Re-invention	Re-invention		Re-invention	
			Lack of system discipline	Lack of system discipline			
			High process and arrival variation				
			System over utilization and expediting				
			Large batch sizes				
			Redundant tasks				
			Stop-and-go tasks				
			Unsynchronized concurrent tasks				
			Ineffective communication				
				Limited IT resources			
							Poor tools
							Barriers to communication
							Useless information
							Testing to specification
							Discarded knowledge
						Rework	
						Defective information	
						Inventory of information	

* Waste categories defined by different authors are compiled in the table. Similar categories are listed in the same row, but the exact notations differ.