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Application of Value Stream Mapping in Product Development

Master of Science Thesis in the Quality and Operations Management Programme

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Abstract

Value Stream Mapping (VSM) has successfully been used as a lean tool in manufacturing processes.

Applying this tool in other areas is an interesting issue for organizations and might involve particular considerations and adaptation.

The purpose of this study is to identify the considerations for adapting Value Stream Mapping in a product development environment and provide a “best practice” approach for VSM. The findings from a literature review and interviews were tested during a case study at Renault truck.

According to this study, identifying key specific objectives, choosing the suitable scope and project, and noticing the information and output uncertainties are the main subjects that should be considered during the application of VSM in the product development area. Based on the findings a step by step procedure is provided that helps organizations to apply VSM in Product development environment.

Key words: Lean principles, Lean product development, Waste, Value stream mapping (VSM), Value stream mapping in product development.

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I would like to take this opportunity to express my gratitude to my beloved ones. Special thanks to my family and friends for their continuous support in carrying out this thesis work.

Hariprasad Settyvari

Contents

1. Introduction

This thesis work is carried out at Volvo Group Trucks Operations with a case study at Renault Truck, as a curriculum of the Master of Science program at Chalmers University of Technology, Sweden.

This chapter briefly describes about the case company and the background to the problem that this project work addresses. This is followed by purpose and problem analysis illustration. The problem analysis resulted in two research questions which serve as a framework for this project work. Finally, this chapter includes delimitation of the study.

1.1 Company Profile

The Volvo Group is one of the world's largest suppliers of trucks, buses, construction equipment and drive systems for marine and industrial engines, and up until recently aerospace components. Volvo group can also offer various types of financing solutions, insurance, rental services, spare parts, preventive maintenance, service agreements, assistance services and IT services. Products, services and complete solutions are developed in close cooperation with customers in selected segments. The goal is not only to meet customer expectations today, but to contribute to improve customers' productivity and profitability. That is how Volvo Group creates value for customers, communities and society, and contributes to shaping the future of sustainable transports.

Brands include Volvo Trucks, Renault Trucks, UD Trucks, Mack Trucks, Eicher[1], Volvo Construction Equipment, Volvo Buses, Volvo Penta, SDLG[2], Prevost and Nova Bus. The Volvo Group, which employs about 115,000 people, has production facilities in 20 countries and sale of products in 190 markets. Most employees are located in Sweden, France, Japan, the US, China, Brazil, and South Korea.

The Volvo Group is organized into four large clusters. They are Group Trucks, Construction Equipment, Business Areas (Buses and Penta) and Volvo Financial Services.

[1]Through a joint venture company, the Volvo Group sells trucks and buses under the Eicher brand, primarily in India.

[2]Through a joint venture company, the Volvo Group sells construction equipment under Lingong's brand, SDLG, primarily in China.

A Group function provides services and/or products for the entire Volvo Group, on behalf of a corporate function or a Group process owner. Volvo Group encompasses more than twenty Group functions. Each group function is providing services/products for the entire Volvo group and also supporting activities at a lower cost with higher service levels. Each Group function can act as a center of expertise, thus providing a concentration of resources and competences. Making knowledge and support available in this way creates economies of skills and scale.

This thesis work is carried out in OD/VPS function. This group function is organized under Group Trucks Operations. The mission of this group function is to support the Volvo Group to meet business and customer needs through improved business performance by providing the knowledge, methods and tools for a total operational excellence solution, using the Operational Development (OD) and Volvo Production System (VPS).

A pilot case study was performed at Renault Trucks as a part of this thesis curriculum. Renault Trucks is, located in Lyon, France. Renault Trucks is a part of the Volvo Group since 2001. Renault Trucks has set up a local network in more than 100 countries to provide more appropriate transport solutions for their customer needs.

1.2 Problem Background

Today's competitive market forces organizations to be more efficient and effective, and this includes the Product Development. Many companies have turned to the lean philosophy as a potential solution to their needs. Lean principles and practices are established as a best practice in the manufacturing environment today. From the manufacturing environment, the lean movement has had difficulties to spread to other functions like product development.

A value stream includes all activities which are necessary to refine a product, whether they are value adding or not (Rother& Shook, 1998). Value Stream Mapping (VSM) has successfully been used as a lean tool in manufacturing processes. VSM assists companies to identify wasteful activities and processes and serves as an input for continuous improvement towards reducing lead time and cost. But is it applicable in a Product Development environment?

In a study from the NCMS project (Michael Kennedy: Knowledge Based Product Development Understanding the true Meaning of Lean in Product Development Presentation slides: January 27, 2010), many product developing companies were asked to rate themselves on a number of performances indicating productivity. Then, after a decade of implementing manufacturing lean

techniques that historically had yielded great results such as 5S, Value Stream Mapping (VSM), etc. no progress could be shown, and none of the companies ranked themselves even close to the performance of Toyota, which was considered as a benchmark.

1.3 Purpose

The purpose of this master thesis is to study the theory (literature) and success stories (industrial experience in a product development environment outside of Volvo) from different Value Stream Mapping practitioners in order to:

- Identify the considerations for adapting Value Stream Mapping in a PD environment (soft and hard)
- Provide a "best practice" approach for Value Stream Mapping in a Product Development environment including how to take care of the results. This should be in a step by step description including success factors for all steps.

1.4 Problem Analysis and Research Questions

Since the manufacturing environment is significantly different from the Product Development area, translating value stream mapping directly into a product development environment is not completely straightforward (Ingrid Fritzell and Gustav Göransson, 2012).Value Stream Mapping has been successfully applied in different manufacturing processes; but the nature of product development might force some limitations that companies need to consider when they try to use it in this area. The application of value stream mapping into a product development environment raised different opinions on its applicability (Ingrid Fritzell and Gustav Göransson, 2012) (Locher, 2008) (Morgan, 2002).Translating and adapting VSM in a product development environment might involve different aspects of processes and interrelationships.

Volvo is striving to reduce its Product Development lead-time, it will be a competitive factor in itself, but also in an effort to identify and eliminate waste in its current practices. Volvo has successful experiences of utilizing value stream mapping in a manufacturing context. VSM has also been applied in a Product development environment, but even though these initiatives are reported as being successful, these initiatives have been isolated and have seldom been repeated in the same environment. The descriptions of how VSM has been applied, internally and at other companies,

have been so different from the descriptions in the literature that representatives from a manufacturing environment have questioned if what was applied really can be defined as VSM.

We would like to consider following research question in this study to clarify some noticeable areas for adapting VSM:

1. ***What considerations have to be taken in order to adapt Value Stream Mapping to a product development environment?***
2. ***What are the main emphases in developing an instruction for applying Value Stream Mapping in a product development environment?***

1.5 Delimitations

This thesis will only consider product development and other processes such as production and sales will not be included. The proposed methodology is limited to the mapping and improvement of a single, definable product development process and it is applicable for all levels of the process from single process to entire product development process.

The proposed methodology of the VSM in Product development is based on Literature review, Expert interviews with Global and Local companies and one pilot case study. The pilot case study is limited to two stages of VSM (Preparation and Mapping the current state).

2. Methodology

This chapter presents the structure of the methodology that will be used throughout this thesis work. First, the research approach along with research design will be outlined to give a holistic view to the readers. Then we will give an overview about the methods chosen for data collection. Figure 1 shows the general outline of the methodology used in this thesis work. Finally this chapter is concluded with validity and reliability of the chosen methodology.

2.1. Research approach

2.1.1 Qualitative versus Quantitative analysis

Qualitative analysis and quantitative analysis are methodologies, which are using different types of data in the research. According to Bryman and Bell (2011):

Qualitative analysis

In this analysis theory elaboration and concepts are generated (emerged out) from data collection. In this process of data collection and analysis, qualitative methods use the Researcher as a data gathering instrument and data is in the form of words, pictures. Researcher genuinely understands the world through their eyes by maintaining close involvement with the people being investigated and this investigation of people happening in a natural setting. The qualitative research approach is unstructured and data is richer and less able to be generalized, the researcher seeks an understanding of behavior, values, beliefs, and so on in terms of the context in which the research is conducted.

Quantitative analysis

Quantitative analysis is used for testing the theory and concepts. The researcher uses tools, such as questionnaires or equipment to collect numerical data and to analyze the processes. The data are in the form of numbers and statistics. Quantitative researchers conduct research in an artificial setting and this research is concerned with people's behavior. In quantitative research, the researcher is uninvolved with their subjects.

2.1.2 Selection of Research Design

Selection of research approach is based on the nature of research. Methodology and design used for this specific study are based on Qualitative methods, which includes Literature review, Semi structured interviews, meetings and Case studies.

The project aims to investigate possibilities of adaptation of value stream mapping in a product development environment. Researchers believe that the qualitative study would be the best idea to explore the hidden aspects of identifying waste and understanding value in product development because value stream mapping in product development is a new phenomenon. Quantitative study is based on number and lacks the person's perception and the reason behind authors choosing qualitative study instead of quantitative study due to the fact that the VSM in Product development method has limited literature and less practitioners, so it would make a quantitative study difficult (Ingrid Fritzell and Gustav Göransson, 2012).

The actual study was begun by doing literature study, it gave an overview about Lean concepts, wastes in product development, differences between Manufacturing and Product development, value stream mapping for Manufacturing and value stream mapping for lean Product development. In the second step, findings from the literature study helped us to form a Questionnaire to conduct semi structured interviews with experts in Volvo, SAAB Aeronautics and RUAG Space with experience from VSM in PD Setting and we also interviewed one employee who has experience in VSM in Manufacturing. Literature review and semi structured interviews would help us in order to understand what is waste and what is Value and how the product development process works in Volvo.

The purpose and research questions of the thesis were initially proposed by supervisors in the company and the research questions are continuously refined to keep the project on track with the help of the literature study, data collection under the guidance of supervisors in Volvo Group and Chalmers. According to Yin (2003) case studies are useful in the following cases: (1) Focus of study is to answer how and why questions (2) When you can't manipulate those who are involved in the study (3) When you want to cover contextual conditions due to you believe they are relevant to your study (4) When the boundaries are not clear. According to his idea, the best way to answer our determined RQ's is by using qualitative case study. In our case we have done one pilot case study. By using this pilot study we test, develop and evaluate value stream mapping method in a product development environment.

After implementing the case study, we have sent some follow up questions to pilot case participants to collect their reflections about the VSM case workshop and VSM in PD setting.

In the analysis part we will try to analyze findings from literature study and empirical study. In the end we will have some discussions and draw the conclusions based on theory and empirical data.

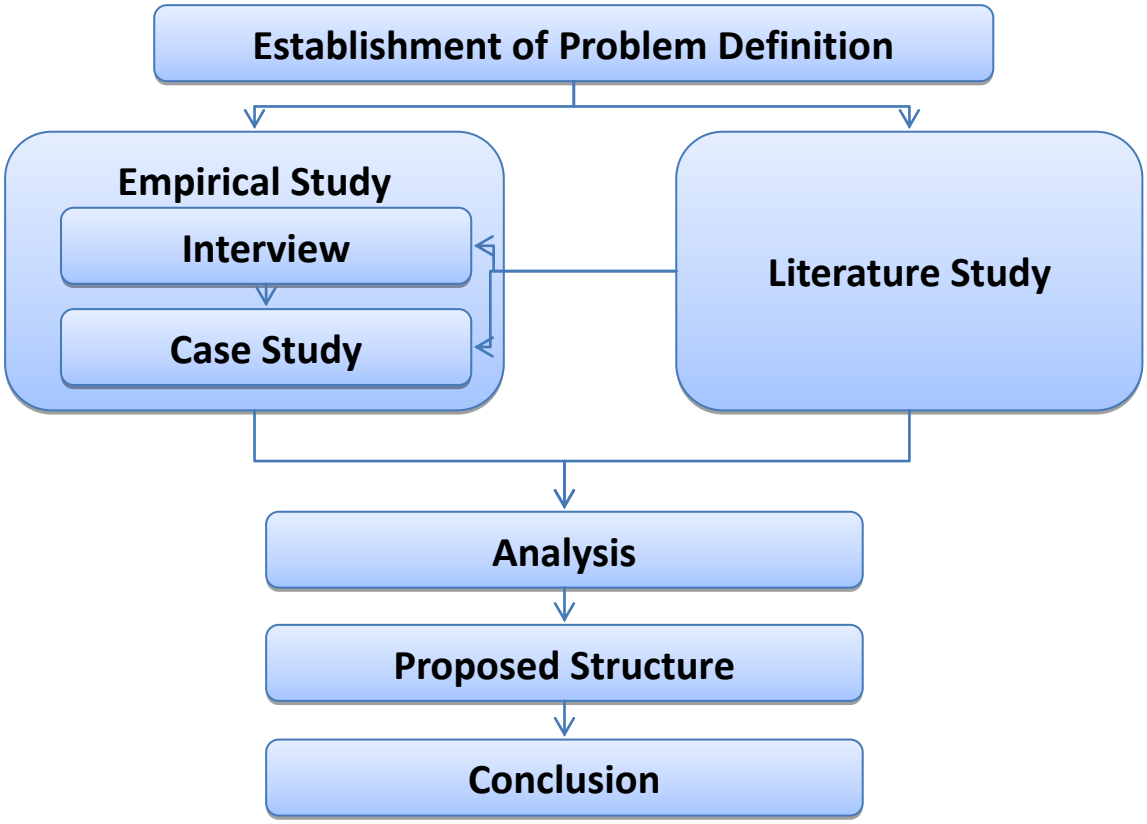

Figure 1: Methodology

2.2 Data collection

Overview of data collection methods:

2.2.1 Literature Study

The actual study was begun by doing literature study. According to Yin (2003), Theory development prior to the data collection is essential in case studies. Reviewing the existing literature is of great importance to gather the relevant information pertaining to any problem. According to Bryman and Bell (2011), purpose of reviewing existing literature is to know:

What is already known about this area?

What theories and concepts are relevant to this area?

What research methods and research strategies have been employed in studying this area?

The literature study also helped us to frame and refine the research questions in an iterative way.

In the literature study we used different sources to give the necessary background and understanding about the topic. Since Value stream mapping in Product development is kind of a new concept in product development setting, it was important to identify the right sources to utilize. To gather the relevant information regarding this project we used textbooks, electronic journal articles. The search phrase strategy was used in Chalmers Library database and Volvo data base.

Literature study will give an overview about Lean concepts, Lean product development, wastes in product development, differences between manufacturing and Product development, value stream mapping, and value stream mapping for lean product development.

This is not only a matter of reproducing theories and other scholars' opinions but being able to interpret what they have written for instance by using their ideas to support a particular viewpoint.

2.2.2 Semi Structured Interviews

Major data collection for implementation of the VSM in PD environment was done by face to face, live meetings and by telephone. In total, five interviews have been conducted. All interviews have been recorded with interviewees' permission and duration of each interview from 60 minutes 90 minutes.

Qualitative Semi-structured interview method was used for data collection. According to Bryman and Bell (2011), Qualitative Semi Structured interviews have flexibility in the pattern and structure. According to the loosely bounded structure of Semi structured interviews, our interview guide kept the interviews as open as possible and it gave the possibility to emphasize a specific subject during the discussion to get an in depth understanding. In this interview guide, the interviewer uses a list of questions on specific topics (See Appendix 1) and there is a possibility to change the order of questions according to the flow of the interview process.

In this thesis work, the researchers conducted five expert semi-structured interviews concerning applications of the VSM in Product development setting and Manufacturing setting. Thus four of five expert interviews were from PD, and one was from Manufacturing. Three of the expert interviews were conducted within the Volvo Group and the remaining two interviews were carried out outside Volvo, with SAAB Aeronautics and RUAG Space.

2.2.3 Case Study

According to Yin (2003) using Qualitative case study is the best way to answer Research questions. In our case we have chosen explanatory case study, this is because the explanatory case study may be useful when we are seeking to answer a question that is seeking to offer an explanation to the assumed casual links that require extensive real life intervention making it difficult for the survey or experimental strategies (Pamela Baxter and Susan Jack, 2008) (Yin, 2003). The case study was held in Renault Truck in France. Interviews results and literature review were the primary sources of data for planning of different stages of case study. In this pilot study we test, develop and evaluate our value stream mapping method in a product development environment. Two stages of VSM (Preparation and Mapping the current State) have completely done during this case study. We, as the facilitators and observers, accompanied team members (four managers) during the mapping workshop. Our observations during the mapping workshop and the results of applying VSM as well as results from interviews and literature review were the inputs for analyzing stage of this study.

2.3. Reliability and Validity

In order to judge the quality of the study the degree of validity and reliability has to be considered.

According to Thuren(2007) if several people study the same thing and comes up with the same result, the method has high reliability. Reliability is about repeatability of results from a study, meaning that the measures of the concepts should be consistent. Three prominent factors are involved when considering whether a measure is reliable; these factors are stability, internal reliability and Inter-observer consistency (Bryman and Bell, 2011). Stability concerns that the results relating to that measure for a sample of respondents do not fluctuate over time. Internal reliability exists when there is a mutual agreement between the researchers on what they see and hear resulting in higher consistency between themselves. Inter observer consistency is about when a great deal of subjective judgment is involved in such activities as the recording of observations or the translation of data into categories and where more than one observer is involved in such activities, so there is a possibility of lack of consistency in their decisions.

According to (Bryman & Bell, 2011), validity is produced from a piece of research provided the integrity of the conclusions are maintained. Validity means to study what actually is supposed to be studying. For instance can we draw the conclusions we want to draw from the data collected? Is what we really measure what the research concerns? According to (Bryman & Bell, 2011), Validity can be divided into measurement validity, internal validity, external validity, and ecological validity.

Measurement validity referred to as construct validity is concerned with the question of whether a measure used (developed from a theory) actual measures the concept of interest. Internal validity is about how far the findings of this research work are believable or trustworthy with regards to casuality. External validity is concerned with the extent to which results from a study can be validly generalized beyond its particular context. Ecological validity concerns that the extent to which research results can be applied to real life situations outside the research settings.

Reliability can be considered to be strong enough as the study was conducted in an environment where changes occur frequently due to highly diversified and competitive market. We can achieve same or similar results if this study is replicated in the same or different company with similar settings. For instance during the data collection process, we interviewed experts in the service and product development people and from different industries but we have not seen any difference in their high level procedure. The methodology (VSM procedure) used in this pilot project is developed by several methods. To ensure the reliability and validity of our findings, data have been collected by a literature review, Expert interviews from different organizations which are local and global organizations, pilot project and later confirmed by follow up questionnaire. Employing several methods or sources of data in a study is referred as triangulation (Bryman & Bell, 2011). According to Webb et al. (1966) (Bryman & Bell, 2011), if several methods are employed in the development of measures, this result will increase greater confidence in the findings.

3. Theoretical framework

The theoretical framework presents all the concepts and theories needed in order to answer the research questions of this master thesis. Studying the Value Stream Mapping needs information about Lean Principles. According to Slack (1998) once the value stream is mapped , regardless to it in manufacturing or product development areas, Lean Principles are applied to eliminate the waste. Therefore this chapter starts off with Lean concept and its principles and continues with the explanation of this concept in manufacturing and Product development where the different kinds of waste are presented in both contexts. Afterwards the concept of Value Stream Mapping is explained in order to give the reader some knowledge about this method in manufacturing and product development areas. Furthermore the differentiation between manufacturing and product development environment is introduced to give a deeper understanding to the reader about conditions of each area.

3.1 Lean

The concept of "lean Production" originally comes from the Toyota Production System (TPS) which is now known as a synonym for Lean Production. The expression of "lean" was coined by Womack et al (1990) when they did a study to compare the performance differences between car companies operating with traditional mass manufacturing systems and companies using TPS. (Womack et al 1990, 1996)

"Lean is a production philosophy that focuses on the streamlining of value added activities and eliminating waste within the process with the goal to better meet customer demand."

Lean helps companies to provide exactly what the customers want and it is a way of doing more with less use of resources, like human efforts, equipment, time and space. (Womack and Jones, 1996)

Womack and Jones (1996) formulated five key lean principles that are expected to be addressed in order: Specify Value, Identify the Value Stream, Flow, Pull and Perfection.

3.1.1 Value

Womack and Jones (1996) introduced a definition of value:

"A capability provided to a customer at the right time at an appropriate price, as defined in each case by the customer"

According to this definition, Value is described by three main attributes: Quality, Cost of Ownership and time. Slack (1998) argued that in Womack's approach value is measured against an ideal, a condition without waste, while the customers are sensitive to their need in the context of the entire market and they compare products to each other.

Slack (1998) investigated about two other Value perspectives that assist in relating Lean Principles. He thinks it is necessary to understand Stakeholders and Employee Value and their attributes in addition to customer Value.

For defining the right value of the products or services it is necessary to identify real needs, wants as well as wishes of customers. Identifying real customers is not always as easy as it seems. It is a challenge for companies to find their customers and their needs, either external customers who explicitly pay for a product or service or internal customers who receive outputs of a task or activity.

It is hard to currently define value because most producers want to make what they are already making. They often fall back on simple formulas like lower cost instead of challenging old definitions and seeing real needs. Moreover value is often created by the combined effort of different companies and each company tends to define the value of their own, and not the final customer's perspective. In most cases companies do not consider other related value and this causes them to start improving the processes with the wrong priority. (Womack and Jones,1996)

3.1.2 Value stream

The Value stream is all the activities required to provide a specific product, service or both through the "problem-solving" task (from concept to production launch); "information management" task (from order-taking to delivery); and "physical transportation" task (from raw material to a finished product) of any business. (Womack and Jones,1996)

According to Womack and Jones's (1996) study, three types of activities could occur during the value stream: (1) Value Added (2) Non Value Added (3) Necessary Non Value Added. Slack (1998) later added a fourth type of activities which not only do not create any value to the customer, but they reduce customer value. This can happen in the process where the customer value is not correctly understood and the efforts for adding value will actually have the opposite effect.

One of the best ways to visualize and analyze the value stream of a process is to create a value stream map (VSM). We will discuss about VSM in section 3.6.

3.1.3 Flow

The next principle in lean thinking, after specifying the value and identifying the value stream, is making value flow. Flow is defined “As the lining up of all necessary sequences of activities required to achieve a steady continuous job flow, without interruption, wasted steps, batches or queues” (Slack 1998).There are three techniques that make the flow more smoothly: (1) focusing on actual objects and values associated them, (2) ignoring the traditional boundaries of jobs, careers, functions and firms and (3) rethinking specific practices to eliminate backflows, scrap, and stoppages of any sort (Womack and Jones, 1996).

3.1.4 Pull

The fourth principle in lean concept is Pull. This principle applies in the whole value stream and thus means that upstream should not produce a good or service until the immediate customer downstream request it. This principle creates the ability to design, schedule and produce exactly what and when the customer wants while inventories are reduced. (Womack and Jones, 1996) Kanban and Just-In-Time are two related tools used to control resupply and to optimize inventories.

3.1.5 Perfection

The fifth and final principle of lean concept is perfection. Perfection plays an important role in getting value, so strive for perfection by continuously removing wastes because when the first four lean principles are fulfilled things will start to happen and these principles interact with each other in a vicious circle. The faster flow exposes hidden waste in the value stream, the harder you pull, and the more the disruptions and bottlenecks in the flow can be revealed and removed (Womack and Jones, 1996). To pursue perfection, every organization needs to have both continuous radical and incremental improvements.

3.2 Waste

Lean concept focuses on value delivered to the stakeholders. Five Lean principles facilitate increasing the value while simultaneously reducing waste. Waste means any activity, which absorbs resources but creates no value. The Toyota Production System defined three types of waste, they are Muda ("non-value-adding work"), Muri ("overburden"), and Mura ("unevenness"). Usually all these wastes cannot be seen separately, they are interconnected. For instance when a process is not balanced, this leads to an overburden on equipment, facilities and people which causes of all kinds of non-value adding activities.

3.2.1 Muda

Muda means any activity that does not add value to the product or service. It increases the time spent on product or service but does not create value for the customer. The following wastes are examples of Muda. The first seven wastes are defined by The Toyota Production System and accepted as main waste in a manufacturing environment: Later an eighth waste "unused human talent" was defined by Womack and Jones (2003). Many others have added "the unused human talent`` to the original seven wastes, making them "the seven plus one wastes".

1. Overproduction;
2. Waiting;
3. Transport;
4. Inappropriate processing;
5. Unnecessary inventory;
6. Unnecessary motion;
7. Defects;
8. Unused human creativity

3.2.2 Muri

The second type of waste is Muri. Muri means overburden of equipment, facilities and people beyond its natural limits.

According to Liker (2004), "Muri is pushing a machine or person beyond natural limits. Overburdening people result in safety and quality problems. Overburdening equipment causes breakdowns and defects".

3.2.3 Mura

The third type of waste is called Mura. Mura exists when the work flow is out of balance and work load is inconsistent. Muda and Muri will be a result of Mura. (Liker, 2004)

In the Lean journey, companies should avoid all of them because one of them may lead to another.

3.3 Lean product development

In last decades New product development (NPD) has become a critical process in terms of quality, cost and time. Enterprises must design and produce the right products in an efficient way.

Enterprises must create and deliver the products that meet the needs of all stakeholders. Companies try to find principles and tools to increase NPD efficiency. Lean Product Development (LPD) as a domain approach addresses these challenges. It is a general idea of Lean Thinking in the field of product development and tries to achieve a value-oriented, resource-efficient, and fast product innovation process. (Hoppmann et al, 2011)

According to different studies from different authors, it seems there is an agreement that lean manufacturing principles must be translated to the Product Development environment. However, the dominant re-defined lean principles in product development have not yet been reached.

Liker and Morgan had an in-depth study of Toyota's approach to process and product development and they identified 13 management principles considered the basis of the Lean product development. These principles are defined in three frameworks: process, people, and tools and technology (See table 1). (Liker& Morgan, 2006)

Table 1: 13 Management Principles (Liker & Morgan, 2006)

Framework	Principle
Process	1. Establish customer-defined value to separate value added from waste.
	2. Front load the product development process to thoroughly explore alternative solutions while there is Maximum Design Space.
	3. Create a leveled Product Development Process Flow.
	4. Utilize Rigorous Standardization to Reduce Variation, and Create Flexibility and Predictable Outcomes.
People	5. Develop a "Chief Engineer System" to Integrate Development from start to finish.
	6. Organize to balance Functional Expertise and Cross-functional Integration.
	7. Develop Towering Technical Competence in all Engineers.
	8. Fully Integrate Suppliers into the Product Development System.
	9. Build in Learning and Continuous Improvement.
	10. Build a Culture to Support Excellence and Relentless Improvement.
Tools and Technology	11. Adapt Technology to Fit your People and Process.
	12. Align your Organization through Simple, Visual Communication.
	13. Use Powerful Tools for Standardization and Organizational Learning.

Ward believes there are five pillars for lean product development:

(1) Value focus; (2) entrepreneur system designers (ESDs); (3) set-based concurrent engineering (SBCE); (4) cadence, flow, and pull; and (5) teams of responsible experts.

Cusumano and Nobeoka (1998) identified nine lean principles for New Product Development: Heavy weight project managers; Overlapping phases; Cross-functional teams; High-level of supplier engineering; Rapid model replacement; Design team and project manager continuity; Good communication mechanisms; Frequent model-line expansion; and Model incremental product improvements.

According to Locher (2008) lean development system based on four principles:

1. Distinguishing between knowledge reuse and knowledge creation
2. Performing development activities concurrently
3. Distinguishing between good and bad iterations
4. Maintaining a process focus throughout

While some authors introduced some new principles for Lean Product Development, another group of authors like Haque and Moore or Slack tried to adapt five traditional lean principles to the Product Development environment. Slack (1998) was the first to discuss how the Womack and Jones's Lean principles could all be applied to the PD process. He explained that the value, value stream, and flow principles needed to be changed to be applicable to PD. He questioned the application of the pull principle to PD, but supported the generality of the perfection principle.

3.3.1 Value in product development

Industry members want to identify and measure how effective and efficient they are creating value in product development in an objective way to be able to compare them with leading companies to determine where the greatest potential for improvement lies. (Chase, 2001)

There are several alternative definitions for value in product development. Some of these definitions proposed by academics and industry experts are listed in table 2.

Table 2: Value definitions for product development (Chase, 2001)

Source	Value Definition
Miles, 1961	Value is the appropriate performance and cost.
Kaufman, 1985	Value is function divided by cost.
Shillito&DeMarle, 1992	Value is the potential energy function representing the desire between people and products.
Womack & Jones, 1996	Value is a capability provided to a customer at the right time at an appropriate price, as defined in each case by the customer.
Slack, 1998	Value is a measurement of the worth of a specific product or service by a customer and is a function of: (1) Product's usefulness in satisfying customer needs (2) The relative importance of the need being satisfied (3) Availability of the product relative to when it is needed (4) Cost of ownership to the customer
LAI, 1998	Value is anything that directly contributes to the "form, fit, or function" of the build-to package or the buy-to Package · Form: Information must be in concrete format, explicitly stored · Fit: Information must be (seamlessly) useful to downstream processes · Function: Information must satisfy end-user and downstream process needs with an Acceptable probability of working (risk)
Browning, 1998	[Value is] balancing performance, cost, and schedule appropriately through planning and control.
Deyst, 2001	Value is the amount by which risk is reduced per resource expended.
Stanke, 2001	[Value is] a system introduced at the right time and right price which delivers best value in mission effectiveness, performance, affordability and sustainability and retains these advantages throughout its life.

3.3.2 Value stream in product development

According to Slack (1998) Value Stream in product development is "*the uninterrupted succession of product development activities along which there is continuous addition of product attributes including quality, functionality and usefulness, which directly address customer needs*." Value Stream activities in product development like all process in an enterprise put the intended customer value into the product.

Kennedy, Harmon and Minnoch (2008) introduced knowledge value stream in addition to product value stream in the product development process. They emphasized creating, capturing and reusing knowledge during different product development project. The captured knowledge from all previous projects is used as a foundation for having a faster and higher quality product development. The relationship between knowledge value stream and product value stream is shown in figure 2.

Figure 2: The knowledge value stream and product value stream (Kennedy, Harmon and Minnoch, 2008)

3.3.3 Flow in product development

The concept of continuous flow may be applied in all phases of the product Lifecycle, but the Flow in Product Development is more complicated to analyze than it is within manufacturing. In the manufacturing environment flow is related to physical material flow, while in Product development in addition to material flow, the most part involves information flows. Slack (1998) divided the information on product development into four categories: Product Information, project Information, Process Information, and Business Information. Product Information is related to information for transforming customer needs to parts requirements and transforming parts requirement to design parameters. Project Information refers to project management information like resource planning, cost management, schedule management. Process information defines how product development processes are implemented. And finally Business Information is related to the business processes of marketing, sales and finance. (Slack, 1998)

The scope of most studies has been often a single project, while in reality organizations have to manage several projects at the same time. These projects affect each other, some of them depend on others and they compete for resources. Multi-project management creates extra challenges and potential for waste. Moreover there are some tasks that are not related to any specific projects. These tasks also can affect any value stream and the VSM team should consider them.

3.3.4 Pull in product development

The Lean Pull Principle is the critical guard against the waste of unneeded work and associated rework.

Manufacturing processes are generally sequential in nature, they are repetitive. In contrast, Product Development processes are highly iterative with loops to earlier steps and they are not repetitive in

the sense that they are in manufacturing, i.e. both input and process do not vary. There can be both sequential and parallel processes.

In manufacturing, each workstation uses Kanban[3]to signal to the supplying station for the next part or work-in-progress. But in Product Development, tasks are fulfilled and passed to the next process as soon as finished. The pace of product development process is typically controlled through the use of schedules (project plans). Scheduling process used in product development is like push processes for scheduling in manufacturing and it is not pull. (Slack, 1998), (Oppenheim, 2004)

3.3.5 Perfection in product development

The other four principles provide guidance on understanding the current state of the Value stream and help to having the perfect future state. "Perfection is the implementation of the required activities to bring the future state to good results. There is nothing unique about product development process improvement which would indicate that the same policy development techniques which have successfully been demonstrated in manufacturing setting could be used in product development lean transition." Slack (1998) appropriately mentioned that this principle can be generalized to any area.

3.4 Waste in product development

Various studies have been done to find and categorize waste in product development. In most cases it has been trying to adapt the seven wastes in manufacturing into product development environment. Oehmen and Rebentisch (2010) investigated most of these studies and concluded them into eight wastes in product development:

Overproduction of information, Over processing of information, Miscommunication of information, Stockpiling of information, Generating defective information, Correcting information, Waiting of people, and Unnecessary movement of people.

Bauch (2004) in a study found six different factors relating to the question what could be wasted: Resource, Time, Information/knowledge, Opportunity/potential, Money/investment, and Motivation. He used root-cause analysis to cluster waste in product development. He reinterpreted identified wastes and introduced 10 categories and 37 sub-categories.

[3]Kanban is scheduling system for lean and it works with a visual signal used to trigger an action.

Ward believes that the most important wastes in Product Development are “knowledge wastes.” He divided knowledge waste in 3 different categories and 6 sub-categories. See Table3

Table3: Knowledge Waste

Scatter	Communication barriers Poor tools
Hand-off	Useless information Waiting
Wishful thinking	Testing to specifications Discarded knowledge

Haque has a hierarchical approach to waste in Product Development. He believes hierarchy approach will enable to eliminate waste in a better way. Waste in a product development environment will happen in three different levels: Strategy level, Organizational level, and Operational level.

Mascitelli (2007) found Top-Ten sources of PD wastes to be:: Chaotic work environment; lack of available resources; lack of clear prioritization of projects/tasks; poor communication across functional barriers; poorly defined product requirements; disruptive changes to product requirements; lack of early consideration of manufacturability; over designing; too many meetings; and E-mail overload.

3.5 Difference between manufacturing and product development

Before applying lean concepts in product development, it is necessary to know the differences between manufacturing and product development.

McManus (2005) considered three main differences of Engineering processes and manufacturing process. (1) Uncertainty: in product development the exact content of the output is not known while manufacturing process makes a part exactly the same as the last one. (2) The outputs of manufacturing are physical material while ultimate outputs in Product Development are information and specification of a product. (3) Processes in PD are more complicated than manufacturing processes.

He also compared five traditional lean principles in manufacturing and product development context. The (Table 4) shows this comparison.

Table 4: Traditional lean principles in manufacturing and product development (McManus, 2005)

	Manufacturing	Engineering
Value	Visible at each step, defined goal	Harder to see, emergent goals
Value stream	Parts and material	Information and knowledge
Flow	Iterations are waste	Planned iterations must be efficient
Pull	Driven by Takt time	Driven by needs of the enterprise
Perfection	Process repeatable without errors	The process enables enterprise improvement

Morgan (2002) introduced five major differences (Table 5) between PD and manufacturing that can have an effect when applying Lean to PD environment:

1. PD deals with the flow of information, not physical things
2. PD time measures are much longer and often vague
3. PD works in intangible situation, and it is less predictable.
4. PD information flows are often non-linear and multi-directional, with iterations, and then it needs more communication
5. PD needs more people, with a more various kind of knowledge and skills

Table 5: Morgan (2002) Difference between Product Development Process and Traditional Manufacturing Process.

Product Development Process	Traditional Manufacturing Process
Virtual Data Flow	Physical Product Flow
Weeks and Months	Seconds and Minutes
Primarily knowledge Work	Physical Manufacturing
Non-linear and multi-directional flows	Linear Evolution
Large, very Diverse group of technical specialists	Primarily Manufacturing Organization

3.6 Value stream mapping

According to Shook & Rother (1998) "a Value Stream is all actions (both value and non-value added) currently required to bring a product from raw material to the arms of the customer or through the design flow from concept launch". Value Stream Mapping (VSM) is a technique for depicting these activities and the related flow of information and product.

Jones and Womack (2002) introduce a perfect definition of Value stream mapping; *"Value Stream Mapping is the simple process of directly observing the flows of information and materials as they*

now occur, summarizing them visually, and then envisioning a future state with much better performance."

Value stream mapping is a means for showing the value stream with symbols and numbers and it helps to understand the entirety of the transformation in a company.

Learning to See, is the first publication in the field of Value Stream Mapping written by Rother and Shook (1998). This book provides a step-by-step guideline for applying VSM in manufacturing environment. They proposed four steps for VSM:

1. Getting started
2. Current-state map
3. Future state map
4. Achieving the future state

This proposed way focuses on value stream of individual product families within plants. This approach focuses on wastes within the walls of each facility, but it seems there are more wastes between facilities and plants. Jones and Womack (2002) noticed this point and introduced the Extended Value Stream Mapping. They followed the same structure as Rother and Shook had done, but they expanded the scope of VSM from a single plant to multiple plants and across companies.

Value Stream Mapping applies Lean Principles to eliminate Waste (Slack, 1998). VSM focuses on Value of products and services to eliminate all activities that do not contribute to product/service creation. VSM is one of the best ways to visualize and analyze the value stream of a process. VSM is a technique for visualizing the value stream to show the flow of information and materials between activities and it is used to make the steps in the product creation process *flow more* smoothly. This method is used to improve pull/Push flow between process steps. VSM is static dynamic methodology to eliminate waste in the pursuit of perfection, i.e. it usually has to be reapplied to the same process.

Shook and Rother (1998) believes VSM is a powerful tool because:

- It helps to visualize more than a single process
- It helps to see waste and the source of waste
- It serves as a common language for all participants
- It forms the basis of an implementation plan
- It makes a decision about the flow apparent
- It ties together a lean concept and techniques
- It shows the linkage between information flow and material flow

3.7 Value stream mapping in product development

VSM is a powerful tool for optimizing the product development process (Morgan, 2002). VSM helps to visualize the entire system and complex system interaction as the product development is. In fact, complexity can be as one of important barrier to improving product development process. VSM is an invaluable tool for simplifying this complexity. This ability strengthens understanding of the total process and even enhances the performance of all other optimization tools and identifies critical system leverage points where other improvement tools will be most effective. In total perspective, VSM is useful in synchronizing concurrent, cross-functional activities as well as hidden interdependencies.

Before applying VSM in product development it is important to address some fundamental challenges in mapping the product development process. Despite several research studies focused on translating lean principles and wastes to Product Development, there are relatively few efforts focused on adapting and applying Value Stream Mapping in PD context.

McManus (2005) provided a practical guidance for applying Value Stream Mapping in Product Development Process. This manual focuses on mapping value stream for a single PD process. McManus tried to adapt VSM to PD environment by translating the waste and lean concepts in PD context. PDVSM uses lean concept to eliminate waste, improve cycle time, and quality in Product development Process. He proposed 6 steps for applying VSM in a product development environment:

1. Getting started
2. Mapping the current state Value Stream
3. Identifying Waste
4. Improving the process
5. Beyond the future process
6. Striving for perfection

Locher (2008) later introduced an adapted VSM in a product development environment. This kind of VSM follows the same structure as what Rother and Shook introduced. Eliminating the translated seven wastes in Product Development is the aim of this approach which relies on four specific principles: Distinguishing between knowledge reuse and knowledge creation; performing development activities concurrently; distinguishing between good and bad iterations; maintaining a process focus throughout.

The manufacturing model of VSM provides a reasonable basis for VSM in product development. Depicting of what is flowing is tailored for product development by VSM. There are two kinds of flow in a manufacturing environment; information and material flows. In product development at the same as manufacturing there are physical material flow like physical mock-up and prototype. The product development information flow can be subdivided into two categories: product information flow and program information flow. Product information flow relates to the value stream which defines and develops a specific product. This flow corresponds to manufacturing material flow. The program information flow is related to information used to control and manage the process like scheduling and reporting. The program information flow corresponds to information flow in manufacturing area. (Slack, 1998)

Morgan (2002) introduces four levels of focus that VSM can be used at: Single Process, Single Function, Multiple Functions, and Entire Product Development Value Stream. He believes mapping at each of these levels can be valuable.

Morgan (2002) believes that the VSM tool is needed in the complex world of product development even more than it has been in manufacturing. There are some problematic issues that can be improved through the application of the Value Stream Mapping tool:

- Task in long queues and data-in-process inventories are pervasive in PD process.
- Non-value added activities are rampant in PD process. The longer time frames and highly complex nature of the PD process tends to obscure these activities.
- Product evolution from one state to another over time. The PD process does progress from concept to customer.
- Capacity and scheduling related issues.
- Hand offs from one functional activity to another.
- There is a work methodology, which must be analyzed and continuously improved.
- A challenging time constraints.
- Tasks must be synchronized.
- Constraints must be identified and managed.
- Creating flow.

Once the wastes have been eliminated and cross-functional tasks have been synchronized, the overall process flow must be made.

4. Interview Results

This chapter presents the findings from interviews with some people who had experience in Value Stream mapping. The study consists of five interviews with people from different companies in Sweden and Brazil. They were from SAAB, Ruag, and Volvo group. Each interview was separately conducted with one interviewee at the time and was held in different ways. In some cases it was conducted face to face and in some cases interviews were conducted by phone and video call. All interviewees work with process improvement and have practical experience of value stream mapping, all but one in a product development context. Based on the literatures, some basic questions were prepared for these semi-structured interviews. These questions are available in appendix1. In order to better understand and identify the interviewees' opinions, the results of the interviews were clustered into thirteen different elements. These elements will cover two main areas that we aimed to figure out during the interviews:

1. Considerations of applying VSM in PD environment
2. Instructions of applying VSM in PD environment

The following subjects are common issues that different interviewees explained to clarify what should be considered and executed during the applying VSM in Product Development environment.

4.1.1 The reasons behind applying VSM in product development

Increasing communications and understanding of processes and activities across departments is an obvious advantage of VSM. Most of the interviewees mentioned that VSM not only makes a common view on problems through different departments, but also causes different departments understand each other and each needs better. This is very valuable for people and can help them in their own activities. For example next time the problem happens; they will understand better why they are late or why they have interruptions.

4.1.2 Identifying purpose

It is important to have a purpose before applying VSM. Most interviewees emphasized the importance of having a purpose or a particular problem that you want to solve by VSM. Taking too long, having high cost, and getting the wrong output are examples of problems and VSM purposes. One of the interviewees even mentioned they applied a VSM to depict the flow of their process. Because of having a complicated process, they decided to use VSM to clarify flow to know what

happens in the process. In one case one company applied VSM for improving its process in general. Although they did not have a significant problem, they tried to improve their process by using VSM.

4.1.3 Choosing process and scope

According to the interviews, most participants have a common idea about avoiding to choose a scope that is not suitable in size. Choosing the correct scope is crucial for being successful. ' In the beginning maybe you cannot select the suitable scope. Then you need to be aware of this issue.' One interviewee said and added that compared to manufacturing, processes in product development are more complicated, and choosing a large scope can be time consuming and lead to few if any results. Large processes can be broken into smaller processes. This really has helped them to address the scope issue quickly. In one case they divided the process according to the gates.

One interviewee said: 'Before you do VSM it is important to think that you have lots of different products in the same flow to handle in the same way. If the difference is too much, don't do everything at one time. Don't try to solve everything at one time. If you have different products in the flow process, you might use 1 or 2 products quite similar and choose representatives from different parts. It is important to look at the connection to each other and you really have to understand the variations to secure things between the departments'. This can be particularly true if, as in this case, the objectives of the process are the same, but the products have different customers, with different demands on how the work is performed.

4.1.4 Managing different VSMs

Employees as resource sometimes need to handle different activities or do the same activity for different products or projects. In this case, prioritization of activities will be an important issue. For coping with this problem some interviewees estimate the amount of capacity needed for each activity during the mapping Value Stream. This helps managers to allocate their resources in a better way when they need to fulfill different projects simultaneously.

One interviewee mentioned that they did not notice this issue in VSM, but all departments in their organization have their own discussion about prioritization of activities every morning and if there is problem manager can adapt it.

4.1.5 Fluctuation of demand

Fluctuation in demand is one of considerable points for some interviewees. They mentioned it is important to notice demand during applying VSM. In some cases demand is not stable and it may be different in different situation. Knowing when the demand will reach to the top and when it will decrease to the low can help the team to have better solutions. As an example one of the interviewees mentioned they have low demand during Christmas and Easter.

Opposite of this idea one of the interviewees mentioned their process is not sensitive to fluctuation of demand. Although they have very different demand, because of having enough resources we will not face this problem.

4.1.6 Team members

According to the interviews, depending on the situation the number of team members can be different, but it should not include more than 10 members. Since VSM most commonly applied in processes that involve several functions/ departments in the product development processes, the VSM team should be a cross-functional team with representatives of all involved parties (see 4.3). One of interviewee said “we decided to invite all managers of each function involved, and one key player for each function to support his or her manager”. Another interviewee stated we use almost only engineers who were involved in the particular case. We do not have manager in the mapping meeting’. This is because he believes managers have a tendency to describe the process as it is documented instead of how the work actually is done.

Moreover, there was overall agreement that the VSM team needs a facilitator. According to the interviews the facilitator presents the concept and purpose of the tool/workshop and creates an awareness and a holistic view in the team about what is happening upstream and downstream in the process and motivate them towards the goal. One interviewee said: ‘I as a facilitator always try to ask: what do you do to make it simple for the next person in the process? Most people do not think about this and I try to ask this question over and over again’. Another interviewee mentioned: ‘The Facilitator was the key factor in our successful’. He added they did not have any experience in VSM and the facilitator supported them a lot. The facilitators on the other hand usually have no experience in the process where VSM is applied. The workshop is therefore also a learning opportunity for the facilitator to learn more about the company.

Interviewees also emphasized on the importance of having an owner of the VSM results before the workshop. One interviewee mentioned they had a lot of ideas for improving but because of not having an owner of the results, i.e. a process responsible, they had just prepared a list and there was not any execution. Another interviewee also mentioned: 'In many cases the owner of the VSM results is the same person who asks for the VSM, often a manager Also, some interviewees stated that the ''VSM team should also be the resources for solving the identified problems''.

4.1.7 Training team members

Having a short introduction of the methodology is important to prepare the team to start thinking about the wastes and the problem. 'There is always an introduction about VSM for team members who may know nothing about VSM. First we as facilitators talk about what is the concept and purpose of VSM. We talk about the three different concepts of time (value adding, Non value adding and Necessary Non value adding time). Then we have a picture with different kind of production waste (7+1 waste). This is just trying to open their eyes and reflect on the things they do routinely. Then we try interpreting these wastes into product development. Finally we have some advice like having an open mind for the meeting' one interviewee explained about their training activity during the workshop. According to the interview commitment and engagement of the involved people had an important role in being successful in some cases.

4.1.8 Workshop duration

The interviewees had completely different concepts about the duration of the workshop. The duration of workshop ranged from 3 hours to two and half days. They think it depends on the scope of the project. Some of them prefer to have the workshop split in different days while some of them had workshops that were concluded in one day. One of interviewee said: 'Our workshop took two and half days. One day for current state, one day for identifying waste and describe the future state, and half a day to discuss about the implementation and prioritize ideas. It may not enough but it is hard to get people out of their daily works'. One way of solving this, is to secure the whole team to define the current and future state, but have a smaller group meet later for a prioritization and solution workshop.

4.1.9 Drawing the current state map

According to the interviews, in most cases they used visual material like A0 paper, sticky notes for depicting the flow of the process. 'It was very dynamic and everyone could put up notes or change something. Then we have a lot of discussions'.

Against the usual approach in VSM, some interviewees mentioned that they started from the beginning of the process to the end for depicting current state. They believed that this way is better for following the process.

In some cases they use a swim lane chart for depicting value stream maps. They believe it is useful for showing different departments that are involved in the flow.

One of interviewee mentioned that in most cases there is not an agreement about what they do during their product development processes. It was common to have loopback during the decision activities. Therefore reaching an agreement on the activities took a lot of time in some cases.

4.1.10 Collecting data

All interviewees believe data collection is one of the biggest challenges of the VSM in Product development environment. They think finding related data in the product development area is more difficult than what we can do with manufacturing. In manufacturing there usually is a system for gathering data and even in some cases every machine and conveyer are connected to an online system and you can pick the data online. In product development it needs to estimate data by some imperfect methods like interviews. On the other hand gathering data in product development takes a long time. Moreover the accuracy of data depends on team members (as source of data) and the way of data collection. Then if there is no suitable data it is very important to have the right people and right method for collecting data. On the other hand one interviewee mentioned not to discuss a lot about minutes and seconds because it is difficult to find accurate time.

Another pitfall in data collection is also typically when there is variation in the process. This is a common problem in manufacturing and product development areas, but some interviewees believe process variation in manufacturing is less than what is in product development. For coping with this obstacle some interviewees use average of different data and some of them use the largest ones or most common ones. As an example in one case they ask different people about the duration of a process and then calculate the average of data and put it as a process time. In another case they write all the possible data in a matrix below each process to help team member to have a better analysis.

According to one interviewee variation of data can also be because of having different products in a family. Since we try to apply a VSM for a family of products then variation will be inevitable. This is a

noticeable point when we want to choose a family of products. It was suggested if there are different products in the flow, it is better to be used one or two products quite similar.

Another approach was to apply the entire VSM on an actual completed project. In this case, usually the time to complete each process step can be defined by e.g. the date a report was issued.

4.1.11 Analyzing current state and finding waste

'In this session we can get into finding the problem mode, which starts with a silent brainstorm session. Participants will write down all the interruptions and problems that they experience in the flow either caused by themselves but most often caused by others' one interviewee explained about this part of the process and he also believes it is important to give time to all members to discuss about their own problems before having conclusion and focusing on some identified waste.
If someone in the team is struggling to express their problems then an initial formulation is stated on a sticky note on the wall, and other team members can help further develop the formulation
According to one interviewee, it is important to understand what is in the notes so they ask members to write full sentences.
Brainstorming was a popular way for gathering information in most cases. Most of the interviewees have used Brainstorming method during different phases of VSM such as defining process, waste, and countermeasures.

4.1.12 Prioritization

Despite of using different ways of prioritization, all interviewees are unanimous on the importance of prioritizing the waste and solutions.
Different companies use different factors for prioritization. In one case they use four factors; Complexity, cost, impact on information alignment, and impact on admin hours. In another case they use just cost and benefit as two prioritizing factors. In a third case, potential Value for the company and estimated amount of hours are two main prioritizing factors that are used to get rid out problems.
Beside the different factors, there are different ways of prioritizing. In some cases they use numbers, for example 1 to 5, for creating and executing an action plan list; in other cases they use a Pick Chart.

4.1.13 Quality in VSM

According to the interviews there are two aspects of quality of product development. First, some quality issues that are related to quality of products like a flawed design, and that impacts production and customers. Second, issues related to the product development processes and should be detected at the gates. VSM focuses on the second quality issues (PD efficiency) and the first issues (PD effectiveness) should be addressed by other tools.

4.2 Comparison of the Value stream mapping method in different organizations

Since there is not a standard approach for applying VSM in product development, comparison of methods that different organizations used can help us to figure out common and different areas. This comparison helps us in creating purposed structure for applying VSM in product development.

According to the interviews On the major steps, have not seen much difference in Value stream mapping procedure but on the minor steps, have similarities and differences between the value stream mapping method (applications) as applied in SAAB, RUAG and Volvo Group.

On the major steps, the VSM procedure includes the following steps.

1. Getting started
2. Current-state map
3. Analyzing the current state map/Identifying waste
4. Achieving the future state

The main results from the VSM interviews are compiled in the following table 6:

Table 6: Comparison of the Value stream mapping method in different organizations.

Subject	Company 1	Company 2	Company 3
Why did you choose VSM as a tool?	To get a common view on problems, and also it causes different departments to understand each other and each needs better	people in different departments can understand other departments' activities and documents and may help them in their own activity	Increasing communication, Common view on problem, understanding other processes and activities may be useful the next time the problem occurs
Choosing Process and scope	Avoid to choose wide scope and too complex processes, these processes can be broken in some smaller processes	Avoid to choose wide scope and too complex processes, always focus on the flow of a single component(but not whole PD process)	avoid to choose wide scope and too complex processes you need to break it into small pieces, divided the process according to the gates
Identifying purpose	Depict the flow of their process to find improvements, knowledge sharing	Mostly reducing cost, depict the flow of their process to find improvements	Important to have a purpose before applying VSM. For instance decreasing lead time, reducing cost and improving the process flow and product quality
Format	Lead by a facilitator	Lead by a facilitator	Lead by a facilitator
Team members	Support is very crucial for	Support is very crucial for	Support is very crucial for success.

(Facilitator and team members)	success. Can be engineer or manager. Someone in the team should have responsibility for the results of the workshop.	success. Mostly Engineers. Every team member will take responsibility of some improvement activities.	All managers of each function and one key player of each function to support their manager. Usually manager will take responsibility of VSM workshop results
Training Team members	Important to have a short introduction of the methodology to prepare the team to start thinking about the waste and problem and trying to open their eyes. Should be open minded.	Important to have a short introduction of the methodology to prepare the team to start thinking about the waste and problem and trying to open their eyes. Should be open minded.	Important to have a short introduction of the methodology to prepare the team to start thinking about the waste and problem and trying to open their eyes. Should be open minded.
Group size	7-9	5-7	5-9
Focus	Usually focusing on problems that the employees are experiencing associated with, hand off, but depends on the process	Focusing on Hand-offs improvement or depending on the process	Lead time
Workshop Duration	3 hours	8 hours	2.5 days +, 2.5 days +, 2 days
Mapping Procedure	From the beginning to the end	From the beginning to the end, or From the end to the beginning	From the beginning to the end
Aids to drawing current state map	Sticky notes with different colours, pencils, pens, A0 size paper or swim lane charts	Sticky notes with 8 different colours, pencils, pens, A0 size paper or swim lane charts, secretary	Sticky notes with different colours, pencils, pens, A0 size paper or swim lane charts, secretary
Collection of Data	Brain storming. Having the right people, right method is important to get most accurate data.	Brain storming. Having the right people, right method is important to get most accurate data.	Brain storming. Having the right people, right method is important to get most accurate data.
Metrics	Lead time, depends on the process. Estimated data is average of maximum, minimum and medium	Depends on the process. Estimated data is average of maximum, minimum and medium	Lead time, depends on the process. Estimated data is average of maximum, minimum and medium
Prioritization	Pick chart	Pick chart	Pick chart, prioritizing table(use scale for ranking the solutions for example from 1 to 5)
Creation of future map	Depends on the type of process	Yes, but depends on the process	Yes
Results from session	Improvement suggestion that enter into an established PDCA process	Action list that enter into continuous improvement board(PDCA) process	Action list with responsible people and follow up meetings

5. Case Study

This chapter describes an application of Value Stream Mapping in Product Development. This is done in order to collect pre-requisites, and also examine the proposed instruction for applying VSM. The case study was applied to a piece of the product development process at Renault Trucks. Renault Trucks is, located in Lyon, France and it is a part of the Volvo Group since 2001.

Based on Rother and Shook (1998) and McManus (2005) and also findings from interviews we proposed 6 steps for applying VSM in product development. We also divided these steps into 3 sections. There are some activities in step 1 that needs to do be done before the Workshop. The steps from 2 to 5 will be done during the Workshop and finally the step 6 will be conducted After the Workshop. These steps listed in Table 7

Table 7: 6 steps procedure for applying VSM in PD

No.	Step	Section
1.	Preparation	Before Workshop
2.	Introduction	During Workshop
3.	Mapping current state	
4.	Analyzing current state	
5.	Mapping future state	
6.	Following up the counter measures	After Workshop

In this case study, because of some limitation we just performed steps 1 to 3. Although we had planned to do steps 1 to 5, we could not follow the plan. The reasons behind this issue will be discussed in the next chapter.

5.1 Before the Workshop

5.1.1 Preparation

Preparation is the first step in value stream mapping and includes identifying the mapping team and planning for mapping workshops. This step refers to all activities required to do before the Workshop.

We had an offer from a Quality manager of Renault Trucks for applying VSM. He wanted to apply VSM in their product development process. They did not have any experience and knowledge about VSM. We followed these activities during preparation step:

Warming up

As a starting point we prepared some questions for getting some information about the company and its processes and activities and ask them to give us some related information. We also prepared a brief introduction of VSM and its steps to introduce VSM and its benefits.

Selecting process

We had some discussion of finding a suitable process of pilot study. We had some consideration for choosing process. Two issues were important for us in selecting process: availability of related people, and also the scoping, selecting a "simple" process. After some discussions with the Quality manager as a customer for the VSM and because of some internal conditions, ``Contract preparation´´ process (the second process in product development) was chosen for VSM.

Identifying purpose and problem

When we asked what their problem is and why they wanted to apply VSM in product development. The initial answer was: 'We do not know if there is a problem. The target is to measure the development process and see where we can have improvement.' After some discussion they realized that one of their main problems is long Lead Time and they hoped to reduce it by applying VSM.

Selecting project

For pilot study we suggested to select a project that is ongoing or recently has been finished. They selected a project, which was currently ongoing.

Identifying product family

Due to time constraints we just focused on one project with one product.

Identifying the boundary of the process

For having a better view of the process and for finding related people in selecting mapping team we tried to have primary information about the boundary of the process. This information included inputs, outputs, beginning point, ending point, constraints, additional inputs.

Identifying stakeholders

In this selected process we had an order from an external customer but outputs of this process delivered to the next internal process.

Selecting mapping team members

For the team members, we decided to invite some key people: The process owner, people from departments who do some part of the process, and the next process owners. We decided to have maximum 10 members and this included the VSM manager and facilitators. The team members could be managers and engineers. According to the process we invited people from these departments: Marketing, Aftermarket, project manager, section manager, Chief Project Manager (CPM).

Selecting VSM manager

Since the Quality manager was responsible for improving the processes, at least in this pilot, He was the VSM manager for this case study. He invited different people and did all coordination.

Identifying VSM procedure

For having a structure and instruction during the workshop we prepared a VSM procedure. The procedure can be found in appendix 2. We explained all steps of the workshop in this procedure. This is a guideline that the facilitator and members should follow and it includes identifying activities in different steps of mapping the current state, analyzing it and finding waste and depicting the future state.

Preparing time schedule

After some discussions we decided on the date for the VSM meeting. We prepared a schedule for the workshop as we needed to identify the duration of the workshop and also have a plan for the different steps of the VSM workshop. According to some feedbacks from the VSM manager and also regarding the date of the workshop, it was in December and most of the people were so busy, we

decided to have a workshop in a whole day instead of having some separate meetings. According to the finding from interviews and literatures and also regarding the scope of the process we estimated that 6 to 7 hours could be enough for the workshop. The Time schedule of VSM workshop is shown in Table 8.

Table 8: Time Schedule for VSM workshop

Time Schedule for VSM workshop Date: 20121212		
Time	Activity	Description
9:00 – 9:20	Introduction	· Introducing the project and VSM
9:20 – 10:45	Drawing the current State Map	· Understanding the existing process and activities · Gathering related data · Calculating related metrics · Depicting current state map.
10:45 – 11:00	Break	-
11:00 - 12:00	Analyzing the current state map	· Finding possible waste · Filtering and prioritizing the waste
12:00 – 13:00	Lunch	·
13:00 – 14:30	Analyzing the current state map	· Finding reasons of the waste · Creating related countermeasures
14:30 – 14:45	Break	·
14:45 – 16:30	Drawing the future state map	· Prioritizing the countermeasures · Depicting future state map · Recalculating related metrics · Brief discussion about action plan

We divided the workshop into four sections, Introduction, Drawing current state map, Analyzing the current state map, and Drawing the future state. We decided to have a short introduction of the project and VSM at the first step. It was planned to be just 20 minutes. We assigned around one and a half hours for drawing the current state map. This step included Understanding the existing process and activities, Gathering related data, Calculating related metrics, Depicting current state map. We assigned two and half hours for the Analyzing step. We should find possible waste, filter and prioritize the waste, find the reasons of the waste, and create related countermeasures during this step. We assigned 105 minutes to do the future state map. That includes prioritization of the countermeasures, depicting the future state map, recalculating related metrics, and having a brief discussion about the action plan.

Inviting team members to the workshop

The VSM manager invited the team members to the workshop. He shortly explained about the purpose of the workshop and VSM, and also he attached the time schedule in the invitation.

Preparing facilities and training material

For conducting the workshop we needed some facilities. Before the workshop we prepared some materials according to the procedure. We needed sticky notes (in two sizes and different colors), A0 papers, a white board, pens, and pencils. We also needed a suitable room for the meeting and also a video projector for the presentation.

For introducing the project and VSM we prepared a presentation in the format of PowerPoint which we also printed for all of the members as handouts.

5.2 Workshop

Before starting the workshop we should prepare the room. We put A0 paper on the wall where all members can see and access it easily. The workshop was ready according to schedule. The workshop was started with three managers and another manager joined the team later. Some of the team members had been urgently called away and could not come to the meeting. This resulted in that we were only able to do the introduction and draw the current state map (steps 1 and 2).

5.2.1 Introduction

In this step first the VSM manager introduced the team members and also the project. He explained about the purpose of the meeting. After that we as facilitators introduced ourselves and VSM. First we explained the definition of VSM and also discussed about Value added and Non value added activities. Then we explained the 7+1 wastes and translated them into the product development area (See appendix 3). Finally we introduced the different steps of our proposed VSM process.

5.2.2 Drawing current state map

This was done using the A0 papers previously prepared. According to the procedure first we asked members to identify the start point (trigger) and end point of the process. We wrote the Start point on the left side of the paper and also the Endpoint on the right side of the paper. After that we asked the team members to discuss about inputs and outputs of this process. We wrote inputs and outputs by pencil above the start and end points.

We asked the team to define customers of this process and discuss about what the output will be related to which customers. We put the name of the customers in the related symbol and rewrote the related outputs. In this case we identified the CPM (as a customer) to trigger the process (demand) and also identified internal customers who receives the output of the targeted process. We also asked about the frequency of demand from the customer and stated it in its symbol.

We discussed about the time that the customer expected to receive the outputs. In this case we did not have any data about customer expectations regarding the time and there has been just an expected time for completing the whole product development process. Then the team decided to use internal target time as a base for customer needs in this process.

In the next stage we asked the team members to find different processes and activities in the Feasibility process. We ask them to write the name of the process steps and related departments in a big sticky note and put on the paper. Then the process was broken down to sub-processes until it was just one department involved when we had a sub-process with only one department involved we asked the team members to write the process and involved department on smaller sticky notes. There were a lot of discussions. During the discussion one of the members said: ‘ I do not know what happen in other departments but in our department we do these related activities’ then he draw a line on the paper and put his sticky notes on the paper.

In the next stage we asked members to adjust the position of processes and draw the flow by pen. They just drew the main flow. The final result is shown in Figure 3

We used small light green sticky notes for showing the outputs of each process. By this way we could realize which documents we recreated by these processes.

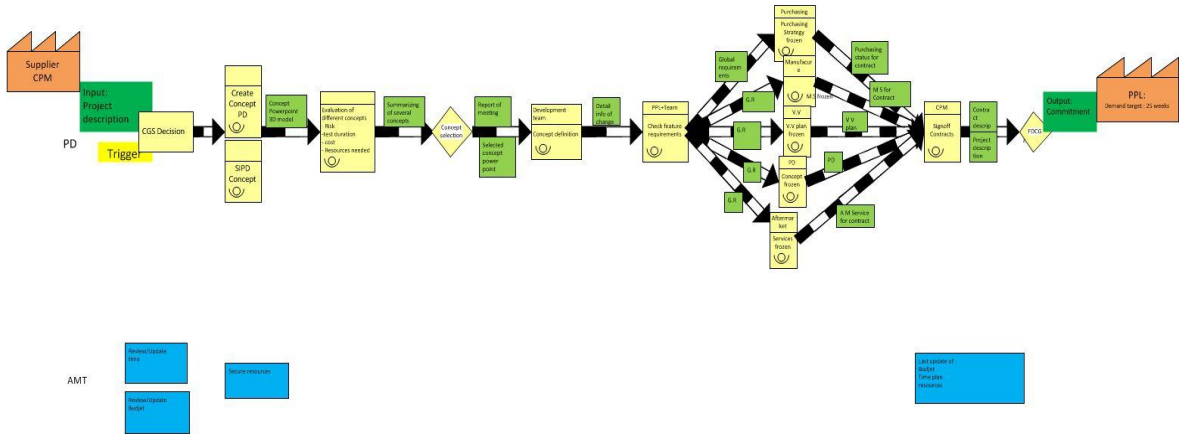

Figure 3: Current state mapping

6. Analysis

In this chapter the results and findings are discussed briefly from both theoretical and practical perspectives. This part discusses about practical and theoretical consideration that have to be taken in order to adapt Value Stream Mapping to a Product Development environment.

The concepts of value and value stream are crucial to the philosophy of Lean, and a better understanding how these concepts relate to product development is essential for the creation of a Lean PD strategy. According to Slack (1998), the manufacturing template of the Value Stream need to be tailored to a product development context. He suggested that the product development flow can be tailored in three different kinds of flow: material flow, product information flow and program information flow.

Our findings show the VSM cannot be applied in Product Development exactly the same way that it is applied in a manufacturing environment. Differentiations between manufacturing environment and product development area cause that some steps and techniques cannot be applied in product development. As an example some techniques like Supermarket or Kanban are not applicable in Product development because there is no mass production in product development.

In the following sections we will discuss about different issues in VSM that needs to be tailored for product development.

6.1 Identifying the particular purpose for each VSM

Step-by-step VSM guidelines in manufacturing introduced by Rother and Shook (1998) and Jones and Womack (2002) did not mention anything about selecting purpose in VSM while VSM in product development emphasizes on having an objective and a purpose for each VSM. Locher (2008) stressed on identifying and recording key specific objectives and measures in the preparation step of VSM. Because of complexity of process in product development finding improvement opportunities in product development is harder and more complicated. Having a defined purpose for VSM can help the VSM team to be concentrated on some especial issues and waste. The Value Stream mapping can be used several times for finding waste and improving and the VSM team can have a different purpose each time.

6.2 Involving team members before mapping workshop by training and discussing about current problems

The Purpose of VSM can come from problems that the organization is suffering from. It is important that the process owner and team members know about their problems and are eager to solve them. In our case study the Quality manager wanted to use VSM as a useful tool for improving. Most of the team members did not know about VSM and its ability to solve their problems. They did not know anything before coming to the meeting. Analysis of our case study indicates it is necessary to have training and preparation meetings before the workshop. In this meeting team members can be introduced to VSM and its benefits and also can discuss about problems and purpose. When it is not possible to have a meeting before the workshop, the ideas from team members about their main problem and purpose can be gathered. This idea can help to select a suitable purpose for VSM.

6.3 Selecting a reasonable scope

Rother and Shook define a manufacturing value stream scope by the receiving and shipping "doors" of a single facility—a "door-to-door" value stream. This is much the same as the function level that Morgan (2002) stressed. VSM can be applied in different level of process. According to Morgan, a single process of product development to entire of product development can be selected for applying VSM. Although it is possible to apply VSM at all levels, our findings show that the team should reduce the scope of the value stream as much as the analyzing becomes simple. Choosing a narrow scope for value stream mapping at the beginning help the team to learn more about the process and be able to address the problems better. In most cases the team members do not have enough experience in the beginning and choosing a too wide process may take a long time and cause frustration.

On the other hand when a piece of the product development is selected for VSM the team cannot find waste and interruptions in the whole flow. The team investigates different piece of product development separately then they may neglect to consider the whole flow of product development and sub-optimize. It is important to have VSM for whole process after applying VSM for lower levels. Moreover, you may lose some data when you choose a narrow process. As an example in our case study the demand of customer for our selected process was not clear. We just had information about customer's delivery time for the whole process and final output. In most cases customer demand is obvious for the whole product development process but customer demands for each sub-process may not be obvious. In this case the team can estimate demand.

6.4 Considerable factors for selecting the scope of VSM

Baggaley & Maskell (2003) explain that the number of people involved in processes is important when you want to choose the value stream scope. They suggested choosing a value stream that contains 25 to 100 people. According to this it seems it is needed to notice more issues in choosing the scope of Value Stream in the product development area. In our case study we chose "Contract preparation" process for our case study. Although it is not a wide process, many departments are involved in this process. Having all managers in the workshop was a big challenge for our first experience in VSM. According to Morgan (2002) complexity of product development process and hand offs between activities are two of challenging issues that VSM should cope with. The VSM teams should consider the complexity and the rate of hand offs and iterations when they want to select the VSM scope. Therefore it can be said that apart from the number of people involved in process, the rate of hand offs and interactions of information and the number of departments involved are noticeable issues on choosing the scope of value stream mapping.

6.5 Project and product family selection

Rother and Shook define a product family in manufacturing VSM as a group of product that pass through similar processing steps over common equipment in downstream processes. This definition also can be applied in product development. But in product development there are more considerations in selecting the product like: demand of each product, future business objectives and current problems facing the company. In addition product development VSM needs a project or projects to serve as the subjects for the mapping event.

Product Development is a project based process and a VSM can be unique for a project or projects. In manufacturing where we have production we need to choose a product family for each VSM while in product development we need to choose a product family and related projects. The selected project can be a finished, or ongoing or future project. An ongoing project has already passed some processes but we can do VSM for whole processes (Passed, ongoing and uncompleted processes) because it will be used for other projects in its product family. When we choose a recently completed project we have more information and related data for applying VSM and there is no need to go through a decade of more history but purposed countermeasures can be applied to the next related project.

6.6 Selecting a combination of managers and engineers as the team members

According to Nielsen (2008) few people really understand the entire value stream, or have the knowledge to anticipate the impacts of specific changes to it. The VSM team should include people who know the process very well. These people can be a manager or engineer. According to our findings managers have lots of ideas about the flow of the process and counter measures while engineers know details of process and waste and they know what happen exactly in the process. Then depending on the purpose of VSM and complexity of process the role of managers will be more important than engineers and vice versa. In generally a combination of managers and engineers can be more effective in VSM because in most cases information is needed about the details of the process and its waste and also someone who help to find problems in the flow and countermeasure for solving the waste and problems.

6.7 The number of VSM team members

Although there is no a standard rule about the number of VSM team members, our finding shows that the number of team members depends on the level of VSM and organizational chart. Having a multi-functional VSM involves more departments. This makes the team larger because it is important to get information from different points of view and effective sections. In some cases we may not invite all people in VSM meeting and just gather related information from these people. The role of these people can be like Mapping Participants. Morgan (2002) explained Mapping Participants as people who will be keeping activity journals and participating in the interviews and debriefings. As an example maybe we can not invite customers in VSM meeting but we can get their needs and demands and discuss about it during the meeting. According to our findings the number of team members can be around 5 to 10 people. Large number of team members will increase the time of meetings and managing the meetings will be harder. On the other hand less team member will make a potential threat of losing information.

6.8 The facilitator should be a member of the VSM team

McManus (2005) explains that the VSM team needs a Facilitator, someone who has knowledge and experience in Lean theory as well as the methods and tools used for the process improvement. The facilitators have an important role in VSM especially when there is not enough experience in the organization. Facilitators can be from inside or outside of the organization. If the facilitators are from

outside of the organization or are not familiar with the process it is better to have a warming up stage before starting anything.

6.9 Importance of Team manager power

Morgan (2002) believes that in order to have a significant organizational change you must have real power behind the effort. Formal and informal position of a team manager can be representative of power behind the VSM effort. Our findings showed that the position of team manager is important. As an example the position of team manager can effect on the rate of participation of team members. In some culture it is crucial that who invites people to a meeting. People cannot invite others who are in a higher position in a meeting. If we do not select suitable VSM manager we may miss some key team members.

6.10 Creating a VSM procedure

Having a suitable procedure for VSM meeting causes the team to follow a planned structure for the meeting. Although the procedure is not typically mature at the beginning, it can be improved after each experience. Depending on the purpose of VSM, methods and activities may differ during the VSM meeting. For instance some methods and activities will differ when the purpose of VSM is just to depict flow of a process in comparison to when the purpose is to reducing lead time during a process. Choosing suitable methods and activities needs an extensive experience in VSM. Facilitators can help the team for selecting methods and activities.

6.11 Duration and time of workshop

There is no standard rule for the time schedule and duration of applying VSM. Although Locher (2008) considers three days for typical durations of mapping event, others like our interviewees have different ideas. The duration of different activities can differ according to different situation. Facilitators can guide the team to have a suitable schedule for VSM. Having and following a reasonable schedule can be one of the success factors in VSM. A VSM schedule can effect on the rate of participation. If team members have a limited time then it may be hard to add on extra time for continuing the meeting. It is the responsibility of Team manager to manage the time of the meeting and push the team to follow the schedule. Moreover it is needed to consider the time of VSM meeting. For instance you may face some problems if you plan for having a workshop near new year because most of people are so busy, then you may not be able to secure some critical people.

6.12 Identifying internal and external customer and their needs and values Customer

According to VSM researchers like MacManus, VSM emphasizes on internal customers as well as external customers. It is crucial to find who the process customers are and what their demands and needs are. When we choose a sub-process as a VSM scope we need to identify both internal and external customers and their needs. In this case, when the external customers' demands and needs are not typically obvious then it is needed to translate their overall needs and demands to each sub-process. Moreover it is hard to currently define customer value and needs because most producers want to make what they are already making. On the other hand in some cases some process works in push system and the process may deliver its outputs to customers that did not order the results. In other words the customers are different to who orders. Finding the real customers and who orders and their needs help the team to have a better analysis in VSM.

6.13 People are the main sources of data

MacManus (2005) explains the condition of collecting data in product development: "Lacking a physical part to ride on, you must strap yourself to the information." Doing this will require some creativity. Since there is not a perfect system for collecting data on the product development environment and usually people are the main sources of information it is important to access to suitable people for collecting data. Team members may not have all related information but they usually know how they can find it. It is significant to find someone who retrieves data before starting the workshop.

6.14 There is not objective data

Uncertainty is one of three main differences of Product development processes and manufacturing process that MacManus considered. In product development the exact content of the output is not known while manufacturing process makes a part exactly the same as the last one. Activities in a manufacturing environment will repeat so many times while in product development project most of activities will happen just one time. Therefore the data of process can be more accessible than in the product development area. Data in manufacturing will come from objective data while in product development it will come from the experience of people in previous projects.

Moreover in some cases we have some targets or standards for some process. If we could not find exact data we can use them. For example if we do not have exact data about the customer demands

for each sub-process we can use the process duration targets that have already been defined by the organization.

6.15 The action plan will be done in future projects or oncoming activities

Uncertainties that MacManus mentioned as a differentiation of manufacturing and product development can make some difficulty in future state phase. After improvement we can apply the improved flow in manufacturing processes and determine the improvement because they are repeating while in product development the flow will not repeat in the same manner and since cycles are long, it can take years to determine the success of the improvement.

6.16 The knowledge value stream will not be depicted in product development VSM

According to Morgan (2002) the Product Development process does progress from concept to customer. The Product evolution will happen from one state to another over time. In other word the knowledge (new or reused knowledge) will transform to product during the product development process. On the other hand Kennedy, Harmon and Minnoch (2008) introduced knowledge value stream in addition to product value stream in the product development process. In the knowledge value stream, knowledge will improve during conducting different product development projects. The Value Stream Mapping that we discussed in this thesis cannot cover the knowledge stream because we just focus for depicting the value stream from concept to product along the product development process.

7. Proposed Structure

The findings from interviews and literature review shows there is no standardized way of applying VSM in Product Development. Depending on the conditions, the steps of VSM may differ and it is important to be flexible during the application of VSM. It seems that the definition of Jones and Womack (2002) in Value stream mapping is a base in the most cases. They all observe current flows and summarize them visually, then envision a future state with better performance.

In this section we provide a proposed step-by-step guideline for applying VSM in a product development environment.

7.1 Purpose and scope

This procedure is intended to provide practical guidance for applying Value Stream Mapping to PD process. The content is well grounded in research, theory, and experiences.

The scope of this procedure is limited to the mapping and improvement of a single, definable product development process and it is applicable for all levels of the process.

Step by step of applying VSM:

Value stream mapping in product development should be carried out in the following 4 steps:

Step 1: Preparation

Step 2: Mapping the current state

Step 3: Analyzing the current state

Step 4: Drawing the future state and developing the action plan for implementation of Future state

7.1.1 Preparation

The first step is crucial for effective value stream mapping, which includes identifying the mapping team and how the mapping event will be planned. This step refers to all activities required to do before the mapping meeting.

Selecting process

A process should be selected as a starting point. The process should be selected based on a known problem, a higher-level analysis such as an Enterprise Value Stream Map, or a previous higher-level iteration using a tool such as this one. The selected process can be in different levels (single process, single function, Multi-functional and Entire product development).

Note: the owner of this phase is different in various companies. Depending on the organizational chart, different people or an improvement committee can select the process and define related problem.

Identifying key stakeholders

Stakeholders should be identified to have the right team. Stakeholders are the people who derive value of any sort from a process. Stakeholders typically include the process participants, the users of the output of the process, indirect users, customer of the design or other final product development output, and the end user of that product.

Selecting a value stream manager

Regarding to the selected process a suitable manager should be selected. This person should manage the meeting and also be responsible for implementing all improvements in the future. The process owner can typically be a suitable VSM manager.

Note: the power and position of VSM manger should be matched with the level of VSM. For example if the scope of VSM is in the entire product development process the VSM manager should be selected from the top level of organization.

Defining a mapping team

Value stream manager should make up the mapping team of people with functional expertise necessary to truly understand the value stream. Different roles are needed in the VSM team but depending on the conditions some or all of them can be invited to the team: Facilitator, process

owner, process experts, customer, supplier and other key stakeholders. The team members can be managers and engineers.

Training the team members

Training in the fields of Lean concepts, Wastes and VSM should be conducted for all members. The duration of training course depends on the organization and team members but a short day (around 6 hours) is suggested. This phase can be ignored when all members have suitable knowledge or experience or can be conducted for some members.

Identifying purpose

The mapping team should define and record the purpose of applying VSM and what is expected to reach during this improvement journey.

Defining project and product family

The mapping team should select a product family for applying VSM regards to the selected process. A product family is a group of producers that share similar process steps, which are the main activities performed as part of process development. Having common activities, work contents, demands, future business objectives, and problems are the main factor to consider in identifying product families.

Once a product family has been defined, the mapping team should select a project or projects to serve as the subject or subjects for mapping events. The team should select only projects that have been recently completed.

Preparing time schedules for mapping meetings

The mapping team should prepare a schedule for mapping workshop. The schedule should include activities, time and duration of VSM workshop. The duration of the workshop depends on the team members and the scope of VSM. It can be conducted in some continuous meetings or in some separate meetings.

Inviting team members to the workshop

The value stream manager should formally invite all team members and participants to the workshop. The time schedule of the workshop should be attached to the invitation. It is suggested to shortly explain about the purpose, problem, and scope of VSM.

Preparing facility's material

The value stream manager should prepare the materials that the team needs for mapping event. These materials include sticky notes (in two sizes and different color), A0 papers, white board, pen, pencil, eraser, a suitable room for a meeting(s) and a video projector. A written guideline for the task of different sizes and colors of the sticky notes should be prepared for the mapping meeting. This guideline should include the way of writing and using the sticky notes and be printed before mapping meeting.

If it is applicable, the value stream manager should prepare a presentation about the scope of VSM and what have done so far. This can be very useful for participants.

7.1.2 Mapping the Current State

In this step the mapping team should depict the current value stream.

Introduction and kicking off

In this phase Value stream manager should introduce team members to each other because some members may be new. The Value stream manager should present a problem, the purpose of VSM and the meeting, selected process, product family, and selected project.

The A0 paper should be put on a wall or on a stand that everyone can see and access easily. Everyone should have a pen, pencil, eraser and different sizes and colors of sticky notes.

The task of different color and size of sticky notes should be explained to all members. Everyone should access the written guideline for using sticky notes.

Identify boundary of process

As the first point of depicting the current state map, the team should discuss about the start point (trigger) and end point. The start and end points are activities that by doing it the process will

respectively commence and finish. The start and end point should be written respectively on the left and right side of A0 paper.

The team should discuss about inputs and outputs of the process. After initial discussion anybody can write inputs and outputs on sticky notes and put on the A0 paper on the left side of the starting point (for inputs) and on the right side of end point (for outputs). Each input or each output should be written on separate sticky note.

Team members should discuss about each written input and output. It may be needed to remove some of them or merge with another one.

The team should discuss about customers and their demands and related outputs. The name of each customer and its demands should be written on one sticky note (The color should be different from the color of output sticky notes). The customer demand can include date, information, material and documents. There are different customers with different demands.

Identifying the process lead time

Depending on the purpose of the value stream mapping this phase can be applied. If reducing the processing time is the purpose of VSM, the team should identify the current lead Time.

Identifying processes

Mapping Team should identify all processes from the start point to the end point within investigating process. The team should identify all processes that are in just one level below the level of main considered process. As an example if a Multi-functional process is selected for VSM, the team should identify all processes in function level during this Multi-functional process.

It should be asked of everyone to write ‘the name of processes’ and ‘the name of related department’ on each sticky note and put it in the suitable place of A0 paper. Then the team should discuss and finalize proposed processes. It is better to follow the process from the start point to the end point instead of going backward.

Identifying process flow

The team should discuss about the relationships and the flow between identified processes. The sticky notes, representing the process steps, needs to be adjusted to the correct positions that show

the sequence of the processes. The thick arrows that should be drawn by pencil between processes show the flow of processes. The arrows should be drawn between two processes when information, material, or documents go from one process to another. This is related to material flow and product information flow. If the level of VSM is a multiple process or entire product development process it is suggested to use swim lane chart. It means the processes that are done in the same department or function should be put in a common lane titled by the name of a department or function.

Identifying the outputs and inputs of processes

The team should discuss about outputs of each process. The team should focus on all process one by one process and discuss about the outputs. After finalizing for each process, the title of each output should be written on specific color of small size of sticky note(s). Each sticky note (output) should be put on the arrow between two related processes. This means the output of one process will be an input to the next process. The team should notice maybe there are some inputs from other process that are not in the scope of ongoing VSM. The team should discuss about further inputs of each process and write them on sticky notes and put them on related places.

Note: one output can go to more than one process. In this case more than one sticky note needed to put on each related arrow. For example the title of the output should be written on two sticky notes when a common output goes to two different processes and should be put on each related arrows.

Identifying the program information flow

The team should discuss about all information flows that are related to awareness, management and control of processes. This kind of flows should be shown by thin arrows between different processes and should be drawn by thin pen with different color from arrows that show material and product information flows.

Collecting related data

Depending on the purpose of the VSM the kind of data that should be collected and the way of depicting on the VSM will differ.

Case1: If reducing the lead time is the purpose of VSM, the team should discuss about the actual time of conducting each process and waiting time between two consecutive processes. If there is a valid data from the selected project to follow the team should use them, otherwise the team should

estimate three times for each process: Most likely Time, Worst case Time and The best case Time. The team should calculate the Expected time by Lichtenberg's model:

Expected Time = (3 *most likely time+ worst case time + best case time) /5.

The team should write Expected Time in the timeline below the processes of the A0 paper. In this case the team should calculate the lead time by using the expected time of each process, and write at the end of the time line on the A0 paper.

Case 2: If improving the quality of information is the purpose of VSM, the team should discuss and record the iterations to finally correct problems. This can be noted by use of iteration icon (See Figure 4). The team should note the iteration icon above the arrows. The team should note the number of iteration and impact on Value Stream like the time that will take and will prolong the lead time.

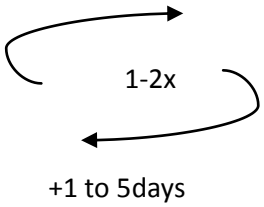

Figure 4: a sample of iteration icon with notes on number and impact of lead time (Locher, 2008)

The important measure of information quality is the percentage of time that all necessary information is received, and whether the information is accurate. This is referred to as "Complete and Accurate". This index will calculate by dividing the number of passing correct information in the whole process of total number of transferring information.

Case 3: Depending on the purpose of the VSM it may be needed to mention how many people or resources are shared in each process and estimate the percentage of time that people or resources spend on it. In this case the team should note the number of people or resources and the percentage of time in sticky notes that is already used for the process. The team can write this under the process name.

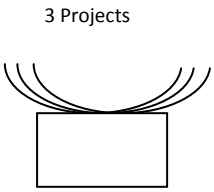

Figure 5: In Box icon with number of projects and scheduling priority (Locher, 2008)

Case 4: If allocating the resources and prioritizing the various underway development projects is the target of VSM the team should use “in-box” icon to depict the number of development project underway for each process, as well as how this work is prioritized (See Figure 5). The team should note this icon before each process and note the scheduling priority under this icon.

Recording the finding

After finishing the current state map the team should record the finding in the retrievable methods. Taking photos or recording on the computer are two suitable options for recording the current state map. For recording the current state map on the computer the team should use standard icons and signs that show in appendix 4.

7.1.3 Analyzing the current state map

In this step the team should analyze the current state map and define some suitable action for overcoming the problems. Depending on the purpose of the VSM some of following phases can be conducted by mapping team.

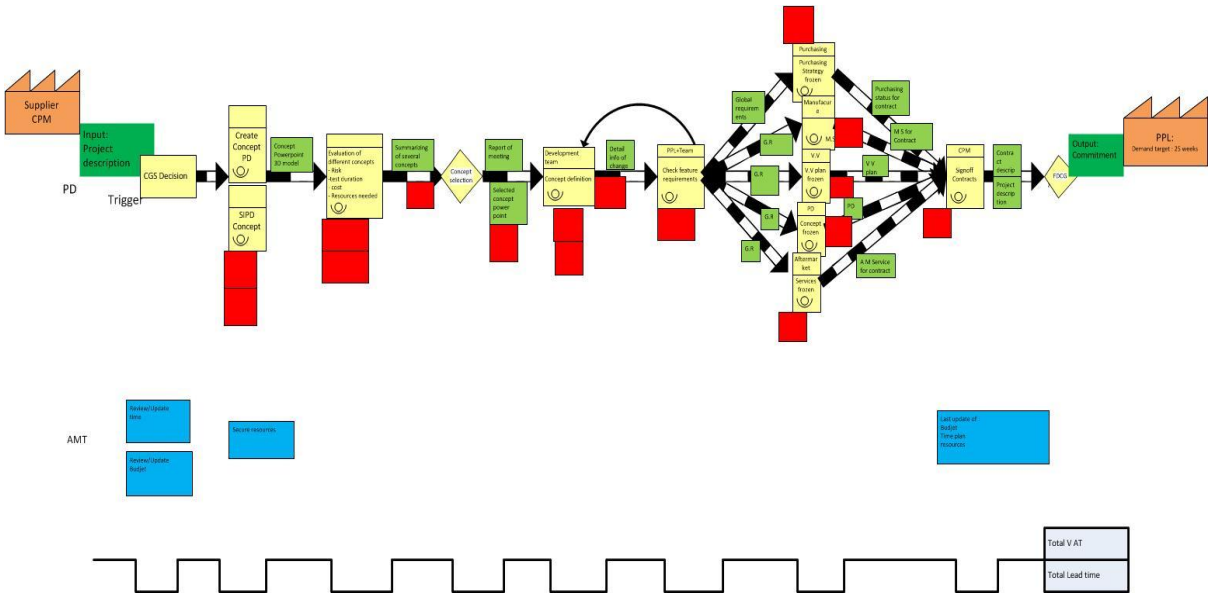

Figure 6: Analyzing the current state map

Finding non value added process

The team should discuss about each process and try to find the processes that are completely non value added. The team should remove the non-value added process from the A0 paper.

Identifying the interruption of flow

The team members should think and discuss about the way of having better flow. It should be asked everyone to write some interruption problems in a particular color of small sticky notes and put them on the map. Each interruption problem should be written on one sticky note in complete and clear sentences.

Identifying waste

It should be asked of everyone to think about the possible waste in the whole process. Then everyone should write his/her suggested wastes on sticky notes and put them in related process (see figure 6 – red color sticky notes). It needs to write in full and clear sentences and also mention the name of the process on the top of the notes.

Some general questions can help team members to find more waste:

- Where are the queues?
- What is the rework?
- Any highly iterative processes?
- Are there too many reviews or hand-offs?
- Are there any redundant tasks?
- Are there any Stop-Go tasks?
- Any other clearly non-value added activities?

Filtering the waste

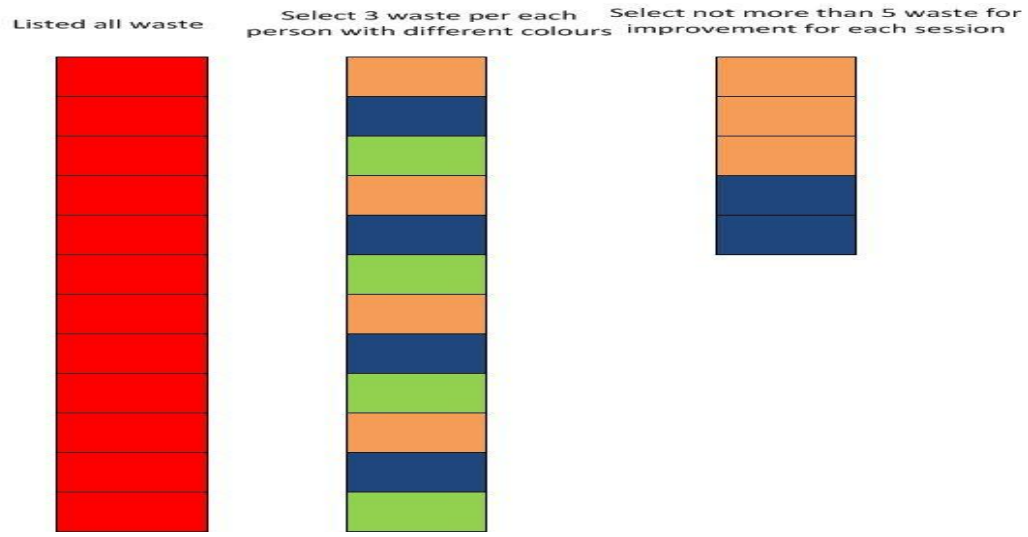

Figure 7: Filtering the waste

It should be asked the team members to discuss about suggested wastes one by one and suggested to list all wastes on a white board as all members could see them obviously.

Then it should be asked members to choose three most important wastes between listed wastes. Everyone should write the tree important wastes on three different colors of sticky notes. (As an example orange for the first top, blue for the second top and green for the third top)(See figure 7)

Note: Members cannot choose all three in the same color.

The team should consider the first important wastes for improvement. It may happen that some team members select common waste as a most important waste. In this case there will be limited wastes for improving. The team can go to next level and select the second top waste for improvement. It is suggested to choose not more than 5 wastes for improvement to start with.

The team should discuss about the selected wastes to confirm them. Some members may change their suggested waste during the discussion.

Finding root causes of selected wastes

The team should discuss about the root causes of each waste, one by one. It is suggested to use the 5 Why tool for finding the reasons of waste. After finalizing the answer of any why question, it is

suggested to write the answer on the white board then going to next why until improvable root cause.

Creating counter measures

The team members should think for a while about possible counter measures and write on sticky notes and put on the white board. After that the team should discuss about the suggested idea, written on the sticky notes, one by one. The team should finalize possible counter measures.

7.1.4 Drawing Future state map and developing the action plan for implementation of a future state

The following is an outline for creating a future state map from the current state map.

Prioritize the counter measure

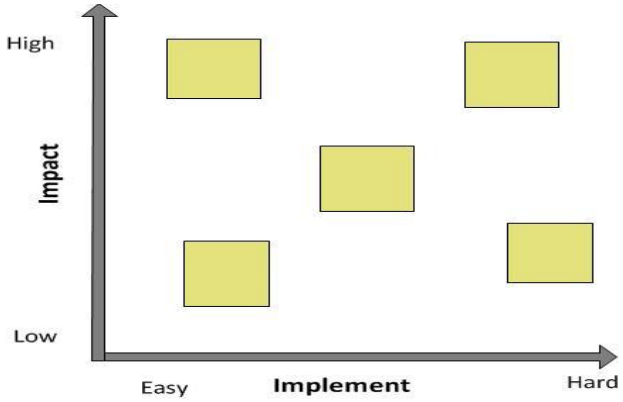

Figure 8: Pick chart

The team should prioritize the suggested countermeasures. It is suggested to use Pick chart for prioritizing the countermeasures (see figure 8). It should be asked the team to identify the place of each countermeasure that have been written on sticky notes on a chart with two dimensions, impact and easy to implement. Those countermeasures that have higher impact and are easier to implement should be selected as the main countermeasure.

Drawing the future state

According to the selected counter measure, the team should depict future state on another A0 by pencil. It should be recalculated the metrics like Lead Time where it is applicable.

Developing the action plan for implementing

The team should develop the action plan for implementing the counter measures. The action plan should include related activities, date, time, owner (responsibility for doing the activity), starting point and finishing point, and resources. It also should include the way, time and responsibility of following up the implementation of counter measure.

After successful implementation, the team should continue with the rest of the prioritized wastes until the wastes are exhausted or it is decided that the cost/benefit is unfavorable. This is very important.

8. Conclusion

This chapter presents the key results by answering the research questions and discusses about some suggestions for further research.

RQ1. What considerations have to be taken in order to adapt Value stream mapping to a product development environment?

According to the literature and interviews, the VSM cannot be applied in Product Development exactly the same way that it is applied in a manufacturing environment. The researchers like Slack (1998), Morgan (2002) and MacManus (2005) emphasize that the manufacturing template of Value Stream needs to be tailored in product development context. Our findings show some considerations that should be noticed for adapting the VSM in the product development area:

- Identifying key specific objectives for each VSM is a considerable point in product development. Because of the process complexity in product development, finding improvement opportunities in product development is harder and more complicated. Having a defined purpose for VSM can help the VSM team to be concentrated on some special issues and waste. The Value Stream mapping is used several times for finding waste and improving, and the VSM team can have different purposes each time.
- Choosing the suitable scope for VSM is another considerable issue in the product development area. Number of people involved in the process, the rate of hand offs and interactions of information, and the number of departments involved can also be effective issues in choosing the scope of value stream mapping.
- Choosing a suitable project is a particular stage in product development VSM. Product Development is a project based process then a VSM can be unique for a project or projects. To analyze a value stream it is necessary to follow a specific product family and project along the different processes. In manufacturing it is sufficient to choose a product family as focused area and selecting a project is not applicable.
- There are two kinds of uncertainties that should be noticed during applying VSM in product development; Information Uncertainty and Output Uncertainty. Since there is not a perfect system for collecting data on the product development environment and usually people are the main sources of information then naturally there is an uncertainty in data and information. Accessing to the suitable people for collecting data can decrease the information uncertainty. Moreover the exact content of the output is not known in product development while

manufacturing process makes a part exactly the same as the last one. This makes an uncertainty in the output. This issue can effect necessary time of conducting activities and it will make some difficulty in proving the improvement especially when the VSM purpose is related to the time.

- In a manufacturing environment, activities are repeated so many times while most of the activities in product development project will have the same output just one time. Therefore after improvement, the improved flow will be applied in future projects.

Moreover we found some comments that can be useful for VSM in any areas. Although we found these comments in product development areas, they are also useful issues in manufacturing.

- The number of team members should be around 5 to 10 people. Large number of team members will increase the time of the meeting and less team members will make a potential threat of losing information. The team should be a combination of managers and engineers because typically engineers know valuable detail information about the process and managers have a wide view in finding problems and countermeasures.
- The position and power of VSM manager can affect the effectiveness of VSM. It affects the rate of active attendance of key team members and also shows the willing of organization for applying VSM in order to improve.
- The duration of VSM workshop is different and depends on the situation. It is not possible to consider the same duration for all VSM workshops.

RQ2. What are the main emphases in developing an instruction for applying Value stream mapping in a product development environment?

- In theory there is no new definition for VSM in product development and it follows the same structure as it has in manufacturing. Although there are some differentiations between applying VSM in manufacturing and product development, it seems the VSM definitions that were introduced in manufacturing can be applied in product development. In fact since we just used the tool in a new area then it is not necessary to introduce a new definition. Notwithstanding of this resemblance the structure and steps of the VSM in product development are more flexible than in manufacturing areas. Product development VSM is a tool for visualizing and improving the process. Large emphasis of the VSM in manufacturing lies on collecting and evaluating lead time metrics while there are various emphasis areas in product development. VSM in product development also emphasizes on distinguishing between knowledge reuse and

knowledge creation; performing development activities concurrently; distinguishing between good and bad iterations; maintaining a process focus throughout, and synchronizing the tasks.

8.1 Further Studies

- VSM is originally developed in a manufacturing environment and used in product development. There are other areas and different services that have potential for implementation of the VSM in future studies.
- Most studies in product development VSM are involved in one project. According to Kennedy, Harmon and Minnoch (2008), there is a knowledge stream between different projects. VSM can be applied and a useful tool for depicting and improving this steam. Investigation about this issue is another potential subject for further studies.
- Lots of suppliers are typically involved in product development. VSM is limited to product development activities conducted by the organization. The performance of suppliers, time of involvement of suppliers and information transaction is some kind of factors can affect the output of product development. How can VSM involve in these issues? This can also be a potential subject for future studies.

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10. Appendices

Appendix 1 Interview Guide

Categories	Subcategories	Questions
VSM		- Can you tell us about when a value stream mapping event can be successful or unsuccessful? Why? - What were the obstacles you have experienced while applying VSM in your process? * - There are different VSM in an organization, how can we manage the whole of them in an enterprise? (Some resources like especial machine are used for different family product (different VSM), how can you prioritize they activities?) * - What is the relationship between production planning (resource allocation and timing) and VSM?*
PD		- According to your experience, what are the main problems in product development area? - What are differences of manufacturing environment and Product development environment? * - How is Value stream mapping different for PD? - What is value and wastes in PD? Which are most common? - How many projects are you launching at a specific time? - How can managers allocate the resources when they want to inefficient way in different flows? How do employees prioritize their activity when there are forces from different project at the same time?
PDVSM		- Why did you choose applying VSM in your process? - According to your experience, is it possible to apply VSM in PD environment? Why do you think? Do you think VSM is useful for finding and eliminating waste in PD? Why? - Which problems have you experienced while adapting VSM? If you had a problem how did you get out of that situation? - Which points will be useful for adapting VSM in Product Development environment? - How engineering can reuse previous knowledge more? Instead of creating new? - How long time does the pilot study take in reality according to your experience? Which factors are effected in?
Preparation	**General**	- What considerations have to be in mind before applying VSM? * - Who are your main customers in PD? Can we say 'future projects' are some kind of customer? - When you did the VSM, did you have a discussion about who is a customer of the process you looking into and what is the value of the output was?
	Selecting	- How do you decide where to use value stream mapping?

	process	(Which process, which level, which project) - Which process do you recommend for pilot and why? (Ongoing or just completed)
	Team	- What are the points behind selecting and preparing the team?
Current state	**General**	- How can we get clear information about process to map current state? - Do you have any comments in current state mapping? - In actual process you said people work differently, did you start by agreeing on the current state mapping?
	Process data	- How do you deal with variations in the process when making a value stream map?
Improving		- How VSM symbols can lead us to find waste in the process? Is it necessary to use these symbols in PDVSM? Or we need to change it? - How you prioritize waste to improve in VSM? Which method is best to prioritize waste?
Planning and implementation		- How can we trust the proposed future state?

*can be deleted for interviewing with who has experience PDVSM.

Appendix 2 Procedure of VSM Workshop

1. Current state

- Identify boundary of process.
  Identify start point (trigger). Identify end point.
  We ask member to discuss about it and we write the conclusion on the white board.
- Identify inputs. Identify outputs.
  We ask members to discuss and we write the conclusion on two different sticky notes and put on the A0 paper. One color for input and one color for outputs.
- Identify customer. Identify customer demand.
  We ask them to discuss about it and write the customer names and their demand. The demand can be date, information, material and documents. Maybe there are different customers with different demand.
- Identify processes.
  We ask them to discuss about it and write on large sticky notes and put on the A0 paper. We ask them to identify process from start point to end point.
- Identify sub process and activities. (If there are more than five levels we can ignore this step)
  We ask them to discuss about each process and try to write sub process of activities on small sticky notes and put on A0 below of related process.
- Identify flow and relation between sub processes.
  We ask them to discuss about it and try to draw the relation and flow between sub processes. At first they need to follow the material and information that iscreated in each process from start point to end point. These relations are drawn in thick pen and by changing the position of sticky notes. After that the flow of information for awareness and the order is drawn with thin and different color pen.
- Collect related data
  We ask them to discuss about the actual process time of each process/sub process and also waiting time between two consecutive processes. We ask member to identify three time measurement for each process, most likely time, worst case time and best case time. We calculate the expected time by Lichtenberg's model: Expected time = (3 *most likely time+ worst case time + best case time) /5. We write the expected time in the timeline below the processes on the A0 paper.
- Calculate related metrics
  We calculate the total lead time by using the expected time of each process, and write at the end of the time line on the A0 paper.
- Transfer to computer.
  After finishing the current state map we document it on the computer.

2. Analyzing the current state map

- Find non value added process or activities:
  We ask the members to think about the process and find some process or activities that are completely non value added. We can remove them by marking with red pen.
- Finding alternative of current flow (Reduce interruption of flow):
  We ask the members to think how we can make better flow. They may change the order of some process steps that can reduce the lead time.
- Identifying waste:
  We ask member to think about the possible waste in whole process (10 min).

Ask them to write wastes on sticky notes and put them in related process. (They need to write in full and clear sentences and also mention the name of the process on the top of the notes)

- Filtering the waste:

  We ask the members to pick up the wastes that have not effect on lead time. Now we have just the wastes that can effect on lead time.
- Write the filtered wastes on the computer and showing them by video projector. (This is necessary for the next step)
- Prioritizing the waste:

  We ask members to choose the three most important wastes in the whole process. They can write in three different colors of sticky notes. (Red for the first highest priority, blue for the second highest priority, and green for the third priority) (They cannot choose all three in the same color)

  We ask members that they can add one more waste related to their activity that they think can be in three top. (They can use red, blue or green sticky notes). We select the red waste for the next step. (If there are not enough waste in red area we can pick up the blue area also)

  After selecting we ask team members to confirm the importance of selected waste. They may change the selected waste during the discussion.
- Find the root cause of selected wastes:

  We use the 5 why tool for finding the reasons of waste. We ask the members to discuss about reasons of each waste, one by one, and after discussion we write the reasons on the white board.
- Create counter measures:

  We ask the members to think for a while about possible counter measures and write on sticky notes and put on the white board. After that we ask to discuss about their idea. Finally we write the finalized possible countermeasures on the whiteboard.

3. Future state map

- Prioritize the counter measure:

  We use a Pick chart for prioritizing the countermeasures. We use the sticky notes and asking members to identify the place of each countermeasure in the chart with two dimensions (impact and easy to implement)
- Draw the future state

  We depict future state on another A0 by pen.
- Recalculate the metrics:

  We recalculate the lead time and write in the timeline in the future state map.
- Action plan for implementing:

  We ask the VSM manager to summarize the findings, and take responsibility for the plan for implementing the action plan.

Appendix 3 7+1 traditional wastes translated into the product development area

Waiting

- Information is waiting for people
- People waiting for capacity available (human or machine)
- People waiting for data (specifications, answers, requirements, test results approvals, decisions, releases, review events, signs)

Over production/ unsynchronized processes

- Poor synchronization as regards time and capacity (like: Completing design elements that are not needed for some time)
- Over-dissemination of information
- Redundant tasks (like: features that the customer does not see as value)
- Poor synchronization as regards content

Movement

- Lack of direct access (like: going to and from printers, meetings, other departments)
- Remote locations (like: Travel)
- Information hunting

Transport / Handoffs

- Excessive data traffic (Incompatibility of the different software and hardware systems, useless information)
- Multiple Handoffs (circulating paper work for signatures)
- Stop and go tasks/ Task switching
- Ineffective Communication

Over Processing

- Unnecessary detail and accuracy
- Unnecessary features and processes (like: Reentering data, extra copies, reinventing the wheel)
- Inappropriate use of competency

- Use of inappropriate tools/ methods
- Excessive approvals
- Excessive transactions

Inventory

- Unnecessary testing equipment and prototypes
- Excessive data storage (like: filled inboxes (electronic or paper), retaining documents beyond what is required)
- Queues on the critical path: (High system variability, Exceeding capacity utilization, Large batch sizes)

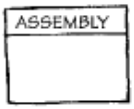
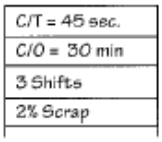
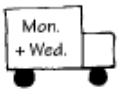
Defect and Rework

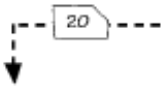
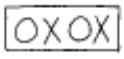
- Erroneous data and information
- Deficient information quality
- Poor testing and verification
- Engineering change orders due to errors

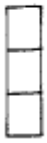
Unused Employee creativity

- Not sufficient sharing knowledge
- Not involve suppliers/ manufacturers early in the development process
- Limited authority and responsibility for basic tasks
- Poor design reuse
- Poor knowledge reuse

Appendix 4 VSM icons (Rother & Shook, 1998)

Material Icons	Represents	Notes
	Manufacturing Process	One process box equals an area of flow. All processes should be labeled. Also used for departments, such as Production Control.
	Outside Sources	Used to show customers, suppliers, and outside manufacturing processes.
	Data Box	Used to record information concerning a manufacturing process, department, customer, etc.
	Inventory	Count and time should be noted.
	Truck Shipment	Note frequency of shipments.
	Movement of production material by PUSH	Material that is produced and moved forward before the next process needs it; usually based on a schedule.
	Movement of finished goods to the customer	
	Supermarket	A controlled inventory of parts that is used to schedule production at an upstream process.
	Withdrawal	Pull of materials, usually from a supermarket.
	Transfer of controlled quantities of material between processes in a "First-In-First-Out" sequence.	Indicates a device to limit quantity and ensure FIFO flow of material between processes. Maximum quantity should be indicated.

Information Icons	Represents	Notes
	Manual Information Flow	For example: production schedule or shipping schedule
	Electronic Information flow	For example via electronic data interchange.
	Information	Describes an information flow.
	Production Kanban (dotted line indicates kanban flow)	The "one-per-container" kanban. Card or device that tells a process how many of what can be produced and gives permission to do so.
	Withdrawal Kanban	Card or device that instructs the material handler to get and transfer parts (i.e. from a supermarket to the consuming process).
	Signal Kanban	The "one-per-batch" kanban. Signals when a reorder point is reached and another batch needs to be produced. Used where supplying process must produce in batches because changeovers are required.
	Sequence-Pull Ball	Gives instructions to immediately produce a predetermined type and quantity, typically one unit. A pull system for subassembly processes without using a supermarket.
	Kanban Post	Place where kanban are collected and held for conveyance.
	Kanban Arriving in Batches	
	Load Leveling	Tool to intercept batches of kanban and level the volume and mix of them over a period of time.
	"Go See" Production Scheduling	Adjusting schedules based on checking inventory levels.

General Icons	Represents	Notes
	"Kaizen Lightening Burst"	Highlights improvement needs at specific processes that are critical to achieving the value stream vision. Can be used to plan kaizen workshops.
	Buffer or Safety Stock	"Buffer" or "Safety Stock" must be noted.
	Operator	Represents a person viewed from above.