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TOWARDS A LEAN INTEGRATION OF LEAN

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Abstract

Integrating Lean in a process has become increasingly popular over the last decades. Lean as a concept has spread through industry into other sectors such as service, healthcare, and administration. The overwhelming experience from this spread is that Lean is difficult to integrate successfully. It takes a long time and requires large resources in the integration, as it permeates all aspects of a process. Lean is a system depending on both tools and methods as well as human effort and behavior. There is therefore a need to understand the integration process itself. As many companies have worked with the integration of Lean, there should be a great deal of accumulated knowledge.

The overall intent of this research is therefore to examine how a current state of a Lean integration can be established, that takes into account the dualism of Lean regarding the technical components of Lean, as well as the humanistic components of Lean. Both issues must be addressed if the integration process of Lean is to be efficient.

Through a literature review, eight views of Lean are established. Taking into consideration historical, foundational, and evolutionary tools and methods, systems, philosophical, cultural, and management views, a comprehensive model of Lean at a group level in a process is proposed. Through two multiple-case studies, the experiences of actual Lean integrations are compared with Lean theory to establish a current state of a Lean integration. There were large similarities in the experiences but also differences due to context and the complexity of Lean as a system. The *current state* is described in:

- 9 instances of *strongly positive* findings. They are often simple tools and methods.
- 11 instances of *weakly positive* findings. They are often of a system nature in the dependencies between the Lean methods.
- 3 instances with *vague* findings. Seems to be due to lack of focus on the intent of integrating Lean.
- 3 instances of *mixed* findings. Can often be connected to personal commitment and the creation of efficient islands.
- 3 instances of *conflicting* findings. Seem to be connected to contextual factors.
- 3 instances of *insufficient data*. The indications are too few to draw any conclusions.

Accurately establishing the current state of the Lean integration process is seen as a necessary first step of a Lean integration of Lean.

Sammanfattning

Att integrera Lean i en process har blivit allt populärare de senaste årtionden. Lean som koncept har spridits via industrin till andra sektorer, så som service, hälso- och sjukvård samt administration. Den samlade erfarenheten är att det är svårt att lyckas integrera Lean. Det tar lång tid och kräver stora resurser i införandet eftersom det påverkar alla delar av en verksamhet. Lean som system beror både på verktyg och metoder så väl som mänsklig möda och beteende. Det finns därför ett behov av att förstå själva integrationsprocessen. Eftersom många företag arbetat med integrationen av Lean bör det finnas en tillräcklig mängd ackumulerad erfarenhet.

Det övergripande målet med forskningen är att förstå hur man kan beskriva ett nuläge i en Lean introduktion som tar hänsyn till dualiteten hos Lean, avseende de tekniska delarna av Lean och de mänskliga delarna av Lean. Båda frågeställningarna måste besvaras om en integration av Lean skall kunna vara effektiv.

Med grund i litteraturstudier beskrivs åtta olika synsätt på Lean. Genom att samtidigt beakta historiska, grundläggande och evolutionära metoder och verktyg, system, filosofiska, kulturella och ledarskapsmässiga perspektiv, byggs en omfattande modell av Lean på gruppnivå i en process. Genom två multipla fallstudier jämförs upplevelsen av att införa Lean med hjälp av det analytiska ramverket, för att kunna beskriva ett omfattande nuläge i ett införande av Lean. Det finns stora likheter i erfarenheterna men också skillnader på grund av kontext och komplexiteten hos Lean som ett system. *Nuläget* beskrivs med:

- 9 fall av *starkt positiva* indikationer. Dessa är ofta enkla verktyg och metoder.
- 11 fall av *svagt positiva* indikationer. Dessa har ofta systemkaraktär i beroenden mellan olika Lean metoder.
- 3 fall med vaga indikationer. Synbarligen beroende på bristande focus på syftet med en Lean integration.
- 3 fall med blandade indikationer. Kan ofta kopplas till personligt engagemang och skapandet av effektiva öar.
- 3 fall av motstridiga indikationer. Kopplas mot kontextuella faktorer.
- 3 fall av bristande data. Indikationerna var för få för att dra slutsatser.

Om ett tydligt nuläge i en integration av Lean är beskrivet, finns förutsättningar för att beskriva det som är viktigt för en Lean integration av Lean.

Preface

Every journey has to start somewhere and my journey began over two decades ago. As a new operator at a automatic machining line at IBM's plant in Järfälla, I became both frustrated and fascinated with how work was organized. Fascinated by the synergistic effects of creative people working toward a common goal, and frustrated at the inefficiencies of the plant organization. I suffered through the first attempt to organize a Just-In-Time process flow. The attempt was quickly abandoned with a shrug and a curt statement "*Doesn't work here. Only works with Japanese. They are different than us. We aren't robots*". Other attempts to organize efficiently followed in succession with names such as Six Sigma, Business Process Reengineering, Taguchi Process Control. Each abandoned as quickly as the one before. Each curtly dismissed with a "*Doesn't work*". Each time I was left with a feeling of bewilderment. Why did nothing improve? There clearly were huge potentials in the process, and still everything stayed basically the same except for the employees, who turned more cynical at every attempt to change. Many years and jobs later I was assigned as a Kaizen team leader at Scania, with the task of using the Scania Production System to quickly improve the assembly processes at the chassis assembly plant. Over a period of several years, there was a new assignment or problem every four weeks. I can't imagine a better school in the fundamentals of Lean. Hard work with clear but nearly impossible goals. Then on to the next assignment in rapid succession. Every task taught me something new. Even the ones that failed to reach their goals were good training. The power of properly implementing and applying Lean became clear. Also, through inexperience and mistakes, it became clear how complex Lean was. Where we succeeded the gains were immense. Where we failed I would experience a sense of déjà-vu, throwing me back to the days I worked at IBM. The same sense of frustration was felt by members of my group. But with one crucial difference, we didn't give up and abandon the attempt, but kept trying. And there was the epiphany! Trying and failing is a normal part of the process. As long as you learn and continue trying there is no loss. Understanding Lean comes from hard work, results, reflection and study. There are no shortcuts.

Since almost three years, I have had the opportunity to train as a researcher. In many ways it is the same as trying to apply Lean in a process. Try over and over again and learn at every step. Even though the topic of my research is familiar, there are new issues to contend with. How do you define Lean? How do you research Lean? How do you present the new knowledge you discover?

This thesis therefore has several purposes. Firstly and most importantly, it is the vessel by which to convey my findings and further analysis of the case studies, that are the basis for my research. Returning to the raw data opened up new questions and avenues of exploration in the attempt to unify the knowledge they gave. Secondly, it is a halfway milestone on the journey to a full PhD. Summing up and concluding many days, weeks and months of reading, writing and reflecting, my thesis symbolizes the initiating phase of my journey. Thirdly, my thesis establishes the foundation for my future research of the PhD, establishing a stable starting point for the next half. The basis for future questions and avenues of exploration is established.

And thus, we take the next step on our journey.

Acknowledgements

Any PhD student will confirm that writing a thesis is sometimes a lonely job. Even so, numerous people have helped in various ways to make it possible. They have all gone far beyond the call of duty and obligation to help. For this I am grateful.

The case study companies for their patience and effort. Scheduling and rescheduling visits can try the patience of the best (and did).

Colleagues and friends at Scania. For your ceaseless efforts in the integration Lean in an ever-changing business.

Fellow PhD students at Innofacture, faculty members, and MDH. We are all in this together. My supervisors, Prof. Anders Fundin, Prof. Tomas Backström and Doc. Lars Hanson. For all your help and advice. Without you I would have been lost at sea.

My family, Eva, Emma and Erik. Love you guys. Always and forever.

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Publications

Appended papers

Paper I

Osterman C. and Fundin A. (2014), *Exploring approaches how to measure a Lean process*, Journal of Management, Informatics and Human Resources 47(3), pp. 132–142 (earlier version presented at and published in the conference proceedings at the 16th QMOD–ICQSS, Quality Management and Organizational Development Conference 2013 in Portorož, Slovenia).

Mr. Osterman initiated the paper, designed and performed the studies, and was the main and corresponding author of this paper as well as the presenter. Prof. Fundin reviewed and quality-assured the paper.

Paper II

Osterman C., Svensson Harari N. & Fundin A. (2014), *Examination of the flexibility paradox in a Lean system*. First presented at the 58th EOQ conference 2014 in Gothenburg, Sweden, and published in the conference proceedings.

Mr. Osterman and Mrs. Svensson Harari initiated the paper, designed and performed the studies, in equal amount. Mr. Osterman was the main and corresponding author of the paper, as well as the presenter. Prof. Fundin reviewed and quality assured the paper.

Paper III

Svensson Harari N., Osterman C., Bruch J., Jackson M. (2014), *Flexibility in Lean Mixed-Model Assembly Lines*. First presented at the APMS 2014 International Conference (Advances in Production Management Systems), in Ajaccio, France, and published in the conference proceedings.

Mr. Osterman and Mrs. Svensson Harari initiated the paper, designed and performed the studies in equal amount. Mrs. Svensson Harari was the main and corresponding author of the paper, as well as the presenter. Dr. Bruch and Prof. Jackson reviewed and quality-assured the paper.

Additional publications I

Bengtsson M., Osterman C. (2014), *Improvements in vain – The 9th waste*

First presented at the 6th International Swedish Production Symposium 2014 in Gothenburg, Sweden, and published in the conference proceedings. Editor(s): Stahre, J., Johansson, B., and Björkman, M.

Early definitions

Given the scope and limitations of this thesis, certain terms are defined. In some cases their meaning is either more specific or limited than in normal use. In other cases there is a risk for confusion with similar terms. Some terms are used in many research fields and have different definitions depending on the field. In some cases terms are defined in relation to other terms.

Continuous Improvement (CI)

Here defined as the *organized efforts to change the state of a situation* from a Normal Situation (see below) to a defined desired state. Consistently achieving the desired state is seen as an improvement when compared to the previous situation. In CI “continuous” can describe the effort of change, the size of the change usually meaning “small”, or the never ending “intent to change” depending on context. Combinations of the meaning exist.

Culture

In this thesis “Culture” is used in its connection to Lean. The meaning is limited to capturing the transformation of ideas (see *Philosophy* below) into behaviors of either individuals or at a collective organizational level.

Flexibility

A property of the currently chosen method of performing a task. *The potential of changing said method with little consequence in time, resources or cost, if conditions or requirements change* (Upton 1994). For the purpose of this paper it is defined as a choice of what properties of the method will be changeable, during the selection of a method.

Industrial Process

This term is used in the case descriptions to distinguish cases describing processing industries, such as food production or material production, which are continuous in nature, from the more generic term “Process” (defined below).

Integrating Lean

Defined in this thesis as the process of integrating or replacing a current production system with a Lean production system. This process can take place over a long period of time (several decades). Can also be the responsibility of a central Lean support function, but many more approaches exist.

Lean and Lean Production

The production tradition based mainly on Taichi Ohnos (1988) findings, where production is classified as *value-adding* activities and *waste* (non value-adding activities). The main purpose is to increase the proportion of value-adding activities in a process using methods such as pull, flow, standardized work, leveling and continuous improvements, among others. Value is based on the end customers perception giving an outside reference to a process. There is a strong humanistic side to Lean as well, further discussed in chapter 2.2.

Manufacturing Process

This term is used in the case descriptions to discern cases describing manufacturing industries producing equipment or machines, for instance. The manufacturing process is typically either station based or based on production lines. Manufacturing process is here distinguished from the more generic term “Process” (defined below).

Normal Situation

In Lean terms a defined situation where a “Process” is operating as intended. An unintended state in the process is correspondingly defined as a deviation or problem.

Philosophy

In this thesis “Philosophy” is used in its connection to Lean. The meaning is limited to understanding the ideas behind Lean at a deeper level. This includes the connections and dependencies within a Lean system, as well as the resolution of dilemmas and paradoxes which may arise. This understanding is on an individual level and is the basis for Lean Culture (see Culture above).

Problem Solving (PS)

Here defined as the *organized efforts to change the state of a situation* from a unintended state to a defined desired state, reestablishing the Normal Situation.

Production System

There are several definitions of production systems as well as some discussion of the hierarchical aspect of production system versus manufacturing system (Bellgran and Säfsten 2005). For the purpose of this paper the meaning of production system is limited to *the interrelating principles and methods used to organize or create an efficient and effective process*.

Process

This is here defined as *the organized effort to achieve a result* in general. There are several preconditions for a process such as purpose, resources, guidance, and intent. Often but not always there is a recipient of the result which may be used as an external reference by which to measure the process.

Standardized Work (SW)

Here defined as *lean tools and methods with the aim of providing of stable working conditions*, where members of a group perform work in a prescribed manner achieving predictable results. The tools and methods may include concepts such as work standards, element sheets, 5S, takt time references, follow-up systems, training methods, etc.

System

In this thesis defined as the interrelation and dependencies of the tools or methods of Lean. For instance, a clock is a system. A bag of parts is not a system, even if all the parts of the clock are in the bag. The interrelations of Lean are seen as the same.

TPS

Toyota Production System is in some literature seen as different from Lean production. In other literature, TPS and Lean are seen as the same thing or very similar (Dennis 2002; Schonberger 2007). There can be no doubt the Lean originated in the practices of TPS. Fujimoto (1999) for instance sees Lean as a reinterpretation of TPS. Therefore, based on the definition of Lean used in this paper, Lean and TPS will be seen as similar if not exactly the same, and TPS will be regarded as a subset of the Lean tradition.

“Do not seek to follow in the footsteps of the old masters,
seek instead what these masters sought.”
Matsu Basho (1644-1694)

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1 Introduction

This chapter gives the background driving the objective of my research. It covers some of the topics that arise from research in general and research in Lean in particular. Academic and industrial relevance are also discussed.

1.1 Background

Much of the contemporary Lean literature seems to agree that the integration of Lean is problematic. Hines et al. (2010), for instance, states that achieving sustainable benefits from Lean is difficult. Liker and Convis (2012), in comparisons to Toyotas track record, finds that despite much effort over the past decades, no one has achieved the same level of sustainable performance as Toyota. Sörqvist (2013) claims that *”Far from every Lean implementation is successful. Many businesses that begin to work with Lean do not achieve their targets and expectations* (my translation)”.

Similarly, *“the majority of attempts to implement lean production end in disappointing outcomes”* (Mann 2005). Commenting on the apparent backsliding of Japanese companies, Schonberger (2007) notes that for many companies, Lean seems to be only skin deep, with a heavy reliance on external consultants. Taking a local perspective in the anthology *Lean i arbetslivet*, a number of authors mention various difficulties of Lean implementation in Swedish society, healthcare, and industry (Sederblad 2013).

Over forty years of research, many different obstacles and problems in the integration of Lean have been noted in papers and literature (Stone 2012). For instance, management commitment, lack of resources and planning, a single-minded focus on cost and lack of customer orientation, focus on methods and tools instead of on people and organization, a fundamentalist view, short-sightedness and a lack of connection with the strategies and goals of the organization, are listed as reasons for failure to implement Lean (Sörqvist 2013). The buy-in of management is noted as important (Emiliani 2007). The commitment to Lean also has to be long term, as is also mentioned (Liker and Hoseus 2008). It can therefore be concluded that a management group looking for a quick fix may be seen as another obstacle to successful Lean integration.

Indeed, Taiichi Ohno (a founder of TPS) himself noted that companies striving to integrate TPS, but for instance keep the standardized depreciation of equipment and cost calculation as a measurement of equipment value, are actually increasing costs unnecessarily (Ohno 1988). Thus accounting methods may also be seen as obstacles to successful Lean integration. Following this, the general economic models used in a process may also be seen as obstacles to proper integration of Lean, as traditional standard costing drives improper behavior and increases cost (Maskell et al. 2011; Huntzinger 2007). Other accounting measures are needed showing the financial impact of Lean on a detailed level, promoting flow and exposing waste. Most importantly the measures should motivate continuous improvements in the process.

Academic research has also proposed other problems in Lean, such as metrics (Pettersen 2009; Osterman and Fundin 2014) and definitions, where the difficulty lies in how to define

what Lean is and not (Netland 2012). The confusion of definitions dates back to even before the term “Lean” was coined by Krafcik (1988). Depending on the author's perspective, different terminology has been used to describe the same phenomena. Adding to the confusion, terminology has changed over time as well. For instance, Shimada and Macduffie (1986) used the term “Fragile” in their research preceding the researchers in the foundational International Motor Vehicle Program (IMVP), in which (among many others) Krafcik was involved (Holweg 2007). Other authors have used “TPS” or “Just-In-Time” (JIT) manufacturing (White et al. 1999), or indeed even “The KANBAN system”. Some of the early studies have used the term “Japanese Management” or “Japanese Manufacturing” in general to describe what we today call Lean (Keys and Miller 1984; Keys et al. 1994). The term “Lean” will therefore be used as a cohesive term which is here meant to encompass the preceding terminology, clearly connected to what we today call “Lean”. Also, apart from the problem of definition, some of the other problems stem from the various views used to explain Lean. For instance, the importance of creating a culture in the organization that supports the implementation of Lean is seen as vital (Liker and Hoseus 2008). Mann (2005) connects this to the integration of a specific Lean management system in order to sustain the conversion from a batch culture to a Lean culture.

To conclude, there seem to be many problems and obstacles preventing a successful integration of Lean in a process. Many of these problems have been well explored and verified in real life. Others are more of an academic nature. Integrating Lean in a process seems to require extensive resources, consultants, a “Lean temple” of some kind, and a great deal of faith. In many cases, the integration of Lean seems to be anything but “Lean”.

So what is the underlying problem?

1.2 Problem Statement

There are authors that criticize Lean as a concept. For instance, Björkman and Lundqvist in the anthology *Lean i Arbetslivet* emphasize the need to combine Lean with formal work science criteria (Sederblad 2013, Chapter 1). Other authors look at the application of Lean and find problems at a less abstract level, such as leadership and training. (Liker 2004; Mann 2005; Flinchbaugh and Carlino 2006). If one studies the problems and obstacles noted in the literature when integrating Lean, most authors seem to agree generally on what Lean is, at a concept level. The problems and obstacles that are described seem to occur in the application of the principles in a context (Flinchbaugh and Carlino 2006; Jablonski 2001).

Going back to the roots of Lean, Taiichi Ohno emphasizes the importance of understanding a situation fully, “*comprehending its nature*” (Ohno 1988). In the foreword to Toyota Production System, an integrated approach of Just-In-Time, Taiichi Ohno also notes that “*even in Japan it was difficult for the people from outside companies to understand our system; more difficult still for foreigners.*” (Monden 2012). Similarly, Katsuaki Watanabe, president of Toyota, concludes that “*Two or three months isn't a long enough for anyone to*

understand the Toyota Way. The managers may have understood what's on the surface, but what lies beneath is far more extensive" (Liker and Hoseus 2008)¹

In his study of the Toyota Production System (TPS) and how it could be applied in other companies, Shiego Shingo states that TPS cannot be applied without an understanding of its principles (Shingo 1989). It is therefore reasonable to conclude that *understanding* is key to a successful integration of Lean in a production system. Following this, it is important to specify what is meant by *understanding*. Understanding tools and specific methods of Lean on a concept level is quickly accomplished. It is suggested that it will take you about 20% of the way to a successful implementation of Lean (Mann 2005). Based on the reasoning above one may conclude that understanding Lean as an interrelated complex system takes much longer.

When Gary Convis, president of Toyota Manufacturing in Kentucky, was asked how long it takes to teach a manager hired from outside the company to be a Toyota manager, he replied "*about ten years*". By this he meant that learning the obvious parts of a production system, such as skills, quality and process requirements, is relatively easy. But to learn how to behave correctly at all times, especially under stress, takes much longer (Liker and Hoseus 2008). Womack and Jones (2003) go even further, claiming that for Lean production to prevail requires a wide public understanding of its benefits. From a management perspective Emiliani (2007) lists 10 common errors in Lean implementation, such as management system, leadership behaviors and participation, metrics, time horizon, etc., based on a lack of understanding of what Lean is and what it entails.

Altogether this indicates that the underlying problem may be a lack of deeper understanding of Lean. This is opposed to superficial understanding of tools and methods, and is not accomplished quickly or without effort. It also indicates that attempting to guide a Lean integration without this deep understanding may be difficult, if not impossible. It is therefore feasible that many of the perceived problems in Lean implementation are simply due to the combination of knowledge and practical ability of the people responsible for the integration. If it was possible to understand the state of Lean integration on more than a superficial level, much would be gained. Establishing a current state of a Lean integration is necessary to assess the efficiency of the integration. This is the means to answer questions such as, "Are we spending resources where needed?" or "Are we getting the effect we want?" or "What are we forgetting?" In total, these indications lead to the objective of the research.

1.3 Research Objective

Taking a pragmatic approach, the intentions of this thesis are to explore how a current state of a Lean integration may be described. The aim of this thesis is therefore to connect the various applications of Lean and ensuing problems in different processes and conditions, to an understanding of Lean as a system.

¹

Secondary source referring to "Lessons from Toyotas Long Drive", Harvard Business Review, 2007, pp.74-83

1.3.1 Narrowing the scope, an early limitation

Research in Lean may be difficult to limit. All parts of a successful implementation of a Lean production system are interlinked and mutually dependent (Monden 2012). Consequently, before specifying research questions, certain limitations have to be chosen. The focus of the research will therefore be on the practical application of Lean, specifically at the level of the smallest organizational unit within a process (i.e., a group or a team). There are many other aspects of Lean, such as the development of inter-firm networks, or the organization of cross functional management teams, for instance (Monden 2012), which may also be seen as important, but which falls outside the scope of this thesis.

The lowest organizational level acts as a common denominator

The group level is arguably the organizational level where the main results of a process are created. One may therefore argue that, if integration of Lean is to be successful, it has to be largely based on the needs and problems relevant at the group level of an organization. Much literature has focused either on the management of Lean, creating flow, or the specific tools and methods of Lean. The group level of a process remains curiously unexplored in much Lean research and ought to have a huge potential if defined and explored (Osterman and Fundin 2014). For the purpose of this thesis, the group level in a process will therefore act as a common denominator for the studies, enabling comparison of cases. It will also act as a limitation for views taken in the frame of reference.

1.3.2 Research question

The research question evolved over the course of several years, through a combination of literature studies and observation of Lean in practice, in many different circumstances. A normal process is often easy to quantify, but how do you assess the current state of a Lean integration? This leads up to the research question:

RQ: *How to understand the integration of Lean in a process?*

The research question attempts to establish a way of capturing the current state of the Lean integration in a process. Much literature describes an integration of Lean in a simple cookbook fashion (Sayer and Williams 2007; Dennis 2002; Rother and Shook 2004). Other literature describes the integration of Lean as a concept (Womack and Jones 2003). Although all the descriptions convey lessons and methods, they do not seem to capture the interrelated complexity of the current state where many factors are important. The RQ aims to take that angle.

The research question is limited to the group level of a process. The current state of the integration of Lean may be put in relation to resources spent in integration, as well as the aim and purpose of the integration. With this understanding it should be possible to determine if the integration of Lean is efficient or not.

1.3.3 Specific delimitations

The research will be limited to the study of larger Swedish companies active in industrial processing or the manufacturing industries. The industries are experienced in Lean production within their context, meaning they have been attempting to integrate Lean over several years. Also, the industries have developed a visualization or a model describing the Lean production system in their own terms, a so called XPS (Netland 2012).

As the research will focus mainly on the lowest organizational level in a process, the individual and group level of the organization, the managerial practices and process flows will be studied only in connection to individuals and groups. The consequence of this limitation is that a deeper description of higher managerial practices and methods and tools used to create continuous flows through a process will not be attempted, except when they connect directly to the group level. This limitation will have great impact on the frame of reference and the analysis.

1.3.4 Contributions

The academical contribution is to expand the understanding of the integration of Lean, given a pragmatic view based on the group level. The purpose is to enable a deeper interpretation of phenomena observed during case studies and other research. This would also allow for a better analysis of collected data, as well as a deeper understanding of the underlying causes of perceived phenomena.

The industrial contribution is, through better understanding, to be able to predict and to avoid the obstacles of integration. Lean has obvious benefits for a process, but is limited by the level of understanding of those responsible for the integration. An approach that takes into account the limitation in knowledge and experience in the target process and is applied at the group level of an organization, should allow for a more successful and sustainable application of a Lean production system.

1.3.5 Outline of the thesis

The first section explains the terms used and puts them into relation to each other. From this basis, Chapter 1 explains the problem in general terms and builds the case for the research question. Chapter 2 presents the theoretical foundation and limitations. Chapter 3 describes the design of the research methods of the multiple case studies, the case study protocols and the semi-structured interviews. Chapter 4 provides a summary of the studies and the results of the published papers. Chapter 5 contains further analysis of the studies. Chapter 6 answers the research question and concludes with a discussion of the quality of research and future research.

2 Frame of reference

This section describes the theoretical foundation for the thesis, structured around eight different interconnecting views of Lean. Each view covers a different angle of Lean and together they give a comprehensive if not complete picture of the questions that have to be understood when integrating Lean in a process.

2.1 Different views of Lean

It has long been known that there are many views (a proverbial jungle) of Lean, and each view carries at least a partial explanation (Keys and Miller 1984). Even though Lean can be seen as one of many organizational recipes (Rövik 2000), and it can be compared for instance with Six Sigma, Business Process Reengineering and many others, the concept of different recipes (sometimes contradictory) may also be used *within* Lean. Indeed, to fully realize the benefits of Lean it has been argued that a complex and holistic view must be taken (Goyal and Deshmukh 1992; Bhasin 2011a). Sörqvist (2013), for instance, notes cultural, leadership, quality, customer, flow, transformation and efficiency aspects when describing Lean.

As the framework of the thesis, a structure of different views is used simply to sort out the different angles that may be used. The views have different focus and are interdependent. Understanding Lean from different views, in the thesis, means:

- *Historical view*: Looks into some factors that influenced the founders of Lean. These factors explain part of the underlying reasoning the founders had in their struggle to form a production system.
- *Foundational view*: Thoughts and ideas most influential in forming what would later be known as Lean.
- *Evolutionary view*: Illuminates the practical development of the various aspects of Lean.
- *Tools and methods view*: Explores various methods. Focus is limited to methods acting mainly on a group level in a process.
- *Systems view*: Resolves some of the interdependencies of the various Lean tools and methods.
- *Philosophical view*: Explores apparent paradoxes and thought processes, ideas, and dilemmas associated with Lean.
- *Cultural view*: Examines some of the factors that hold together a Lean production system, from a human behavior perspective.

- *Management view*: Looks into the responsibilities of management in providing proper directions, balance, incentives, and conditions for a Lean integration.

Note: Relationships between all of these views will be discussed in chapter 3.2.

The selection of the views described above is based on factors that mainly influence Lean at the group level. Other views are possible, for instance a strategic, consumer, societal, ecological, flow, or even ideological view (Bhasin 2011b). However, these fall outside the scope of the thesis. Also, the ambition of the frame of reference is not to fully define Lean, impossible given inherent limitations in this thesis. Instead, the intention is only to illustrate the complexity of Lean integration through exploration of various views.

To aid in this, all views are summarized with a number of aspects directly drawn or with simple logic derived from, that particular view of Lean. These summaries do not aim to add anything new. They should be seen as abstract aggregations of underlying reasoning. These aspects will be used later in a deeper analysis (see chapter 5). It is also important to state that the views and aspects presented here, should not be seen as a closed finite system, but only represent a possible current level of understanding. It is highly probable that, as knowledge of Lean increases, new views will be added and further levels of complexity will be found. The frame of reference is intended to accommodate these new views into the analysis framework, to enable an even deeper understanding of Lean production.

Since Lean is a multilayered complex system with strong elements of human interaction, a broad view is here argued as necessary to somewhat define what “understanding lean” is, in order to grasp the obstacles for its integration in a process. Adding to the challenge is also the use of Japanese terminology. In Lean research one inevitably comes across a proliferation of Japanese terms. Some terms have become part of the lingua franca of the Lean research community and are left as they are. Examples: *Andon*, *Kanban*, and *Heijunka*. Other Japanese terminology has not come into common use, for instance the *Nagara* system, meaning *doing two things at once* (Shingo 1989), or *Kadoritsu*, which can mean either *Operational availability* or *Rate of operation*, depending on the Japanese spelling and context (Ohno 2013). In such cases the terms are not written out, but are instead translated.

The reviewed literature and research should by no means be seen as exhaustive. The field is far too vast for this. Still, a case can be made for the impact of the chosen literature. Of the hundreds of research papers and dozens of books published each year, only a few actually seem to influence industry. The selection of reviewed literature is therefore based on the Lean research tradition, balancing academic publications and influential practice-based publications, as well the author’s own experience.

2.2 Relating the different views of Lean

It is argued above that a number of different views are necessary if attempting to understand Lean. The concept is multifaceted and interrelationships are not always obvious, even if some concepts seem simple to grasp, taken one at a time. Still, since Lean is regarded as one concept, it is here argued as necessary to also establish a relationship between the different views, as every view highlights different aspects of the same phenomena.

Lean has been described as a balance of two ideas. Liker and Hoseus (2008) describe it as an intertwined DNA of a people-value stream and a product-value stream. Liker and Franz (2011) describe it as a combination of mechanistic (machine) thinking and organic (systems) thinking. Such a balance is actually stated in the first research paper published on TPS (Sugimori et al. 1977), describing it as the combination of JIT and respect for people. This twofold balance of technical and humanistic features of Lean is essential for an integration. Using the simple term *duality* of Lean, as discussed by Halling (2013), the following model (figure 1) is proposed to illustrate the relations between the different views as seen within the frame of reference. The image of the model will be used throughout, to symbolize the view being discussed or analyzed.

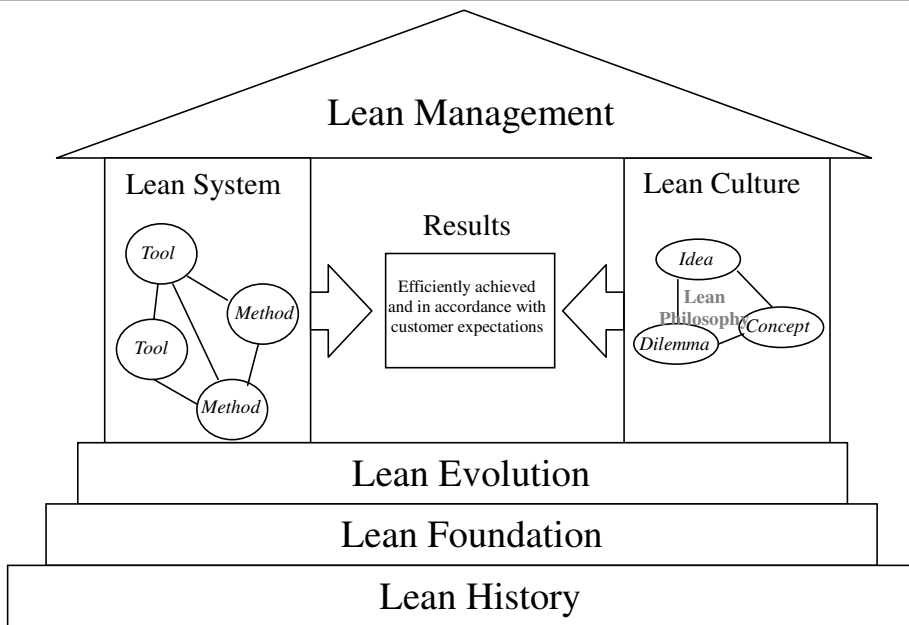


Figure 1. Relating different views of Lean

Explanation of the model

Beginning with historical methods and principles, the foundation of lean comes largely from the Toyoda family, as well as Taiichi Ohno and Shiego Shingo, among others, from which Lean has evolved into what we see today. These three views form the foundation of Lean. Based on the foundation we find the duality of Lean. There, in the left pillar, the Methods and

Tools view describes the content of the building blocks and the System view of Lean describes the interconnections and dependencies of the methods. Together these form the technical or mechanistic part of Lean.

The right pillar describes the humanistic or organic part of Lean with the philosophical view of ideas, concepts, and dilemmas forming the content of the humanistic pillar and the cultural view illustrated by the connections and dependencies between the ideas that in turn form the behaviors of the organization. When in harmony, the humanistic and technical pillars of Lean achieve efficient results in accordance with customer expectations, as illustrated by the two middle arrows of the model.

Bridging the humanistic and technical pillars is the management view of Lean with the task of unifying the system and giving its purpose and sustainability. An essential part of Lean management is resolving conflicts, dilemmas, and problems, in both the humanistic and technical part of the system, as well as balancing the system needs and the external customer needs. This is of course an idealized image. Reality is far more complex. Still, it serves the purpose of the thesis.

2.3 Defining Lean

Going through Lean literature one inevitably is struck by the lack of a clear definition (Modig and Åhlström 2012). What exactly *is* Lean? Hines et al. (2004) notes considerable confusion about what is Lean and what is not. Pettersen (2009) finds that no academic consensus can be found either of a definition of Lean, or of what characteristics are to be associated with Lean. Without a clear definition, what are we trying to research? The problem is not that there are no definitions but quite the opposite (Wilson 2010). There are too many.

“If no improvement technique is excluded then defining what actually constitutes the lean production process becomes extremely difficult” (Lewis and Lewis 2000).

It seems that, depending on the researcher's own experience (or lack thereof), political view, research tradition, temper, inclination, or perhaps even shoe size, Lean can mean just about anything.

To some extent this seems typical of a successful phenomena. As Lean spreads across the world it is applied to many different processes. Some successfully and some not (Jablonski 2001). However, even though Lean is difficult to define on an abstract level, there is remarkable consensus among practitioners about many of the practical aspects (Pettersen 2009). With the more practical approach of an Industrial Engineer, the definition problem becomes less problematic. Consequently, in order to conduct research in Lean it seems vital that reality be the benchmark, as there seems to be agreement on the practices of Lean, even though there is no agreement on the exact definition (Pettersen 2009; Goyal and Deshmukh 1992).

In this light, the definition of Lean used in this thesis, is that *Lean can be seen as a production tradition* with roots mainly in Taiichi Ohno's developments and findings. In this tradition, production is classified as value-adding activities and waste (non value-adding activities). The

main purpose of Lean is to sustainably increase the proportion of value-adding activities when compared to non value-adding activities in a process using methods such as pull, flow, standardized work, leveling, and continuous improvements.

An axiom in the tradition of Lean is that value is based on end customers' (consumers') perceptions (Womack and Jones 2003; Liker 2004), thus giving an outside reference to a process.

Going back to the coining of the phrase “Lean” by (Krafcik 1988), some aspects are important. According to interviews given by Womack et al. (2007), the term was supposedly coined during a discussion around a blackboard where John Krafcik (paraphrased by author) stated “They do more with less of everything! Let’s call this Lean.” The label “Lean” caught on and has grown in popularity. Krafcik was referring to buffers and a lack of buffers as can be read in his paper *Triumph of the Lean production system* (Krafcik 1988), where a lack of buffers in production was termed to be “Lean” in the sense of “Fit” and buffers in production was seen to be excess “Fat” or “Robust”. The original meaning was not as we see “Lean” today but of a more limited scope.

Also, what is referred to as “Lean” can be seen as an Americanized interpretation of a phenomenon that originated in Japan. More specifically the phenomenon originated mainly from one company, Toyota. However, since then, the body of published research has grown, as well as the number of processes aiming to integrate Lean, turning it into a well-established field of research with many aspects. A few of these aspects shall form the frame of reference.

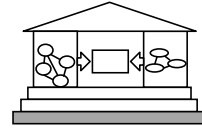
2.4 Different views of Lean

The analysis is based on examination of different views of Lean. The different views are fairly well established in Lean research, but no attempt to combine the views into a comprehensive structure has been found. Nevertheless, it is here argued that each view of Lean gives information or raises questions unique to that perspective. Each view is examined and then summarized into a few concise aspects. These aspects are later used in the analysis to understand what the studies that form the basis of this thesis can tell us. The intent of the aspects is to condense the discussion of each view into a few succinct points to be used in the following analysis, without adding or subtracting too much from the discussion. To give some orientation of the relation of each view being discussed, an image of the system of views (Figure 1.) is used to give clarity to the reader.

For each view there will be several brief descriptions of influential factors, each followed by a conclusion in the form of an aspect. The aspects will be summarized at the end of each view and form the basis for the later analysis. The coding of the aspect will correspond to the first letter of the Lean view. The first aspect of the historical view of Lean will be coded H1, the third aspect of the system view of Lean will be coded S3, etc. The order of the aspects do not signify importance. Differentiation is the purpose.

2.4.1 Historical view of Lean

Lean has roots. It would be easy (and simplistic) to assume that Lean sprang to existence solely out of thoughts and ideas developed by Taiichi Ohno and the Toyoda family. They were all diligent students and influenced by outside knowledge. An understanding of Lean therefore requires at least some effort to understand the ideas that we know influenced them.



It is interesting to note that some of the production practices developed a century ago are still valid today. Defining understanding of Lean therefore to some extent means that a historical view is needed, as knowledge was accumulated over time and based on what others had accomplished before (Wilson 2010). Knowing the historical context is also seen as important in order to understand that Lean is, not only tools and techniques giving results, but is of a more complex nature (Lewis and Lewis 2000). The decision of how far back in time it was relevant to go was based on the foundational view of Lean (see below). The historical view should therefore briefly illuminate people and factors with a major influence on the founders of lean, through either literature or direct contact. There are of course many historical influences as the founders were all voracious readers. And so the selection is limited further to influences with a direct connection to practices we see today as stated by the founders themselves. Chief among such influences are works by Ford and Taylor (Fujimoto 1999).

2.4.1.1 Taylor

Even though many of Taylor's theories have fallen into disrepute (Adler 1993), there is no denying their influence on the industrial rationalization movement (Sandkull and Johansson 2000). Throughout history, the properties of "how" work was done had been left to the people doing the work (Dennis 2002). Based on his own experience as an apprentice and further studies and experiments, F.W. Taylor's insights give us the first two aspects of the historical view of Lean:

- *Work can be objectively studied and described in a work standard.*
Using scientific methods and experiments as a base and taking into account differences in human physiology, the "best way" to perform a task could be defined, based on facts and measurements.
- *Standardization of work enables synchronization of effort.*
The results of a process depends not only on the effort of the individual effort of workers, but also the organization of the process where interfaces between the different steps in a process can be defined as a consequence of the work standards.

2.4.1.2 Ford

In his development of the Toyota Production System, Taiichi Ohno stated that he was greatly inspired by Henry Ford (Ohno 1988). Since much of what we today define as Lean has its

roots in the Toyota Production System, it is to some extent important to understand Ford's methods and principles (Dennis 2002).

Ford had been searching constantly for ways to reduce the cost of manufacturing cars. The best time for assembling a chassis using stationary assembly was twelve hours and twenty-eight minutes. This was far from what was necessary for car prices to go down. In search of a possible solution, Henry Ford had studied meat-dressing in the great slaughterhouses of Chicago. They used an overhead trolley system to carry the animal carcasses between dressing stations, thereby increasing the amount of work done by one butcher during a shift. This principle of moving the work to the worker was first tried in the assembly of the flywheel magneto. Extensive testing took place in order to find the right speed of the moving assembly line (Ford and Crowther 1922).

“The speed of the moving work had to be carefully tried out; in the fly-wheel magneto we first had a speed of sixty inches per minute. That was too fast. Then we tried eighteen inches per minute. That was too slow. Finally we settled on forty-four inches per minute. The idea is that a man must not be hurried in his work—he must have every second necessary but not a single unnecessary second.” (Ford, Crowther 1922)

Further experiments to optimize the height of the assembly line and the subdivision of work tasks, led to the total time required to assemble the fly-wheel going from around twenty minutes to around five minutes, resulting in a four-fold increase in productivity. Next, these results were applied to the chassis assembly. The first experiment used a rope and windlass system to move the chassis forward with a six-man team. The time required to assemble the chassis went from over twelve hours of labour time per chassis to just under six hours. Further experiments and the adoption of “waist high” work and subdivision of work resulted in a total reduction of labour time per chassis to one hour and thirty minutes in total. Lessons learned from these experiments were later formalized into Ford's principles of assembly. The following quote is lengthy but important, as it illustrates an important step in Lean production, from experiment to principle. This is an early example of what is defined as dual-layer problem-solving (Fujimoto 1999).

“The first step forward in assembly came when we began taking the work to the men instead of the men to the work. We now have two general principles in all operations—that a man shall never have to take more than one step, if possibly it can be avoided, and that no man need ever stoop over. The principles of assembly are these:

- (1) Place the tools and the men in the sequence of the operation so that each component part shall travel the least possible distance while in the process of finishing.*
- (2) Use work slides or some other form of carrier so that when a workman completes his operation, he drops the part always in the same place—which place must always be the most convenient place to his hand—and if possible have gravity carry the part to the next workman for his operation.*

(3) *Use sliding assembling lines by which the parts to be assembled are delivered at convenient distances.*

The net result of the application of these principles is the reduction of the necessity for thought on the part of the worker and the reduction of his movements to a minimum. He does as nearly as possible only one thing with only one movement. The assembling of the chassis is, from the point of view of the non-mechanical mind, our most interesting and perhaps best known operation, and at one time it was an exceedingly important operation.” (Ford, Crowther 1922)

Based on Ford's, work, the second two aspects of the historical view of Lean become clear.

- *Continuously experiment to find pragmatic solutions to defined problems.*
In the case of Taylor and later Ford, experiments were used and the results of these experiments were carefully noted and led to further experiments. The purpose of these experiments was not just to generate further knowledge, but to solve real problems.
- *Results lead to practice. Practice leads to principle.*
The end result of the experimentation led to practical solutions which were scaled up and applied in other situations. This was made apparent by the example of methods used for the fly-wheel assembly being transferred to the assembly of the body of the car. When this is done, successful solutions can be redefined as principles as indicated in the example above.

2.4.1.3 Concluding the Historical view of Lean

The end of the nineteenth and beginning of the twentieth century was a dynamic and volatile period in the development of different production systems. With the clarity of hindsight it is easy to underestimate the challenges of developing this ostensibly simple insight and the consequences it would have. It is possible to include other perspectives and actors in an historical view. But in the selection above, Taiichi Ohno himself attributes many of his ideas to H. Ford. Ford was influenced by ideas pioneered by F.W. Taylor (Dennis 2002), so this selection seems reasonable. The aspects of the historical view of Lean will be used in the analysis (Chapter 5) and are as follows:

H1. Work can be objectively studied and described in a work standard.

H2. Standardization of work enables synchronization of effort.

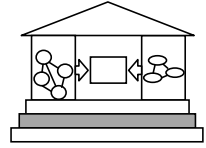
H3. Continuously experiment to find solutions to pragmatic problems.

H4. Results lead to practice. Practice leads to principle.

Influences of the historical view of Lean can be found in the reasoning of the founders of Lean (Ohno and Mito 1988; Ohno 2013). However, the insights of Ford and Taylor were known to many in the world at the time. The historical view is necessary but not sufficient. A foundational view of Lean is required.

2.4.2 Foundational view of Lean

A pragmatic approach and sense of self reliance combined with reflection and insights into human nature defined the people who founded Toyota. This lies behind the purpose of many of the parts of the Toyota Production System and later, Lean. Through selective adoption and adaptation to local conditions it can be said that TPS captures ideas from many sources and is thus neither purely original nor totally imitative but is a hybrid production system (Fujimoto, 1999). A foundational perspective is therefore needed to further understand Lean.



2.4.2.1 Sakichi Toyoda

What is today seen as Lean in many ways has its roots in the work and ideas of Sakichi Toyoda (Liker 2004; Womack and Jones 2003). As an inventor of automated looms he had a problem with thread breaking, causing the automatic loom to produce defective product until the machine was stopped and the thread mended. Sakichi Toyoda invented a device called a *jido*, which detected when the thread broke and stopped the process so that it could be repaired (Ohno 2013). The idea was to incorporate some level of human judgment into automation. This was later incorporated as part of the Toyota Production System called Jidoka, automation with a human element. It developed the meaning of “the avoidance of defects”.

Perhaps more subtle but of equal importance for the development of Lean, Sakichi Toyoda was a self-taught inventor, relying strongly on practice, with a hands-on attitude coupled with deep reflection. First-hand observation and self-sufficiency was essential to this (Ohno 1988). This attitude carried over to what was to become Toyota (Liker 2004) and was further established as *Genchi Genbutsu*, where Genchi means “actual location” and Genbutsu means the “actual material or product”. The interpretation at Toyota is “*going to the place to see the actual situation for understanding*” (Liker 2004). The first two aspects of the foundational view are:

- *Stop a process when a problem is detected and correct the problem.*
Although it was first manifest as a device to stop the shuttle in an automatic loom, the underlying meaning can be seen as mistake proofing or building in quality in the process. This frees up resources from monitoring a process, to performing value-adding work instead (Liker 2004).
- *True understanding of a situation is based on direct observation combined with deep reflection.*
This is the ability to, without bias, observe a situation or process combined with the ability to reflect on what is seen, in order to understand the true state of the process (Ohno 1988). The approach is, to not rely on written reports and other individual’s assessments of a situation. It can be directly traced to Sakichi Toyoda. This approach can also be seen as a prerequisite for creative thinking and problem solving.

2.4.2.2 Kiichiro Toyoda, Eiji Toyoda, and Shoichi Saito

Continuing in the spirit of his father, through experiments, reverse engineering and selective adoption of the Ford system (Fujimoto 1999), the first president of the Toyota Motor Company, Kiichiro Toyoda, is attributed with the idea behind the concept of Just In Time (JIT) as a first step in the development of a production system (Ohno and Mito 1988; Liker 2004). He is quoted as saying “*the most efficient way to assemble parts in an assembly plant was when each part arrived Just in Time*” (Ohno 2013)². Perhaps surprisingly, JIT and Ford’s early production system have much in common, as they both require synchronization between upstream and downstream processes (Fujimoto 1999). The difference is in how they achieved synchronization. Toyota used flexible synchronization (within limits) and Ford relied on inflexible synchronization. The productivity of a Japanese autoworker of the time was only 10% of his American counterpart (Fujimoto 1999). Attempting to bridge the productivity gap in three years was one of the driving forces behind the development of TPS (Ohno 1988).

Eiji Toyoda (cousin of Kiichiro Toyoda) and Shoichi Saito visited the United States for three months during the spring of 1950. They were impressed and inspired. However, when discussing the system with Taiichi Ohno, they concluded that adopting the Ford system directly would not work in Japan (Fujimoto 1999). Certain aspects of what they found could be adapted to suit the conditions of the company. Drawing inspiration not only from Ford, but American society, the following was concluded:

“Assume the supermarket is the preceding process in the production line. The subsequent process (the customer) goes to the supermarket to get exactly what it needs (in the case of the automobile assembly plant, auto parts) when it needs it. What should the preceding process then do? It must replenish that which has been withdrawn by the subsequent process.” (Ohno and Mito 1988).

As a consequence, Saito set up a material-handling committee and subsequently standardized pallet boxes and the material-handling system, making wide use of conveyor systems, thus laying the foundation of much of the flexibility of TPS. Another idea Toyoda and Saito brought with them from the United States was the practice of the suggestion system, where workers make suggestions for organizational or technical improvements. Based on this, they started the “idea suggestion system” (*soi kufu teitan seido*), which became the beginning and core of Kaizen and TQM at Toyota (Fujimoto 1999). One of the most important adaptations in the production system, was the inclusion of customer needs directly into the process (Womack et al. 1990). This was a major difference compared to Ford, who produced to stock. The economic conditions of Toyota prohibited such an approach, as the buffers would tie up too much capital. Therefore the entire flow of production and all the subsequent actions had to be based on an actual customer need.

²

Taiichi Ohno is unclear in this claim. In the books *Workplace Management* and *Toyota Production System, Beyond Large-Scale Production*, the quote is attributed to Kiichiro Toyoda. In his book *Just-In-Time, for Today and Tomorrow* he attributes this quote to Eiji Toyoda, “*In broad industries, such as automobile manufacturing, it is best to have the various parts arrive alongside the assembly line just-in-time.*”

Therefore the third aspect of the foundational view of Lean is:

- *See the end-customer as an integral part of the production system.*
Establishing a tight relationship with end-consumers or customers, enables a process to make the customer an integral part of the production system (Womack et al. 1990). This integration is an enabler for many of the practices in Lean Production Systems, such as low stock, takt, flow, and leveling. It is also essential for the definitions of “value” and “waste” in the system, thereby giving problem-solving and continuous improvements an external reference.

2.4.2.3 Taiichi Ohno

Although popular history mainly credits Taiichi Ohno as the sole father of the Toyota Production System, this is an oversimplification. TPS evolved over a number of years through experimentation and reflection. The purpose and intent of TPS was principally architected jointly by Eiji Toyoda, Kiichiro Toyoda and Taiichi Ohno (Sayer and Williams 2007). It may be claimed that Kiichiro Toyoda created the foundation and through the purchase of simple and flexible equipment prior to World War II, set the stage (Holweg 2007).

Taiichi Ohno developed many of the practical applications that would be put into TPS when working at Toyoda Spinning and Weaving. A benchmark visit at competitor Nichibo (Japan Spinning), revealed a significant gap in productivity in Nichibo’s favor. The company had adopted a line layout, moved yarn in small lots and focused on upstream quality. Ohno applied and developed these concepts at Toyoda Spinning and Weaving and subsequently brought them with him when transferred to Toyota Motor Manufacturing in 1943 (Fujimoto 1999). The concepts evolved into a system where it was possible to economically produce a wide variety of cars in small volumes (Holweg 2007). Therefore, even though he was not alone in this, there is no denying the major influence of Ohno's ideas and spirit in TPS.

Many of the practical concepts of TPS have their origin in Ohno's teachings and discoveries. Mainly he claimed that mass production had two logical flaws. Firstly, large batches resulted in large inventories resulting in high costs. Secondly, mass production was unable to handle diversity in customer demand in an efficient manner (Holweg 2007).

The direct influence of Ford's thinking is made clear by Taiichi Ohno himself, *“I, for one, am in awe of Ford's greatness. I believe Ford was a born rationalist -- and I feel more so every time I read his writings. He had a deliberate and scientific way of thinking about industry in America. For example, on the issues of standardization and the nature of waste in business, Ford's perception of things was orthodox and universal.”* (Ohno 1988).

He continues to develop ideas of vertical integration. However, Ohno's preconditions were different than Henry Ford’s. At the time Toyota had very few resources and was almost bankrupt. So the need for rationality was one of desperation (Ohno 1988; Fujimoto 1999). This is arguably the genesis of the phenomenon that later would be called Lean. It did not

start as a method to rationalize a current system as much as it was necessary in order to stay in business. The fundamental doctrine of the Toyota Production System, as explained by Taiichi Ohno, is the total elimination of waste (Ohno and Mito 1988). This is based on the Non-Cost Principle, with the following definition: The market (the consumer) always determines the value (the price) of a product, giving the following expression:

The Non-Cost Principle: Selling Price – Cost = Profit

Since the selling price is treated as a given that is outside the control of the process, the only way to increase the profit in a process is through a reduction in cost. Operations in a process can therefore be classified into two types, those that add value and those that do not add value to the product and can be labeled as Muda (waste) (Ohno 1988). Taiichi Ohno saw it as necessary to promote a new way of thinking. In order to train people to see problems, he devised seven types of waste (Ohno 1988; Ohno and Mito 1988).

- Waste arising from overproduction
- Waste arising from time on hand (waiting)
- Waste arising from transportation
- Waste arising from processing itself
- Waste arising from unnecessary stock on hand
- Waste arising from unnecessary motion
- Waste arising from producing defective goods

Of the seven, waste caused by overproduction may be seen as the worst (Dennis 2002; Monden 2012) since it brings with it the other waste. All else in the Toyota production system follows naturally from the Non-Cost Principle (see Figure 4. in System view of Lean below) and the total elimination of waste in the process. Understanding waste and its causes may be seen as essential to Lean production.

However, in the words of Taiichi Ohno, *“I don’t know who came up with it but people often talk about “the seven types of waste. ” This might have started when the book came out, but waste is not limited to seven types. There is an old expression: “He without bad habits has seven,” meaning even if you think there’s no waste you will find at least seven types. So I came up with overproduction, waiting, etc., but that doesn’t mean there are only seven types. So don’t bother thinking about “What type of waste is this?” Just get on with it and do kaizen.”* (Ohno 2013).

This leads to the fourth aspect of a foundational view of Lean:

- *Use the Non-Cost Principle to find opportunities for improvement. Then do kaizen!*
The definition of the seven wastes has become a given in Lean. Using a trainer's perspective, Taiichi Ohno exemplifies waste using an old expression. The purpose seems to be an ambition to change behavior. But more importantly, regardless of the label of the waste, do something about it!

Perhaps an aspect of the work done by Taiichi Ohno, more important than the definition of waste and the application of Kanban, is trainer mentality. There are numerous examples and anecdotes of (sometimes harsh) training methods used by Ohno. They may be summarized in two main principles (Monden 2012).

- A. Create a difficult situation for the person you are training. People only excel when challenged.
- B. Do not give the solution. Instead let the student work it out him- or herself, in order to develop problem-solving skills.

This method of training requires hard work by the trainee and a skillful trainer. It also transfers necessary skills to the trainee, so that he or she is able to work independently. It is noteworthy that the mindset of the trainer is vital in this context. A manager is a trainer in Lean. This method is the fifth aspect of the foundational view of Lean.

- *Train people to think as well as act.*
Use challenges that already exist in a process to develop the abilities of people and set the target at a truly challenging level to prevent complacency in students. The road to developing a solution is as important as the solution itself (Monden 2012).

2.4.2.4 Shigeo Shingo

When looking into the foundational view of Lean production, one inevitably comes across the industrial engineering perspective of Shigeo Shingo. He was instrumental in the training of many Toyota employees but never directly employed by Toyota itself. Personally acquainted with Taiichi Ohno (Shingo 1984), he discussed many of the methods used in TPS and worked directly with the development of one of the prerequisites for resolving waste from overproduction. One important realization by Taiichi Ohno was the need for small lot sizes, essential to ensuring flexibility and tying up less capital in production (Monden 2012). An economical lot size is largely dependent on the setup time in a process. Using simple methods and tools, the setup time of a process can be significantly reduced, thus enabling much smaller lot sizes and avoiding overproduction. This was called the Single (digit) Minute Exchange of Die (SMED). It may be seen as a low-level tool in TSP. The generalized lesson of the tool leads to the sixth aspect of a foundational view of Lean.

- *Leveling and operational stability are largely enabled through elimination or reduction of work associated with switching of tasks.*
Being able to change tasks, quickly and easily in any process is a fundamental function of a Lean production system, as flexibility is a prerequisite for avoiding the waste of overproduction. This is equally applicable in direct and indirect or supporting processes, though methods will differ.

Apart from the reduction of setup time, Shingo also was a strong advocate of defect prevention in improving quality. This in contrast to the views of Deming and Juran (see below) and their emphasis on improving quality through statistical methods. Instead of utilizing statistical methods, Shingo argued, why not prevent defects from occurring altogether? Zero defects in a process is the goal (Dennis 2002). To achieve this the concept of Poka-Yoke (error prevention) devices was developed, where small inexpensive failure-proofing devices were implemented in the process. In this Shingo distinguished between errors (due to human nature), impossible to avoid entirely, and defects, which may be eliminated entirely.

2.4.2.5 Deming and Juran

During the rebuilding of industrial Japanese the second world war, few people were as broadly influential as W. Edward Deming. Training hundreds of engineers in Japan in the concepts of statistical process control and quality during a few months in 1950, and credited with the philosophy behind TQM, much of the lineage of the ideas of Lean may be traced back to him. For instance, in the teachings of W. Edwards Deming's "14-point system", point five is "*Improve constantly and forever the system of production and service, to improve quality and productivity, and thus constantly decrease costs*". This may be linked directly to the concept of *Kaizen*, popularized by Imai (1986). Not directly associated with Deming, but in the same field, Joseph M. Juran also lectured and held trainings on the cost of poor quality, but from a management perspective, thus adding a human and management dimension to quality in a process (Imai 1986). The views of Deming, Juran, and Shingo lead to the seventh aspect of the foundational view of Lean:

- *All processes should be improved constantly.*
The purpose of constant improvement serves many purposes in a Lean context. A process that does not improve tends to regress over time (Liker and Franz 2011), thus improvement work is part of the stabilization of a process. The effort to improve a process will also yield increased knowledge and experience of the people involved, thus the constancy of purpose depends on the effort to improve. Improvements are also a balance between effort/risk and benefits, where small improvements give small risks and the frequency of small improvements gives training and better performance (Rother 2010; Imai 1986).

2.4.2.6 Concluding the Foundational view of Lean

Serendipity seemed to be involved when Toyota developed a production system that would lay the foundation of Lean. Many other companies in Japan faced the same conditions during pre-war development and post-war survival. A combination of outside pressure, chance, and most importantly, the right people, led to what we today call Lean. Much understanding can be gained from a foundational view, as it explains why many of the concepts of Lean were developed. The total aspects of the foundational view of Lean are therefore:

F1. *Stop a process when a problem is detected and correct the problem.*

F2. True understanding of a situation is based on direct observation combined with deep reflection.

F3. See the end customer as an integral part of the production system.

F4. Use the Non-Cost Principle to find opportunities for improvement. Then do kaizen!

F5. Train people to think as well as to do.

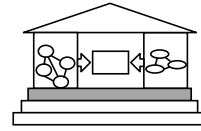
F6. Leveling and operational stability are largely enabled through elimination or reduction of work associated with switching tasks.

F7. All processes should be improved constantly.

It is commonly agreed that it is difficult to succeed in the integration of Lean (Flinchbaugh and Carlino 2006; Liker and Hoseus 2008; Rother 2010). There are numerous stories about attempts and failures. This difficulty is further exemplified in the studies in the context of this thesis. Therefore it may be concluded that simply applying the written teachings of the founders of Lean is in itself not enough. These teachings are the end product of a long chain of experiments and reflection. It is therefore argued that an Evolutionary view of Lean is necessary.

2.4.3 Evolutionary view of Lean

Recognizing the evolutionary aspect of Lean is here argued as necessary as it connects the internal driving force in a process to the external circumstances that affect the process. No process (perhaps with some exceptions in government) exists that are not connected in some way to shifting external demands. It might be argued that an external reference is always needed if one is to work with Lean. An understanding of the evolutionary aspect of Lean is therefore here argued as necessary to avoid seeing Lean as just another management fad.



Given the hindsight of the present day, it is easy to view Lean as a whole, where every part has a given place and the different aspects are fully understood. In reality, the development or evolution of what we today call Lean has been far from smooth, one of trial and error (Monden 2012). The founders of Lean (see foundational view above) recognized this as a sort of unfolding or as an expansion into more dimensions, “*the Toyota system has undergone a certain kind of evolution. Just as a point can expand to become a line and then a plane, so too has this system evolved into more than a set of production tools*” (Ohno and Mito 1988). Just putting the basic production system in place at Toyota required more than twenty years of work (Womack et al. 1990). It may be seen as a set of experiments and trials evolving over decades (Holweg 2007). The evolutionary view helps explain many of the traits observed in a Lean production system (see Systems view of Lean below).

Fujimoto (1999) defines this as a multi-path systems emergence, where “*emergence*” is defined as “*a certain system trait that cannot be explained by the behavior of its constituent parts alone or predicted from the previous states of the system owing to its complexity from the observer's point of view*”. It is also argued that an evolutionary learning capacity is essential for the long-term sustainability of a Lean system, as exemplified by TPS. The evolutionary aspect reshapes the Lean system to meet changes of conditions and demands through what is defined as “*Evolutionary Learning Capability*” (Fujimoto 1999). Other companies have had similar developments, though Toyota was the pioneering company. Looking back, these stages can be categorized. Hines et al. (2004), for instance, sees four main stages in the evolution of Lean thinking. Another view is, “*No new idea springs fully formed from a void. Rather, new ideas emerge from a set of conditions in which old ideas no longer seem to work. This was certainly true of Lean production*” (Womack et al. 1990). In conclusion, to understand Lean therefore means the evolutionary view has to be taken into consideration.

From an evolutionary viewpoint an important external force in the development of the Toyota Production System was the post-WW II conditions. Though Toyota was receiving orders for automobiles, inflation was high and it was difficult to get paid for its cars (Liker 2004). To avoid bankruptcy, extreme cost-cutting measures were put in place, giving an external incentive to the development of the Toyota Production system. Though the Toyota Production System was successful (the company survived and began to grow rapidly) it received little notice outside Toyota. It was not until the oil-crisis in 1973, that other companies started to

take more than a perfunctory interest in understanding what Toyota was doing (Ohno and Mito 1988).

The same pattern is repeated during the nineteen-nineties, when manufacturers outside Japan start experimenting with what was then becoming known as Lean (Womack et al. 1990) on a larger scale³. During the IMVP study, the term “*Lean*” was coined (Krafcik 1988) and popularized through the publication of the resulting books. Though *The Machine that changed the world* brought attention to the production system of Toyota, the details of the system were presented in the following book, *Lean Thinking* (Womack and Jones 2003), in which the authors discussed how to achieve a “sense of urgency” in the organization when implementing Lean in a process. External factors therefore have to be taken into account in the first aspect of the evolutionary view of Lean.

- *A great sense of urgency is normally required to drive evolution in a Lean production system.*

Implementing a new production system or supplanting an old one requires a large investment in labour and cost. Lean production can be incompatible (Rogers 2003) with the current system, requiring a higher level of management commitment and stamina. There normally has to be a valid and current threat to the process before the driving force of evolution is strong enough to motivate a system change. There has to be a sense of urgency in the process to drive evolution and overcome the inertia of established work methods (Womack and Jones 2003).

Connected to the external incentive, a driving force in the evolution of Lean Production Systems can also be a reflection based on increased experience in running the system. For instance, the developing understanding of the concept of waste. “*After trying to identify and eliminate every kind of waste, we concluded that real waste was making products that don’t sell. Even quality products, if they don’t sell, must be discarded. This waste, in fact, is the most crucial because it is not just a loss for the company – it is a loss to society.*” (Ohno and Mito 1988). This leads to the second aspect of the evolutionary view of Lean.

- *Evolution can be driven by internal reflection and not just external circumstances.*

The ability to reflect and reevaluate the aspects of a production system that works and not just the parts that are problematic seem essential to evolution of a Lean production system. It is easy to focus on the parts of a production system that are difficult or do not work. It would seem that it takes a far deeper understanding of Lean to question the parts and definitions that are working well. In the words of Taiichi Ohno “*we are doomed to failure if we do not initiate a daily destruction of our various preconceptions*” (Ohno and Mito 1988).

³

There were early attempts to spread “JIT” and “Japanese management” during the eighties (Shingo 1984), which were not widely successful (Womack and Jones 2003). Such attempts were likely hampered by the lack of system thinking (Holweg 2007).

Studies of the Toyota production system were not conducted in the United States only. Extensive research was for instance carried out by Fujimoto (1999) and published in the book *The evolution of a manufacturing system at Toyota*. The approach is mirrored by Monden (2012) in *Toyota Production System: An Integrated Approach to Just-In-Time*, although Monden takes a more humanistic approach, emphasizing the system's human components. In this classification, both Fujimoto and Monden also take great pains to explain the technical parts of the system. On a more abstract level, Liker (2004), in his book *The Toyota Way*, presents the guiding principles of the Toyota production system boiled down to 14 general principles of operation. They are divided into aspects such as leadership, eliminating waste, etc... This level of abstraction opens the door to a more comprehensive approach to production systems in Lean. Most of the studies have focused on what Toyota is doing and not doing. For instance the work of Netland (2013) reemphasizes the study of lean to a higher inclusion of the individual preconditions of a process, in what he calls the development of an XPS, where the X stands for the company-specific production system. A third aspect in understanding Lean can be derived:

- *Continuous learning and adaption of practice is at the heart of any successful Lean implementation.*

The evolutionary aspect of Lean requires an organization able to learn and adapt. Learning can come from other organizations, or other parts of one's own organization as well as from one's own experience (Holweg 2007).

2.4.3.1 Concluding the Evolutionary view of Lean

The evolutionary view of Lean brings attention to the interplay of several factors. Firstly, the necessity of an awareness of the process in relation to the surrounding world. There has to be a reason to evolve, a sense of urgency. Secondly, as the process is adapted to suit external circumstances, a reactive evolution, there is also a need to reflect. This drives a proactive evolution based on learning and experience. Finally, an attitude of learning translated into adaption is necessary to evolve. Evolution takes place over time. This realization is essential if one is to understand the long-term commitment necessary for the evolutionary view of Lean.

E1. *A great sense of urgency is normally required to drive the evolution in a Lean production system*

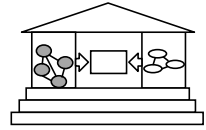
E2. *Evolution can be driven by internal reflection, not just external circumstances.*

E3. *Continuous learning and adaption of practice is at the heart of any successful Lean integration.*

The evolutionary view, together with the foundational view and the historic view, can be said to form the foundation of Lean. The aspects given within these views are important taken one by one. Together they give the understanding necessary in order to build a sustainable, long-term approach to Lean integration. The first step in this is the understanding of the Lean tools and methods.

2.4.4 Tools and Methods view of Lean

A number of tools and methods are commonly associated with Lean (Wilson 2010; Baudin 2002; Dennis 2002; Liker and Meier 2006). Understanding Lean therefore requires an examination of the particulars of the methods used and an analysis of the tools. This can be seen as taking the industrial engineers viewpoint on Lean as the application of the methods affect the results of the process. This is also an important view to grasp before looking into the systems view of Lean, as the design of the tools and methods decide the interconnections and dependencies of the Lean system.



One way of viewing Lean is to see it as a set of Tools and Methods that can be applied in various situations to produce results (Sörqvist 2013; Wilson 2010; Baudin 2002). Cause and effect are linked and results are predictable. Since the methods of Lean have been developed over decades through experiments (see Foundational and Historical views above), they have to be studied if one aspires to understand Lean. The tools of Lean can be seen as the practical application of Lean principles. It is clear that the methods should not be applied in a piecemeal fashion (Liker and Meier 2006), also that a fundamental ability is needed in each method if the system is to work as intended. In addition, the actions and behavior described by the methods reinforce, and indeed define, the culture of a process (see cultural view of Lean below). Therefore one cannot talk about a Lean culture without clearly defined Lean tools and methods.

There are numerous tools and methods described in Lean literature. Most of them have been known in the West since the late 1990s (Fujimoto 1999). The tools and methods described in this thesis are ones with a clear connection to the group level in a process in accordance with the limitation of the thesis described above.

The Tools and Methods view of Lean can be seen as a reductionist, low-level view, of the system where the sum of the parts make up the whole. In essence, they describe the content of the building blocks of Lean. The Tools and Methods view can start with a definition of “Value” (in accordance with the Non-cost-principle) in the production system.

Value can be difficult to define properly (Womack and Jones 2003). Several different perspectives are possible. Taking the end-consumer perspective on value, one definition could be as follows: “*a conscious attempt to precisely define value in terms of specific products with specific capabilities offered at specific prices through dialogue with specific customers*” (Womack and Jones 2003). The definition of Value in a production system can be used to identify the inverse of Value, the Waste of the production system (see Foundational view, Taiichi Ohno). Waste is there normally defined as time spent (by people) in a process doing tasks which do not contribute directly to the value of the product or service. That is, the work costs time, but the customer is not willing to pay for the result. Many variations of the definition exist.

By tradition, Japanese terminology is used when describing sources of waste. The terms Muda, Mura and Muri are used (Liker 2004). The original concept of waste is Muda. The term Mura means "unevenness" or "fluctuation in work" and Muri means "overworking" (Dennis 2002). Further discussion of the connection between these sources of waste is found in the Systems view of Lean below (see Figure 5).

In apparent contradiction to F3 (see Foundational view of Lean) and perhaps counter-intuitively, customer demand also has to be decoupled from production through the practice of *Heijunka*, a leveling or smoothing of production (Monden 2012). Customers do not order products in a smooth and predictable fashion. To design an efficient process some mechanism has to be devised that protects the process from the quick fluctuations of customer orders and creates stable and predictable conditions. This is a prerequisite for flow and standardization (Liker and Meier 2006), and can be done at several levels of the process. Leveling can be done all the way from the initial communication with the customer through an order-stock system, to the internal KANBAN system. It is important to note that the KANBAN system is a method used to achieve JIT and can mainly be divided into production Kanban and withdrawal Kanban, although other types exist (Monden 2012). Leveling can consist of both volume leveling, where fluctuations in order volumes are spread out over a period of time, and variant leveling, where the workload of different variants of the product are mixed to avoid unnecessary buildup of stock. The tools and methods view of Lean is based on the impulses of customers, but also have to be decoupled (protected) from variation caused by customers. The first aspect of the tools and methods view of Lean is:

- *Leveled customer demand initiates the process.*
Any process in Lean production begins with an impulse given by a customer. This is essential to avoid overproduction and other waste in the process, the Muda. Equally important for efficiency reasons is that the impulse is mixed with other customers' impulses or other demands, to avoid the necessity of unnecessary resources. Leveled impulses counteract Mura (unevenness), enabling resource efficiency and predictability in the process. Also, leveling avoids subjecting the process to Muri (overworking), preserving equipment and in accordance with the "Respect for People" principle.

Determining the *Takt* of the system is seen as an essential method, as it links the demand of the customer to the capacity of production, enabling synchronization of the entire process (Womack and Jones 2003; Monden 2012). Takt time by itself is not a tool, but can be seen as a prerequisite for other Lean methods and tools, such as balancing and standardized work, as it presents the *leveled* calculated customer demand as a reference point in the design of the process (Liker and Meier 2006).

Standards should describe a set of tasks in a sequence that is easy to follow, train, and follow up (Monden 2012; Wilson 2010). Standards should be based on the assumption that it is possible to find an optimal way to perform a given set of tasks. This is tempered by the understanding that the best way is only the best way *currently known*. Therefore a Standard is

never finished, but can be seen as the baseline or starting point for continuous improvements (Liker and Meier 2006).

A Standard should give stability in the process, and the work sequence should be based on objective observation and measurements. Closely linked to standardized work is the concept of 5S as introduced by Hiroyuki Hirano (Dennis 2002), where the order of the workplace and the condition of the equipment is closely linked to the variation and results of the process. With the basis in standards, the organizational aspect of process balancing should be achieved. The purpose of balancing is to utilize a minimum of labour and tie up a minimum amount of material in the process (Monden 2012). Also, proper balancing overcomes the problem of fractional workers as defined by Monden (2012, Fig. 8-7).

Each lean tool or method also serves several purposes. This can be exemplified by examining a method from several different viewpoints. The method serves different purposes depending on viewpoint. This example uses Individual-Organization-Leadership viewpoints as defined by Osterman and Fundin (2014), to illustrate the method of Standards⁴(see Figure 2).

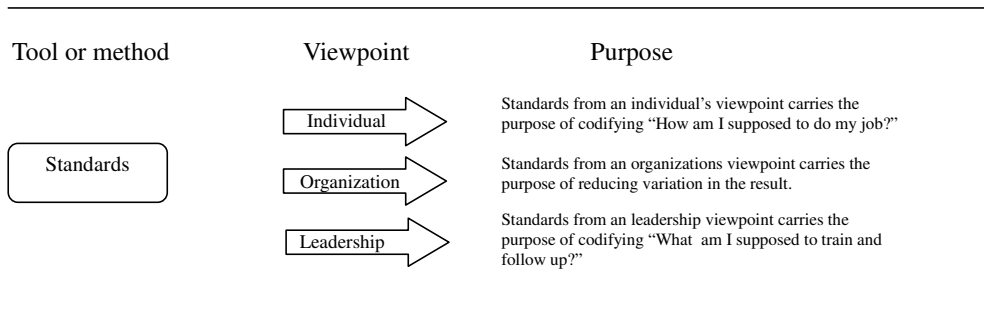


Figure 2. Purpose of Tools and methods

This analysis of the purpose of each tool or method illuminates the complexity of Lean. Each individual part serves multiple purposes, which all have to be fulfilled simultaneously. In addition, Takt, Standards, and Balancing form fundamental aspects of Standardized Work and provide safety and reliability in the process, as well as codify the transformation steps necessary to produce a result. This will be further discussed in the Systems view of Lean below (see Figure 3). It also forms the foundation for problem-solving and continuous improvements as discussed by Osterman and Fundin (2014). Therefore the second aspect of the tools and methods view of Lean is:

- *Through Standardized Work, the impulse of the customer is converted into the results of the process.*

In Lean, Standardized Work is much more than a set of instructions and a work sequence. The Tayloristic assumption of "a best way" to perform a task is combined

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The example is simplified for illustration. There are more viewpoints (such as Strategy or Flow efficiency). Each viewpoint has several more purposes for standards, as well as for every other Lean tool and method.

with a realization that every method can be improved and the currently chosen solution is but a step on the way to an unattainable target of perfection. This combination of a formalistic instruction and a creative aspiration forms the essence of Lean Tools and Methods.

The results of a process are not measured only according to a time defined by customer demand, also measured by the fulfillment of quality as defined by the customer. Based on the Non-Cost principle discussed above in the Foundational view of Lean, there can be several problems associated with quality. Firstly and most obviously, a lack of quality is a problem as it triggers different types of waste. Having to redo a task or scrap a result is obviously wasteful. Secondly and not as obvious, over-processing of a result is equally wasteful, “*Waste is generated when providing higher quality products than is necessary*” (Liker and Meier 2006). When the result is beyond what the customer is willing to pay for, the result will have cost without value. Although there are many other aspects to quality, from a Lean viewpoint at the lowest organizational level, quality in the process has to be defined from the customer's definition of value. From this basis, stable quality should be achieved at as low a total cost as possible, according to the Non-Cost principle. Therefore the third aspect of the Tools and Methods view of Lean:

- *Value, as defined by the external customer, largely defines what quality is in the Lean process.*

In Lean production the definition of waste reveals the inefficiencies of the process. The inverse of waste gives what the customer considers important in the result of the process. Overspecification of a result is in itself a kind of waste, as the result is beyond what the customer is interested in paying for, thus against the Non-Cost principle (see foundational view of Lean).

The tools and methods described above come into play when a process is operating as intended. A fundamental concept in Lean is continuous improvements at all levels in a process (Liker and Franz 2011). In Lean the practical method behind continuous improvement and problem-solving is basically the same, the PDCA loop (Liker and Franz 2011). The difference lies in the intent. Problem Solving is mainly concerned with deviations from Standardized Work, when the process does not operate as intended. For instance, problems can be not achieving the right level of quality, falling behind in the operation, safety and ergonomic issues, using more resources than intended to achieve a result, etc.

Continuous Improvements can be seen as a special case of problem-solving, as the conditions of the process are changed in order to improve some aspect of the operation. For instance, how to achieve better results utilizing the same resources or achieving the same results with fewer resources. Achieving a new level of quality due to a change in customer demand or value at the same cost or lower than previously, etc. The intended improvement is then stated in terms of a problem based on a rhetorical question. “What is stopping us from achieving this

result today already?” The obstacles that are found are then treated as normal problems to be solved with problem-solving tools and methods (Rother 2010; Imai 1986; Imai 1997).

Fundamental to problem-solving in Lean is the assumption of the existence of a “Root Cause”, seen as an underlying problem behind what is perceived (Rother 2010). The initially observed problem is regarded as a symptom. Traditionally the method used to discover the root cause is called “Five Why” where one scientifically asks “Why” a problem occurred (Sayer and Williams 2007; Liker and Franz 2011; Ohno 1988). Based on the answer the “Why” questions proceed. For each answer a new Why question is asked until a “Root cause” is determined. According to Taiichi Ohno the entire Toyota Production Systems can be seen as a result of the “Five Why” method (Ohno 2013). After the discovery of a “Root cause”, a set of countermeasures are put in place to avoid any reoccurrence of the deviation (Spears and Bowen 1999). The ability to utilize the Five Why method can be regarded as a fundamental skill in Lean.

In reality Five Why should be regarded as much a principle as a tool. It is difficult to perform a good analysis without further method support. One example is the A3 method (Shook 2009), based on the logic of the “Five Why”, but is much more formalistic. It serves several purposes (Dennis 2002). The structure of the A3 encourages a thorough analysis of every step in the problem-solving attempt. It also serves as a tool for dialogue between the manager and the person performing the analysis, where they both serve different roles. The manager uses the A3 tool to simultaneously help solve the problem and coach the employee in problem-solving thinking. The third purpose is that the A3 serves as a method of communication within the organization. Both when solving the problem, when it is used to gather consensus from the different parts of the process, as well as after the problem is solved and countermeasures are put in place. Then it is used to spread knowledge to the rest of the organization. The formalistic approach of the method is of help since everyone who reads each A3 will know how to interpret the information (Shook 2009).

There are other methods of problem-solving, such as the one described as the Kata model (Rother 2010), where each individual is continuously performing small experiments under the tutelage of a senior employee. A larger and vastly more complicated method is the eight-step problem-solving approach, used for larger, more complicated problems (Liker and Franz 2011). All of the methods described above have their roots in the scientific method of PDCA thinking (Liker and Franz 2011).

In conclusion, all problem solving methods in Lean use the same logic.

- I. Understand the deviation or problem based on measurable facts
- II. Understand the underlying cause of the problem
- III. Devise effective short- and long-term countermeasures
- IV. Verify the effectiveness of the countermeasures.
- V. Spread the knowledge that was gained so that others will have use of your experience. This is also known as “Yokoten”, or sharing practices horizontally (Liker and Franz 2011).

The main difference between problem-solving methods at a practical level, lie in the source of perceived problems and the scope of the methods. Another difference is that the resolution of a deviation is regarded as a countermeasure which is temporary in nature and can always be improved, rather than a solution which is final in nature (Liker and Franz 2011). This reflects on the “continuous” aspect of the improvement work. In conclusion the fourth aspect of the tools and methods view of Lean:

- *With a basis in Standardized Work, deviations are found in the results of a process in relation to “Value”, as defined by the customer, and also in the relation between value-adding time and waste in the effort spent producing the result.*

A process that has not been standardized cannot reliably be improved in Lean. “*There can be no Kaizen without standardization*” (Imai 1986). A situation can be changed but it cannot be regarded as an improvement until the changes are verified and form the basis for a new standard. This standard has to be trained and followed by everyone involved in the process.

2.4.4.1 Concluding the Tools and Methods view of Lean

The tools and methods connected to Lean implementation and application are numerous and the ones discussed above represent a small sample. On the group level this sample can be seen as fundamental instruments in transforming a desire from a customer into a result that is acceptable at a cost that is reasonable. This is coupled with the never-ending desire to improve the relationship between the time that can be defined as “adding value” to the result and every other task, which may be seen as deviations or waste and thus subject to problem-solving tools. The content and purpose of these tools and method can be described as:

ToM1. *Leveled customer demand initiates the process.*

ToM2. *Through Standardized Work the impulse of the customer is converted into the results of the process.*

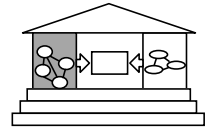
ToM3. *Value, as defined by the external customer, largely defines what quality is in the Lean process.*

ToM4. *With a basis in Standardized Work, deviations are found within the results of a process in relation to “Value”, as defined by the customer, and also in the relationship between value-adding time and waste, in the effort spent producing the result.*

The tools and methods of Lean have evolved over decades through experimentation and reflection. Each by itself can give benefit to a process, but they also have interconnections and interdependencies. These interconnections and interdependencies are what form the Lean system.

2.4.5 Systems view of Lean

All parts of any system have to fit together and support each other. This is doubly true for a Lean Production system. The system is intentionally designed to be “fragile” (Shimada and Macduffie 1986) to force problems to the surface in order to resolve the underlying issues. However, a resolution of the underlying issues requires an intimate knowledge of the connections and dependencies within the Lean system, if the solutions to the underlying issues are to be predictable and not cause new problems.



Lean production is often referred to as a system (Monden 2012). Goyal and Deshmukh (1992) found that even in the early days following the popularization of the IMVP initiative, most writers agreed that understanding the concept of Lean requires a systems perspective. This is in accordance with the teachings of Deming, who argues that the long-term survival of an organization is dependent on the systems view. In Lean it is common to describe the system with a visual image of a house or a temple, but other images exist. These images serve several purposes, but most importantly they codify the XPS of the process so that it can be taught to the organization.

The definition of "system" here is *"an organized and consistent set of principles and related practices that are broadly applied to any situation"* (Emiliani 2007). The characteristics of a system in a Lean context are for instance defined by Dennis (2002):

1. Each part of the system has a defined purpose.
2. The parts of the system are interdependent.
3. We can understand each part by seeing how it fits in the system.
4. To understand the system we have to understand its purpose, its interdependencies and its interactions.

A systems view of Lean production therefore focuses on the interaction between the different parts, the Tools and Methods, of Lean production. Every part of a Lean production system has distinct functions which are often clearly defined and described in the literature (Dennis 2002). However, each part of the production system also has an overarching purpose.

The tool is designed to work together with other tools to create an efficient process. The connections between the tools are often intricate and act on several levels. Continuing to expand on the discussion of Standard-Balancing-Takt-Leveling described above in Tools and Methods. To clarify the reasoning above an example is used in figure 3⁵.

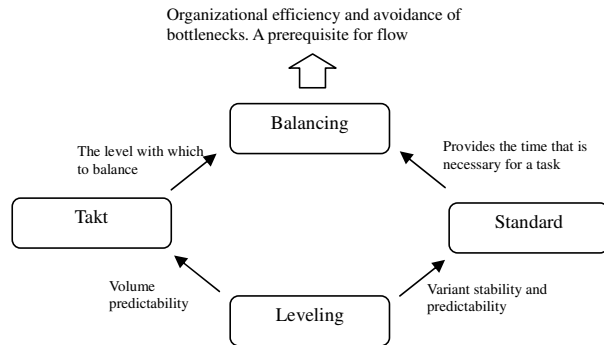


Figure 3. Exemplifying the dependencies of a Lean system.

Based on the reasoning above, the first aspect of the systems view of Lean can be defined:

- *An XPS must not only describe the parts of the production system, it must also describe the connections and dependencies in the system.*

Since Lean can be seen as a system where every part is connected to every other part and also is a system that, by design, will constantly be in flux (see Continuous Improvements in tools and methods above), the connections and interdependencies of the parts have to be well understood if the consequences of the changes are to be predictable.

Though the overarching purpose of the system is described as cost reduction (increase in productivity) three sub-goals have to be met first (Monden 2012):

1. Quantity control. Daily adaption to fluctuation in demand
2. Quality assurance. Each step in the process supplies good results/products to the next step only.
3. Respect for humanity must be cultivated to ensure sustainability in the system

The three sub-goals do not exist independently, but influence each other and the primary goal of cost reduction expressed in the Non-Cost-Principle.

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The example is simplified for illustration of connections between parts of Lean. This is also only from an organizational viewpoint. Many other connections at various levels exist.

The systems view is often signified by a top-down abstract view of management. The system is seen as a whole and the entire value chain is the basis for analysis. One of the pioneers of this view was Henry Ford as expressed in his book *Today and Tomorrow* (Ford 1988), where he describes the consolidation of entire value streams and the striving through experimentation to continuously improve the production system and find new more efficient methods. Using the illustration of TPS as devised by Shiego Shingo as an example:

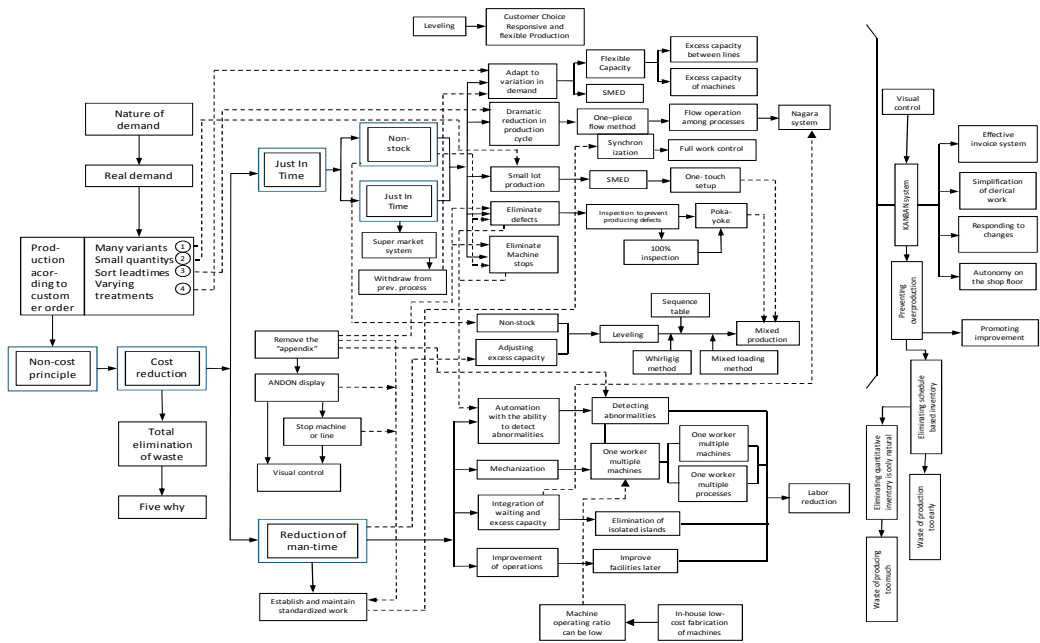


Figure 4. The Systemic components of the Toyota Production System from an industrial engineering point of view. Based on Figure 41 (Shingo 1989) and Figure 32 (Shingo 1984)

A fundamental tenet in Lean is the Total elimination of waste (Ohno 1988). Everything in the systems view presented by Shingo (figure 4) is based on cost reduction and every practice is derived from this point (Ohno 1988). However, not explicitly stated in the figure, are actions taken when the system is not performing as intended. Shingo refers simply to the “Five Why” practice for the elimination of waste, but the underlying system is as complex as the TPS described by Shingo. Understanding problems in Lean inevitably leads to the necessity of understanding waste. Based on this, the second aspect of the systems view of Lean is about the nature of an XPS:

- *The parts of a Lean system must, through implementation and application, be traceable back to the “Non-Cost principle” and connected to the “nature of demand”.* All tools and methods in a Lean system serve a purpose and must therefore be logically traceable back to that purpose. If the logic or purpose of the system is

forgotten, the application of the system might actually lead to a inefficient process rather than an efficient one (Emiliani 2007).

Even though waste is sometimes reduced to the seven traditional wastes of TPS (see foundational view Taiichi Ohno), understanding waste requires an understanding of the sources of waste and the connection between them. This is illustrated in Figure 5 using a common conceptual image where the source of waste is found in the relationship between available resources and market demand⁶. The image can be seen as an expansion of Figure 10-1 in the Toyota Way (Liker 2004).

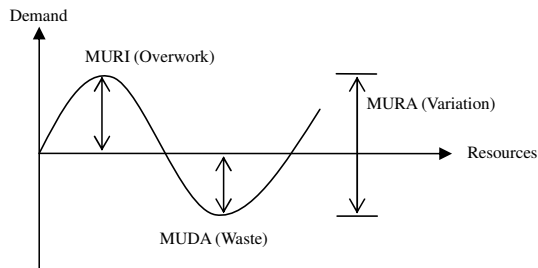


Figure 5, Conceptual image of Muda, Mura and Muri.

In Lean the sources of waste, illustrated in Figure 5, may be defined as (Ohno and Mito 1988; Liker 2004):

- Muda: More resources (costs) than needed to meet market demand.
- Muri: Not enough resources to meet market demand, forcing overwork and leading to equipment wear.
- Mura: Uncontrolled demand forcing an uncertainty into balancing and planning.

Lean is sometimes misunderstood as focusing only on the proportion between value-adding time and non-value-adding time, expressed in terms of productivity and not focused on variation and variability. The opposite is true. Variation is seen as a major source of waste in the system. This can be seen in the definition of Mura (Liker 2004) and in the illustration above. The same misunderstanding occurs when it is claimed that Lean leads to burnout. This is also seen as waste as well as strongly against the value “Respect for People”. In economic terms, wearing out equipment and people forces expensive replacement and training and also introduces quality and safety risks in the process. Both Muda and Muri are caused by Mura (variation), which explains why leveling (Heijunka) is seen as fundamental in Lean (Liker 2004). Without control over variation, everything else becomes proportionately more difficult. This Leads to the third aspect of the systems view of Lean:

⁶

The image is also based on the assumption that market demand always has to be fulfilled to ensure the survival of the process. Other conditions may exist in for instance government or public service sectors, where sources of waste may be different.

- *Operation of the XPS should be based on an understanding of the sources of waste in the system.*

The “nature of demand” is essential to the application of Lean and is different depending on whatever market the process is aimed at. Thus the surrounding outside context also has to be taken into account when describing the XPS.

Shingo (1984) is very clear that the Toyota system is integrated in steps. Certain parts of the system have to be in place before other parts can be integrated (Liker and Meier 2006). For instance, before one can introduce JIT, the process has to be arranged to accommodate flow (Ohno and Mito 1988). Taking an industrial engineering view of the Toyota Production System, it is also clear that just mimicking the tools and methods will not bring the expected benefits. For instance, “*misusing Kanban as a tool can yield disastrous results*” (Ohno 1988). This behavior will instead cause what (Emiliani 2007) defined as “False Lean” where a process, even though all the principles and tools of Lean appear to be there, will not change its fundamental performance. This can be stated as the fourth aspect of the systems view of Lean:

- *The application of XPS is done in stages that should be based on the conditions of the process, the dependencies of the XPS, and the experience of the employees.*

There seems to be no blue-print or recipe that is universally applicable in the integration of an XPS. Every integration of an XPS has to be built up in custom-designed stages, taking into account the unique situation of the particular process and at the same time also has to be based in the Non-Cost principle.

2.4.5.1 Concluding the Systems view of Lean

There are several reasons why a systems view of Lean is necessary. An understanding of the interconnections and dependencies will make the effects of Problem-Solving and Continuous Improvements predictable as the consequences of an action and the conditions that are necessary can be known and understood. An illustrative example could be the removal of buffers from a process. Buffers can be seen as one of the traditional seven wastes and removal of them reduces lead time in the process as well as potential quality costs. But just removing a buffer might have consequences for the process leveling as a buffer might also act as a shock absorber, protecting the process from unpredictable fluctuations (see Muda, Mura and Muri above). Thus removing a perceived problem might have consequences that are larger than the problem that one attempts to solve. An understanding of this can help in the implementation and application of Lean but can also help in the acceptance of Lean as a concept.

S1. *An XPS must not only describe the parts of the production system, it must also describe the connections and dependencies in the system.*

S2. *The parts of a Lean system must be, through implementation and application, traceable back to the “Non-Cost principle” and connected to the “nature of demand”.*

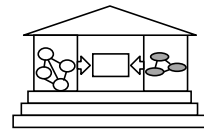
S3. *Operation of the XPS must be based on an understanding of the sources of waste in the system.*

S4. *The application of the XPS is done in stages, which should be based on the conditions of the process, the dependencies of the XPS, and the experience of the employees.*

Taking a systems approach in Lean gives logic to the implementation of Lean in a process. The system works as a whole but is built part by part. However, this realization is not enough as it is not the system by itself that produces results in a process, it is the people working in the process, using the tools and methods, that produce a result. By organizing the process as a system, human efforts can be transformed into results in an efficient way. This therefore requires a more humanistic approach, a philosophical view of Lean.

2.4.6 Philosophical view of Lean

A production system such as Lean is foremost an idea. The system itself does not exist except as an abstract thought of how a process can be organized in order to be efficient. The parts of a production system that can be observed are merely physical artifacts of the ideas and underlying reasons. Perhaps that is one reason why Lean is difficult to implement. When observing, you only see a physical manifestation of a concept, you cannot observe the underlying reasoning.



Toyota's Production System has grown organically at Toyota. It has never replaced a previous production system, it has been *the* production system. This is not so for other companies where the concept of Lean production has been viewed largely as counter-intuitive, when compared with traditional manufacturing (Lewis and Lewis 2000). The other companies have to *replace a current system that they understand* with something else that they do not fully understand (Liker and Meier 2006). Examples of this conventional understanding can be, “*Standardization is the death of creativity. Time and motion regimentation prevents continuous improvements. Hierarchy suffocates learning.*” (Adler 1993). Such thoughts can be seen as common sense, and going against common sense requires a different approach. One can view this as the difference between the *Genes* of Lean and the *Instep*⁷ of Lean (Rövik 2000). Where Toyota defines much of the *Genes*, other companies follow the process of *Instep*, which is different from *Genes*. The challenge of adopting a concept is therefore different from defining the concept.

These attempts at *Instep* has led to the understanding that Lean is not only tools and methods, but that they are mutually dependent, synergistic, parts of a whole. This also leads to the understanding that the application of the methods and tools sometimes are in contradiction to each other, creating apparent paradoxes that have to be resolved (Dennis 2002). A few examples of these apparent dilemmas or contradictions are given by Adler (1993) “*What if*

7

My translation, the original term is “Inresa” in Swedish. A literal translation might be “Intravel”. This however could be slightly misleading when looking at the original definition of the term, as the adoption of a organizational standard happens in two defined steps, according to Rövik (2000).

bureaucracy can actually be designed to encourage innovation and commitment? What if standardization, properly understood and practiced, should prove itself a wellspring of continuous learning and motivation?" Resolving these apparent paradoxes and dilemmas requires a deeper understanding of Lean practices. This more philosophical approach to Lean may be labeled as the second generation of the Lean evolution (Schonberger 2007).

The consequences are that, studying Toyota only tells us little of what other companies that are trying to integrate Lean will experience. The contexts of other companies are different. To a large extent, they must develop Lean into something that suits their operations. Understanding such differences may enable a more efficient transformation into a Lean company. This is crucial in the analysis of the results given by the studies.

One difference between a Philosophical Lean view and a Tools and Methods view lies in the understanding that each Lean tool or method also would seem to have deeper humanistic purposes. Exemplifying this trait is a conversation that took place between Fujimoto Takahiro and Tanaka Michikazu, Plant manager of Daihatsu 1984, *"What do you think is the essence of just in time? There are three possible answers. The beginner's answer would be that JIT is good simply because it reduces inventory cost. An intermediate-level answer is that JIT reveals production problems and triggers Kaizen. But the third answer is that JIT infuses cost consciousness into all employees. When JIT keeps forcing workers to face production problems one after the other, employees start to see everything as a potential source of cost or productivity problems, and then seek problems actively. This is the level we have to reach"* (Fujimoto 1999).

All methods should therefore also expose problems and foster awareness within the process. So in that sense Lean is "fragile" (Shimada and Macduffie 1986). It is designed to force people to face problems and solve them. Take an applied Kanban system as an example: *"At Toyota, it is virtually impossible for workers to hide production problems in their workshop, for the Kanban system actually visualizes the form of line-stops or overtime, and will swiftly generate improvement activities to solve the problem"* (Monden 2012). Therefore the first aspect of the philosophical view of Lean is:

- *Lean methods have to both fill their intended purpose and surface problems. In doing so they should foster consciousness.*
Implementation of a tool, however well designed, is always a closed system. It is possible to be "done". The human desire to be "done" and move on to the next item is contradictory in attitude to the Lean practice of Continuous Improvements. Any implementation should therefore also train the organization in awareness and attitude. Employees have to be trained to "see" and "respond" when faced by deviations and obstacles. This "consciousness" can be translated or codified into priorities within the XPS of the process.

Another example that this duality of purpose is intended and built into Lean from the very beginning, is apparent when looking at Jidoka and elimination of waiting time. They are not

only for the reduction of production cost, but are also seen as effective instruments to enhance the safety of the process (Sugimori et al. 1977).

The paradigm of Lean Continuous Improvements “The tortoise beats the hare” (Ohno 1988) essentially means that many small steps will, in the long run, lead to improvements faster and better than a few big steps. Mathematically this does not seem to make sense. They should be at least equal. When looking into changing the behavior of a process (see Cultural view below) this is something to pay attention to. Normally in a process there is someone that everyone knows they can quickly turn to for a “Kaizen Blitz” if there are problems. A typical “Hero” in a organization (Hines et al. 2010). This is also a symptom that the process improves in leaps and bounds, not incrementally.

Understanding improvement from a Lean perspective means that the need for “Heroes” is a red flag. Improving in big steps means taking big risks and implementing big changes. Risk means the process might have to be in a stabilization phase for longer before the next step and the root causes behind the problems are more difficult to find. Smaller steps mean less risk and greater control of the change (Rother 2010) This also means that many small improvements may be carried out in parallel, as a smaller change often entails a smaller cost.

Five examples of apparent paradoxes, conflicts and dilemmas in Lean

In Lean literature it is common to find descriptions of various paradoxes, conflicts and dilemmas (Dennis 2002; Ohno 2013). Either these are misunderstandings dependent on the phase of implementation (Hines et al. 2010), or they appear due to a partial understanding and cherry picking of the ideas of Lean (Sayer and Williams 2007). Illustrating this are the examples below.

Note: The headings preceding each example are not commonly established. They are included only for the convenience of the reader of this thesis.

The chicken-and-egg problem of flow and stability

In a Lean process, creating flow is seen as an important step in order to remove waste from the process (Rother and Shook 2004; Womack and Jones 2003). A prerequisite to create flow is that the process is stable. Unstable production will require buffers that inhibit flow. The paradox is therefore:

To achieve flow you need stability, to achieve stability, you introduce flow (Liker and Meier 2006).

Superficially, this appears to be a chicken-and-egg problem. The realization is that, by introducing the demands of flow, you surface the problems stopping you from achieving flow, namely stability issues. By dealing with these problems you create stability in the process and are thus able to create flow. One side-effect is that creating stability, removing causes for randomness and chaos, can be likened to clearing the clouds of a process. In a chaotic and unstable process, it is difficult to draw correct conclusions about which activities are

necessary and which are not (Liker and Meier 2006). A stable process makes the distinction easier and creates a foundation for true improvements.

The problem of achieving productivity

Another apparent paradox in Lean is how productivity is to be achieved without excessively forcing hard work on the employees, without regard to their humanity. This is resolved through an understanding of the nature of improvements in Lean (Monden 2012). The elimination of wasteful activities does not *by itself* lead to harder work, it leads to more proportionately more time spent performing valuable activities, assuming a correct pace of work. Increasing work pace over a proper level is indeed considered directly wasteful and a source of Muri (Liker 2004; Dennis 2002) (see systems view of Lean above).

The problem of waste not, want not

An apparent paradox in the application of Lean lies in the attitude towards waste. A fundamental tenet (see Foundational view) is the absolute elimination of waste. However in some cases, waste (for instance inventory) might be useful and necessary. It may therefore be necessary to substitute one kind of waste for another (Liker and Meier 2006). The key to this paradox is two-fold, as it lies in the understanding of the process stability. Unevenness (Mura) in one part of the process will disturb the entire process flow. Before the cause of that unevenness is resolved, removing a certain amount of inventory will remove the shock absorbers in the system, causing more waste than what was removed. Therefore, total process efficiency must be considered when eliminating waste, together with the realization that blindly following any principle will lead to failure.

The intention is to cause enough discomfort (see above) so that problems are resolved. One aspect of this is inspection, which is itself a waste. It does not add value to inspect a result that should have been correctly done in the first place, and Lean is all about removing waste. Still, successful applications of Lean that can be observed, put a great emphasis on inspection (Liker and Meier 2006). This seems contradictory until one realizes that early discovery of a deviation prevents more expensive waste later on; that of correcting. Lean is about the entire process efficiency, not just efficient islands (Modig and Åhlström 2012).

The problem of raising the bar

In this realization lies yet another paradox of Lean: *“In order to improve, conditions must be made worse. There is no way to become truly lean without a certain amount of discomfort”* (Liker and Meier 2006). How can this be achieved without sacrificing the “Respect for people?” The key to resolving this apparent paradox lies in the definition of discomfort, or rather who is to experience discomfort. Forcing people to work too hard is in violation of respect for people and can bring with it quality issues because of stress and overwork (Muri). Discomfort should therefore be at the management level, It is a key incentive to continuously improving the process. In contrast, comfort at the management level leads to complacency, which kills Continuous Improvements (Sayer and Williams 2007).

The problem of how bureaucracy enables creativity

Standardization of a process may be seen as a bureaucratic tool to coerce increased effort from the employees. It evokes an image of industrial engineers and stopwatches enforcing rules and forcing people into molds and unnatural patterns. Standardization in Lean is indeed bureaucratic and might also be seen as wasteful, if not coupled with empowerment of the employees. This creates what may be defined as an “enabling bureaucracy” (Liker 2004). Supporting this, Adler and Cole (1993) find that motivational dysfunctions in standardized work may be mitigated when people are treated fairly, share in decisions and receive the proper training and tools. In that sense, the rules and forms of a work standard are liberating, as they form the foundation for Continuous Improvements (Osterman and Fundin 2014).

Many other paradoxes exist, such as the Jidoka paradox, “Stop the process so that the process will never stop” (Dennis 2002), or the Rigid Flexibility paradox (Spears and Bowen 1999), besides the five examples of paradoxes, dilemmas and conflicts, and their resolutions described above. A pattern seems to emerge to the second aspect of the philosophical view of Lean:

- *The application of a Tool or Method in Lean must be aligned with the purpose of all the Tools and Methods, as well as the intent of the Lean system.*

When operationalizing Lean there has to be an understanding of purpose of each part, (see Figure 2 in Tools and methods view above). There also has to be an understanding of the intent of the system, see for instance aspect S2, in the Systems view of Lean above. Paradoxes, dilemmas, and conflicts appear to arise (see examples above) when there is misalignment between the application of Lean and the purpose of the tools and methods. Paradoxes, dilemmas, and conflicts would also seem to arise when the application of a Lean method is misaligned with the overall intent of the Lean system.

2.4.6.1 Concluding the Philosophical view of Lean

Whereas the concepts of Lean are fairly easy to grasp, the dynamics of a Lean system seem more complex. The ideas behind the system seem both simple and deep at the same time. Going back to the Foundational view of Lean, it would seem that the founders were both pragmatic and also had an ability to deeply reflect on all aspects of a problem. In the Evolutionary view of Lean it becomes clear that the system was not conceived as a whole but evolved over several decades. During this time the founders resolved new problems and added the solutions to the previous methods and tools, thus slowly building a system. The real challenge during the evolution was to stay true to the initial purpose of the first solution and to resolve any conflicts, dilemmas, or paradoxes that appeared. This required deep reflection and understanding and is in accordance with aspect F2 (see Foundational view above). The philosophical aspect of Lean goes beyond the obvious. It requires you to go “*beyond common sense*” (Ohno 2013) Therefore:

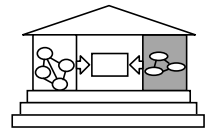
P1. *Lean methods have to both fill their intended purpose and surface problems, and in doing so, foster consciousness.*

P2. *The application of a Tool or Method in Lean must be aligned with the purpose of all the Tools and Methods, as well as the intent of the Lean system.*

The view taken on Lean philosophy in this thesis, is that it concerns ideas, concepts and paradoxes that arise in Lean. Each paradox or dilemma must be resolved on a conceptual level, as the intent of each idea should align with the intent of the entire system. Such a level of understanding is important but insufficient, as each idea must be translated into behavior in order to produce good results in an efficient manner. This leads to the Cultural view of Lean.

2.4.7 Cultural view of Lean

If the Philosophical view of Lean could be said to concern the thoughts and ideas of Lean then the Cultural view of Lean concerns how these thoughts and ideas, when put together, are formed into a behavior within a organization. The Cultural view of Lean also has a collective aspect as it is the total sum of behaviors within a process that will ultimately decide the results of the process.



Using Lean tools and methods is not sufficient to truly attain the levels of performance that could be observed mainly at Toyota. Neither is the systems view sufficient. It is ironic that the human perspective of Lean was forgotten, as the first research paper available in English describing the Toyota Production System (Holweg 2007) was written by Toyota managers and clearly emphasizes the duality of Just-In-Time and Respect-For-Humans (Sugimori et al. 1977). The importance of duality has once again been brought to our attention by for instance Halling (2013).

Although the philosophical view of Lean is a step in the right direction, it is concerned with thoughts, ideas, and concepts. The ideas have to be brought together and translated into sustainable results. Ideas have to form behavior. Some contemporary literature therefore emphasizes the cultural aspects of Lean (Bhasin 2012). Even though huge initial gains are possible when implementing Lean, if they are to be sustainable, a cultural change must occur (Wilson 2010). Mann (2005) defines culture in a working organization as “*the sum of peoples’ habits related to how they get their work done*”.

In *Toyota Culture* this is defined in a Lean context, referring to E. Schein⁸, as “... *The pattern of basic assumptions that a given group has invented, discovered, or developed in learning to cope with problems of external adaptation and internal integration, and that have worked well enough to be considered valid and, therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to these problems*” (Liker and Hoseus 2008). Adler (1993) mentions three sources of motivation forming the behavior of people, which a Lean (exemplified by NUMMI) production system has to tap into.

⁸ Schein, Edgar “Coming to a new awareness of organizational culture,” Sloan Management Review, Winter 1984, No.2, pp. 3-16.

1. *The desire for excellence.* Employees generally want to do a good job. A proper Lean training program will raise employee's real competence and, equally important, their feeling of competence.
2. *A mature sense of realism.* A understanding that if you do not help to improve the process you are working in, competitors will run you out of business.
3. *The positive response to respect and trust.* A sense of reciprocity and the removal of fear is essential to sustainable continuous improvements.

The cultural view of Lean can therefore be seen from an individual perspective and an organizational perspective. The individual perspective deals with the actions and decisions made by an individual in a process. This perspective also recognizes that results in a process may all be traced back to decisions and actions taken by individuals. It was recognized early on that, if given support and time, employees are capable of, and desire to, contribute to organizational requirements in a Lean context such as Quality Circles (Keys and Miller 1984). Employee involvement is seen as a prerequisite for both quality aspects and efficiency aspects of Lean (Schonberger 2007).

There has to be a sense that management values skilled workers and will take measures to retain them, so that employees develop trust in the system of Lean Production (Liker and Meier 2006). Halling (2013) argues that forgetting human factors is the most important reason why attempts to implement Lean fail. Hines et al. (2004) argue that human dimensions are key to achieving long-term sustainability in any Lean program, regardless of sector. Employment may be seen as a long-term commitment encouraging extensive investment in employee training and development, which in turn is translated into loyalty and trust (Keys and Miller 1984; Liker and Meier 2006). Research also shows that workers only accept responsibilities and tasks when there is some sense of reciprocal obligation (Womack et al. 1990; Liker and Convis 2012). In line with this, the most important factor in order to succeed with the application of Lean is the development of highly motivated people. Failure to do so is seen as a probable cause of backsliding in Lean implementation and application (Monden 2012). Therefore the first aspect of the cultural view of Lean is:

- *There has to be a sense of reciprocity between the employees and the management.*
One of the key factors in creating a successful Lean Production System is to create the sense of “We are all in this together”. This is perhaps the most important factor that differentiates “False Lean” from truly successful implementation. Without a sense of reciprocity it is difficult to develop trust between management and employee. Without trust there can be no true problem-solving and creativity simply because people will not actively rationalize a process if they fear it might cost them their jobs (Womack et al. 1990).

A sense of involvement and responsibility on a personal level for employees is crucial (Dennis 2002). As Taiichi Ohno discovered in early teamwork experiments (see foundational view above), the requirement of consciously improving the process is impossible to meet without involved employees. Also, a sense of responsibility can be reinforced through job rotation. If every worker is allowed to participate in every process, he or she feels responsible

for all goals of the shop. For this to succeed there has to be adequate support from management (Khim and Rogers 2008).

Involvement should be channeled through activities that are concrete and have relevance in the daily operation of the process. An example of these channels is the Kaizen process (Imai 1986; Imai 1997), where managers' personal participation is essential (Emiliani 2007), or the Kata process (Rother 2010). Involvement in improvements is, if properly managed, self-reinforcing, leading to the following realization in the second aspect of the cultural view of Lean:

- *A culture of involvement and responsibility is required for continuous improvements. Participating in improvements gives a sense of involvement.*
Passive trust based on a sense of reciprocity, although necessary, is not enough. It has to be translated into a change in behavior, an active decision. Giving responsibility combined with the necessary means cultivates a culture of involvement and ownership. Making participation in improvements mandatory while providing training and targets fosters involvement, commitment, and a sense of responsibility. This is necessary for continuous improvements.

There is some controversy whether Lean is to be regarded as intrinsically motivating. Research has indicated that, although a reduction in for example independent choice can have a negative impact on motivation, other factors, such as responsible autonomy, substantially increases intrinsic motivation emerging from a Lean production implementation (De Treville and Antonakis 2006; Liker and Convis 2012). This indicates that the balance of factors of work design will impact motivation and can be seen in the fundamental philosophy of Respect for People, which can be operationalized in the methods of a process, such as every worker's right, indeed obligation, to stop the process if an abnormality is discovered. This is stated by (Sugimori et al. 1977): *“It is not the conveyer that operates men, it is men that operate a conveyer. This is the first step to respect for human independence”*. This puts Lean in contrast with for instance mass production.

An enabling factor for respect for humans is the method of visual control where anyone can see and act on the deviations of the process. This has to be coupled with delegated authority and responsibility, in order to reinforce the culture of continuous improvements (Sugimori et al. 1977). Therefore, the third aspect of the cultural view of Lean is:

- *A culture of immediate reaction to correct deviations.*
It would seem that normal human behavior when a deviation is detected is to try to “catch up” or to let the deviation slide. “This is not my problem”. Such behavior hides problems and is contrary to a Lean culture. In contrast, there is numerous anecdotal evidence of employees at Toyota being publicly recognized and receiving praise when stopping the process (Liker and Convis 2012). This would seem to reinforce behavior in two ways. The individual receiving praise is likely to continue the behavior. Also,

since the praise is public, the rest of the organization will see that the behavior is praised. This also reinforces the incentives of the necessary behavior in a Lean culture.

The importance of the human dimension for the success of a Lean production system can be illustrated by the example of quality defects at Toyota 2009 – 2010, resulting in massive recalls of vehicles to rectify problems with “sticky” accelerator pedals and defective anti-lock braking systems (Liker and Franz 2011). The root cause of the defects was attributed to “a delay in the development of human resources” caused by the rapid expansion of Toyota's production. There simply had not been enough time to develop employees at the same rate as volume grew (growth of produced volume by 500 000 vehicles annually). This example serves to illustrate the importance of human factors in Lean (Monden 2012). It also serves to illustrate an important aspect of a Lean culture. You not only learn from your mistakes you share what was learned so that knowledge is spread throughout the organization, the so-called “*Yokoten*” procedure or horizontal distribution of knowledge (Liker and Franz 2011). Thus it may be concluded that “*Reinvention is its own waste*” (Liker and Meier 2006). The cultural aspect of this is openness to the experience of others, which can be seen as a differentiating factor in a Lean culture. This may also be seen as supporting Fujimoto's (1999) theory of a *dual-layer problem-solving* framework.

Indeed, employees can be said to be taught to be constructively discontent with their jobs, giving rise to a creative culture of problem-solving, where work problems are thought of as “golden eggs”. In other words, the attitude promoted in the process culture is: “it is good to identify problems” (Basadur 1992). In the process of creating value for customers, the process also allows the organization to learn and thereby create new resources (Lewis and Lewis 2000). Therefore the fourth aspect of a cultural view of Lean is:

- *A culture of creative dissatisfaction drives Continuous Improvements.*

It is one thing to respond to deviations and problems, but Lean requires development if it is to be sustainable. It would seem that normal human behavior is one of complacency. You do not change things that work. There seems to be a need to “be finished” with something. This is contradictory to what is needed in Lean. A sense of discontent helps drive the next step of improvements, the next challenge. This would seem necessary to avoid stagnation after the initial phase of a Lean integration. This can also be seen as “striving for perfection”, whilst knowing that perfection itself is not obtainable (Liker and Convis 2012; Womack and Jones 2003).

2.4.7.1 Concluding the Cultural view of Lean

Lean culture can be defined as the sum total of individuals' behaviors. Each person seemingly behaves according to what is rational, within a given context, for that individual. Therefore a Lean culture has to provide a context where the employee's choice of behavior is compatible with the intentions of Lean. Lifting the view to the organizational aspect of Lean culture, it also serves as a collective pattern, where the actions of one person are aligned with the actions of another person, even when acting independently, or even unaware of each other. Therefore,

establishing a Lean culture within a process is necessary for the long-term sustainability of a Lean process.

C1. *There has to be a sense of reciprocity between employees and management.*

C2. *Involvement and a sense of responsibility are required for continuous improvements. Participation in improvements creates a sense of involvement.*

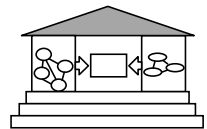
C3. *A culture of stopping the process immediately to correct deviations.*

C4. *A culture of creative dissatisfaction drives Continuous Improvements.*

Similar to the Lean philosophical dilemmas above (see Philosophical view of Lean above) the cultural view of Lean faces dilemmas. The most important seems to be of a “chicken-and-egg type”, where culture informs behavior, and behavior creates the culture of a process. Experience shows that thinking about Lean as a culture yields little. Requiring and reinforcing the right behaviors of individuals forms the culture for all (Mann 2005). This leads to the management view of Lean.

2.4.8 Management view of Lean

Based on the fundamentals of Lean, the tools and methods and system of Lean together with the philosophy and culture of Lean produce the results of the process in an efficient way. There are inevitable dilemmas and paradoxes that have to be resolved in accordance with the intent of Lean. These problems do not resolve themselves. Therefore there is a need to examine the balancing function of the management view of Lean.



Proper management in a Lean Production System is vital (Liker and Convis 2012). The importance of the manager in Lean can be stated as “*orderly production operations may be the result of the effective practice of management rather than the cause of manufacturing efficiency*” (Keys et al. 1994). A manager in a Lean therefore has several different roles to play.

2.4.8.1 Daily operation

Getting Lean to work in a process requires proper training and follow-up (Monden 2012). This in turn requires time, proper conditions, incentive, a sense of responsibility, and commitment from management (Liker and Convis 2012). A manager whose responsibility it is to train others must therefore lead by example to create a template for the organization (Sörqvist 2013). A structured approach is described by Liker and Meier (2006) in *The Toyota Way Field Book*, where the standardized work of supervisors is exemplified. The key role of the supervisor and dialogue with personnel is further explored by Rother (2010), regarding the behavioral aspects and coaching necessary to achieve the Kaizen mindset, as explained by Imai (1986). To thoroughly understand Lean from a manager's viewpoint can only be achieved through direct participation (Emiliani 2007). Part of this participation is to resolve

dilemmas and paradoxes that arise within Lean as well as the responsibility to provide the right working conditions for employees. Therefore, daily operations in a Lean process can be expressed in two first aspects of the management view of Lean:

- *A sense of personal accountability and competence in methods.*
Any training or follow-up has to be grounded in the personal ability of the manager in the methods being taught (Liker and Convis 2012). The methods should be mastered to such a degree that the manager him- or herself is able to achieve results at the desired level. (Emiliani 2007). The reasoning behind this is simple. It would be difficult to lead and coach something you yourself are not proficient at.
- *Self-development attitude.*
To be an effective manager in Lean you have to assume a long-term commitment to the role of teacher, trainer, and student (Emiliani 2007). Lean leadership therefore requires continually challenging the process, thereby also developing the leader's own skills (Liker and Convis 2012). To an extent this depends on cultivating the right attitude in the organization, even at the leadership level. (see The cultural view of Lean aspect C4, above). Creative dissatisfaction extends to the manager's own work.

2.4.8.2 Solving problems and finding balance

Simply put “*if management fails to lead and the workforce feels there are no reciprocal obligations in force, it is quite predictable that lean production will revert to mass production*” (Womack et al. 1990). However, it is important to note that the principle of “Respect for People” is not just altruistic. It is a prerequisite for continuous improvements and also a reason why management in Lean avoids laying off regular employees (Monden 2012). Based on this realization, one important role for the manager in a Lean Production System is that of a coach of improvements. Since involvement of the employees is vital for continuous improvement, the enabler of this involvement is the dialogue between manager and employees (Shook 2009). On the same note is the short cycle between dialogues, sometimes on a daily basis, used to reinforce an improvement culture (Rother 2010). Problem-solving is a large part of a manager's work (Womack et al. 1990). Proper philosophical application of Lean methods is therefore a prerequisite for Continuous Improvements (Monden 2012).

The purpose of having an organizational hierarchy is different compared to for instance mass production. This can be exemplified by looking at NUMMI where “*the function of hierarchy at NUMMI is not control but support*” (Adler 1993). Also, “*at NUMMI, middle management layers are layers of expertise, not of right to command, and if middle managers have authority, it is the authority of experience, mastery, and the capacity to coach*” (Adler 1993). Implementing many of the Lean tools may be seen as the task of process designers, but managers' role within the Lean process is to decide and take responsibility for the level of challenge they are willing to accept and give the organization. Therefore, communication becomes one of the most important, if not the most important, aspect of a manager's job, as it is fundamental for employee motivation (Fujimoto 1999). This leads to the third aspect of the management view of Lean:

- *The drive to continuously improve has to be coupled with respect for people.*

A basic tenet of Lean is continuously improving the process. This requires harnessing the creativity of everyone within a process if improvements are to be sustainable over time. If the resulting improvements are used to lay off people, some initial cost reductions will be achieved, but the involvement of people will be lost. Respecting people is therefore a prerequisite for continuous improvements (Emiliani 2007). The Non-cost principle has to be balanced by Respect for People, if Lean is to be sustainable over time. If not, Lean turns into a tool-based program to cut costs (Liker and Convis 2012).

2.4.8.3 Setting targets and direction for Continuous Improvements

“Practicing Lean management requires managers to questions everything” (Emiliani 2007).

An important aspect of an improvement culture within Lean is the necessity of organizational alignment. Even if employees are empowered, responsible and contributing to improving the process, the total sum of improvement might be less than each effort by itself, if everyone is “improving” by themselves (Bengtsson and Osterman 2014). Therefore there is a need for a “True North” in Lean (Liker and Convis 2012; Mann 2005). A given direction which an organization can use to coordinate and align the improvement efforts even if everyone is working independently. Striving for “perfection” (Womack and Jones 2003; Schonberger 2007) is an example. “Zero defects” serves the same purpose (Shingo 1989). Taking a more strategic view (Keys and Miller 1984; Keys et al. 1994) emphasizes the long-term view as an underlying factor when examining management practices. This long planning horizon is seen as an important factor for Lean management, as it counteracts the tendencies of sub-optimization and rewards a management behavior that builds relationships and encourages responsibility. The long-term view is taken to maintain a continuity of purpose (*in Deming's words, "a constancy of purpose"*) which helps reinforce the shared Lean culture of an organization (Liker and Meier 2007). In the words of Taiichi Ohno, management's responsibility is to identify excess manpower and utilize it effectively (Ohno 1988). The purpose of this is to reduce costs of the production system and achieve a higher profitability. This should be measured all the way from the top management level down to the lowest level of the process, through a consistent set of measures where the upper management's responsibility cannot be overstated (Monden 2012). This leads to the fourth aspect of the management view of Lean.

- *There is an established sense of True North in the organization.*

A real problem in the implementation of Lean is the coordination of different efforts of Continuous Improvements. Depending on the maturity of the organization, there is a need for an aligning vision by which each improvement effort can be evaluated (Liker and Convis 2012). The need grows as the maturity of the organization increases and more people get involved in improvement efforts.

2.4.8.4 Concluding the Management view of Lean.

The importance of Management in Lean can perhaps best be understood returning to the fundamental views of Lean. The historical view is based on visions of leaders (for instance Taylor and Ford) who influenced the founders of Lean. They themselves were highly focused, pragmatic, willing to learn, and able to adapt. The evolutionary view of Lean illuminates the importance of the consistency of purpose that is necessary if the leaders were to resolve problems, paradoxes, and dilemmas during the development of TPS. Therefore the need for what today is known as establishing a True North for the organization. Perhaps the most important function for Lean management is continuously balancing productivity development in the process with the Respect for People principle. Taking shortcuts or increasing productivity by overloading people (Muri) gives initial gains but also kills the sustainability of Lean necessary to keep improving in the future. Therefore a management view of Lean can be stated as:

M1. *A sense of personal accountability and competence in methods.*

M2. *Self-development attitude.*

M3. *The drive to continuously improve has to be coupled with respect for people.*

M4. *There is an established sense of True North in the organization.*

3 Design of studies and scientific approach

The following chapter describes the design of the studies, the scientific methods that were used, scientific validity, ethical, and contextual considerations. In addition, an explanation of the rationale behind some of the research design choices will be given.

3.1 Overview of the studies

Table 1. Summary of studies, Case A and B in study 1 are not the same as case A and B in study 2.

Study	Research design	Data collection	Pilot study	Case	No. of groups	No. of interviews	Paper	Unit of analysis	Lean problem-solving model	
1	Multiple case studies	Semi-structured interviews + observation		A	2	8	Paper I	The group	Current State	
				B	2	4				
				X	C	2				5
				D	1	2				
				Total	7	19				
2	Multiple case studies	Semi-structured interviews + observation		X	A	2	Paper II & Paper III	PII: The decision process & PIII: The production process	Desired State	
				X	B	2				5
				Total	4	11				

An overview of the logic and scientific methods of the studies. To ensure the ability to generalize the conclusions of the studies, the ambition was to follow two groups in each case. For the interviews, the ambition was to span a different relevant function for each single case to ensure validity, as well as to ensure that the same (or similar) functions were interviewed in the different cases, to give comparability.

Research design was inspired by several sources. Storhagen (1993) for instance considers the case study methodology as a natural choice for Lean research. Due to the nature of the questions that were explored, a multiple case study approach was therefore chosen for both studies (Yin 2009). Also, in the gathering of empirical data, both semi-structured interviews and observation were done in a mixed-method approach (Creswell 2009). Study development was iterative, inspired by frameworks such as DRM Figure 2.1 (Blessing and Chakrabarti 2009). Also the structure explained by Salkind (2012), where an initiating assumption was followed by a search for evidence or an indication in the literature and previous research, thus clarifying the research. Based on this, the design of both studies was iterated via a pilot study to verify the design up to the main study.

3.2 Study 1

The purpose of the first study was to explore if there could be developed a measurement system or assessment with which to judge the application of Lean at the lowest organizational level, the group level.

3.2.1 Why is measurement important in Lean?

There are several reasons to assess the level of progress in transforming an organization to Lean. Several methods are possible. Firstly, it is important to realize that though Lean is a system (see systems view of Lean above), implementing and applying Lean is done in stages (Shingo 1989), where each stage is based on a previous stage. Secondly, the next stage in the implementation depends on several factors. The current stability of the process is most important, as is the current level of understanding of Lean. Both these together establish a base from which the next step or target condition can be determined (Rother 2010). Assessing the progress of Lean is of great importance since it determines which current application problems have to be solved and which questions of implementation have to be answered. Special attention will have to be given to the construct validity of the study. A common problem in research is the failure to develop a sufficiently operational set of measures (Yin, 2009).

3.2.2 Initiating impulse and direction of study design.

Attempting to devise Lean assessment systems was nothing new, quite the opposite. There were many such in existence, such as the method developed by Karlsson and Åhlström (1996), or the methods developed by Bhasin (2008; Bhasin 2011a), and many more. In general, the methods of assessing Lean in a process seemed either to be theory-based, high-level assessments from a management perspective, or checkbox type assessment tools where the existence of some low-level Lean tool or method was used to evaluate the “leanness” of a process. Various other measurement methods existed but these two categories appeared to be the most common.

Coming from an operational perspective, there was a need for a simple assessment method that captured the dynamics of a Lean process at the group level. The method should also be as generic as possible, meaning that it should capture factors common in Lean and not be trapped in superficial differences. Assessing at the group level in a process was thought to assist in this ambition, as most if not all Lean processes involve the work of people. People tend to form groups regardless of what the purpose of the process is and indeed “teamwork” is one of the founding linchpins of Lean (Ohno 2013; Ohno 1988). Thus the group level may be seen as a sort of generic common denominator in Lean, where assessment of a process and comparison between processes should be possible regardless of the purpose of the process. Therefore the study was designed as a multiple case study as defined by Yin (2009), using a mixed-method approach inspired by Creswell (2009), where observation of a process is combined with interviews. A case-study protocol was designed as suggested by (Yin 2009), to ensure study reliability. The case-study protocol was also used for the interviews, which were semi-structured in accordance with Bryman (2011).

The intentions of the design of the Lean assessment method used in this study were that it should capture the ability of a process to perform as intended, and have the ability to handle problems within the process on an operational level. In the study, Lean methods of Standardized Work (SW) were used to assess the ability of a process to perform as intended (Wilson 2010; Liker and Meier 2006; Liker 2004). The methods of Problem-Solving (PS) were used to assess a process' ability to deal with unintended events (Dennis 2002; Wilson

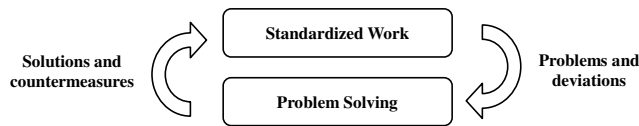


Figure 6. Connection between Standardized work and Problem Solving

2010). Most importantly, the connection between SW and PS also had to be defined, as they are mutually dependent as explained by Fujimoto (1999). If a process is not able to perform according to the defined SW, then there exists what could be defined as a deviation. Therefore non-compliance with SW gives rise to the need for PS. When the deviation is resolved, what could be referred to as a “solution” or “counter measure” is used to redefine SW, in the creation of a new normal situation (Liker and Franz 2011).

Lean Jargon, understanding the apple and comparing apples to apples

After a literature review and based on the author's own practical experience in SW and PS, the first issue to be resolved was Lean jargon. As Pettersen (2009) and many more have pointed out there is a plethora of definitions, In some cases the same terminology is used with different meanings. To enable a generic assessment method in various unrelated processes and get comparable results, this issue of company or process-specific jargon on the operational level, had to be resolved. It was decided to use an assessment question based on the purpose of SW and PS. Disregarding whatever local labels were used, the operationalized methods were of interest. For instance, is the “Why” and “How” of an operation explained? It was not of interest if called a “Standard”, “Element sheet”, “Tempo description”, “SOP”, or anything else.

Interpretation method of Lean in study 1

The use of “purpose” or “intent” when devising an assessment method is mainly based in the decision of exactly what is “purpose”? Where and by whom is the “intent” of a method explained? The assessment questions were therefore designed based on a review of Lean operational literature such as Liker and Meier (2006), Wilson (2010), Baudin (2002) and the author's own experience. The aim of the design of the totality of the assessment questions was that they would form a logical whole, and that even if there was some overlap of assessment questions, the overall intent of SW and PS would be captured. This design decision was intended to resolve the subjectivity issue of question design, so that the assessment questions would give comparable results regardless of process and that the logic of the questions as a

system were intended to give reliable inter-process results when determining the next appropriate step in the implementation of Lean.

3.2.3 Designing the case-study protocol and categorizing the assessment questions.

Both SW or PS were generally defined in terms of Lean implementation. But in order to design an assessment method useful for Lean application in operational terms, deeper perspectives were needed. Since the unit of measurement is the group level of a process, three different perspectives have to be considered. Firstly, group operations are based on the achievement of individuals. In the application of Lean, the individual in the process is the one creating the results (Liker and Meier 2006). Secondly, in a group operation individuals do not act independently of each other (Liker 2004; Ohno 2013; Ohno 1988). Therefore, in addition to an individual perspective, an organizational perspective was used. Finally, a Leadership perspective was necessary, as the development and incentive system of a group is leader dependent (Ohno 2013). Using the perspective of Individual, Organization and Leadership, the assessment questions were further divided into aspects intended to be easily distinguished and answered. For further details of the case-study protocol, please see appended paper I.

Table 2. Overview of the study 1 protocol.

Study 1 Protocol		Standardized Work	Problem solving
Group level	Individual: Creates results in a process	Lean Assessment Protocol	
	Organization: How individuals work together		
	Leadership: Direction and incentives		

3.2.4 Choice of cases

Different research methodologies were initially considered, but case studies (Yin 2009; Bryman 2011) were seen to be the most appropriate due to the nature of my topic. Since the aim of the study was to explore the possibility of developing a general assessment method on an operational level in a process, it was decided that a single case would not suffice and that a multiple-case study was required. The challenge was then to select cases that were alike in important aspects, so that the results could be generalized, yet different enough so that the assessment method would be general. Four companies were selected. All companies are mature in Lean integration with several years experience and all have a central Lean support function. They are all large companies that are internationally active.

All cases had been implementing Lean for several years, deemed essential for the study, so as to weed out any early false positives. The idea was to avoid companies that started a Lean implementation and achieved initial success, simply because imposing some order and direction was better than nothing, regardless of what production system the companies

worked with. Initial success is often unsustainable (Jablonski 2001; Hines et al. 2010). Other important common factors were the stated intent to work with Lean, together with a documented internal interpretation of a Lean production system, a so-called XPS (Netland 2012).

The stated intent was important because at an operational level, different production systems may share similar methods, but the interactions of the methods and which problems intended to be solved with the system may be different (Andersson et al. 2006). One example of this is the difference between a Six Sigma system and a Lean system. The Six Sigma system mainly designates process variation as a source of deviations compared to a Lean system, which for instance finds deviations in the proportional difference between value-adding time and waste.

The XPS of each case was used as a comparison between the cases as well as a base for weeding out the internal Lean jargon through going through the explanation behind each XPS. The comparison revealed that for this study, the XPSs were similar enough to be comparable. Indeed, the employees working in the central Lean support function of each case gave evidence of a level of knowledge and reasoning on a comparable level. It is the author's opinion that they would be capable of similar work in any of the other Lean offices, without any major difficulties or retraining. Thus the information given by the members of the Lean support functions were comparable.

Two of the four cases were from the manufacturing industry, and two cases from the process industry. Though the general hierarchy of the organizations of the cases were similar, the division of responsibility within the hierarchies was different. All cases produced products of a different nature and were intended for different categories of end customers. Therefore, the processes were fundamentally different in scope, speed, and conditions. This led to the opportunity to observe various practical applications of Lean under different conditions.

3.2.5 Pilot study

Before the main study, a pilot study was conducted at one of the case companies (Case C). This was done to ensure the construct validity of the study (Yin 2009). The area used for the pilot study was not directly connected to the area used in the main study. The pilot study was done in two stages, where the first stage was used to verify to logic, disposition, and integrity of the case-study protocol. Based on a revised case-study protocol, the second pilot study was conducted to verify the revised protocol and to check how much time would be needed for the main study.

3.2.6 Conducting the main study

The main study was conducted over a period of one and a half months. For each case a manager in the central Lean support function was interviewed to get the details of the XPS and an explanation of how the implementation of Lean was working in the process from the manager's perspective. In all cases except one (case D), two groups were observed in order to ensure a wide enough sample and to give comparability in the case. The groups were working in parallel processes, sequentially connected processes, or independent processes, depending on the nature of the process. It was noted that both groups of a case used the same XPS, though their maturity levels sometimes differed.

Observation of the process

Observation followed the same pattern of firstly getting an overview of the process and the results of the process, through a fairly quick walkthrough. Secondly, the structure of the protocol guided where the observation was conducted. Depending on the nature of the process and the question, different places of observation were found in a dynamic fashion. Thirdly, in some cases follow-up questions required a revisit to places in the process. An observation typically took place over several hours. Observation time differed both within a process, between the processes of each case and between cases, because of the different nature of observed processes.

Apart from observation of the process itself, the process KPI system was studied. In all cases, KPIs were noted on a board together with historical statistics and targets for the KPIs. In some cases, targets were traceable to strategic process goals. In some cases there were action and activity lists on the boards.

Interviews in the process

Interviews were held as a structured discussion, a factual interview (Kvale and Brinkmann 2009), and intended to support the observation, giving deeper understanding of the observed phenomenon. Much thought was given to study design. The interviews were therefore all conducted with knowledgeable informants in their natural setting, thereby enhancing validity. Since the organizational structures of the cases were different, the exact title of the respondent varied. The case-study protocol was used to give structure to the interviews, held simultaneously with the observation. Since observation took place in real production following the actual process of the plant, safety was of the essence.

The respondent for the part of the process observed was not randomly selected, Instead this was someone who actually worked in the process, for instance as a team leader. The respondent seemed to have a detailed knowledge of minute details of the process, as well as training procedures and the practical application of the Lean methods and tools used in the process. Care was taken not to discuss Lean methods in general, but the respondent was asked to exemplify and demonstrate specifically how the Lean method was applied in the process. For instance, if the content of a work standard was discussed, the same standard was examined where the standard was used in the process. During this employees following (or

not) the standard were observed. The respondents' answers were noted on the case-study protocol together with additional notes on the specifics of the observation.

Since all case studies started with an interview with a representative from the central Lean support function, with the purpose of understanding the XPS of each case, it is possible that unintended bias was introduced during the observation. In other words, the observation was not neutral but colored by the information given during the interview. As a possible remedy for this is that the author has several years of professional experience in both the application of Lean and in observation of various processes. The preexisting knowledge with the interviewer enhanced the quality of the interviews (Kvale and Brinkmann 2009). Also in most cases, several examples of each practice (SW and PS) were observed, giving a range of information with which to compare the information given during the initial interview.

The observations were held in a short time and it is undeniable that a longer observation span would have yielded more information. Since the application of Lean was observed in each process and there was no fixed limit on the time for observation, it was conducted until satisfied that enough consistent information about a phenomenon was gathered. This is also one reason why the time span for the observation of each case differs. The interviews mostly took place in the process environment, often noisy, and the responses were noted on the protocol. It is common to record an interview and to transcribe it, but due to the nature of the interview situation and the intent of the study design, where interviews were intended to support primary observations, they were not recorded. This is not uncommon in sociological workplace research, where different methods of capturing interview material in combination with observations is used (see for instance methods used by Glucksman (1982), Bergman (1995), Jahoda et al. (2009)) where note-taking was a common information recording method during information gathering and observation.

Anonymity

Anonymity was provided to both companies and respondents in the study, in accordance with the ethical considerations concerning planning, interview situations and analysis (Kvale and Brinkmann 2009). The purpose was to increase the probability of receiving unbiased answers and to receiving full access to the processes. Some of the cases regarded the details of the application of their XPS as privileged or trademarked information. Examples were details of a problem-solving method or the specifics of a follow-up schedule. This consideration is reflected in the presentation of the results, which are all factually correct, but devoid of identifying details.

3.2.7 Considering validity and reliability in the research design of study one.

Since the cases chosen for the study were industrial, one possible reservation was that the results would not be valid for other processes. Therefore, to enhance the external validity of the study, the unit of observation was based on human effort. Regardless of the different conditions in a process, on common denominator in Lean is that people tend to organize themselves to achieve a result regardless of the nature of the process or the result (Ohno 2013;

Ohno 1988). Also, the cases were large and thus perhaps not relevant for comparison with smaller companies. Again, the answer to this lies in the unit of analysis. A lean process will most often be organized around teamwork, which should be generally the same regardless of organization size. What can be different are the specifics of the solutions, as the amount of support and resources available in a smaller process may be less than in a larger process. In the design of the research, a combination of interviews and observation was used with emphasis on observations. The combination was intended to enhance the reliability of the study and also to deduce the underlying reasoning behind the observed phenomenon.

To further enhance the reliability of the study (Yin 2009), the interviews took place in the process, as much as possible enabling a discussion of a specific subject at the relevant place of the process. If for instance the subject of the interview was the application of Standards in the process, the Standard had to be in hand for comparison with the observed process. This gave an opportunity for triangulation of information between the process itself, the written standard, and the respondents' information. The internal validity of the study required some consideration. Since "*Correlation is not causality*" (Burawoy 2009), some care had to be taken in the analysis of the empirical findings. This had direct bearing on choices made during research. The connection between the implementation of the XPS of a case and the application of the Lean tools and methods of the case is important both for internal as well as for external validity of the study. Therefore the *intent* of the lean principles of the XPS was used both to ensure comparability between the cases and also to establish a cause and effect relationship between the XPS and the applied methods. Reliability in the study was also assured by the use of an interview protocol and an observation protocol.

3.3 Study 2

The purpose of the second study was to examine the connection between flexibility requirements and Lean and also the types of process flexibility required for a flexible process output. The study was jointly designed in equal measure by the author and PhD student Natalia Svensson Harari, and was intended to deliver two research papers with different focuses.

3.3.1 Initiating impulse and direction of study design.

In Lean literature and research papers, a common view is that Lean is flexible. This seems to be a traditional definition of Lean and can be traced back to the solutions and ideas of Taiichi Ohno (Ohno 1988; Dennis 2002), where variant flexibility was one of the reasons for developing the methods we today call Lean. For this a flexible workforce was deemed necessary as well (Ohno 1988). However, even among proponents of Lean, the inability of for instance a Kanban system to deal with volume flexibility, is a commonly known problem (Shingo 1989). Opponents or critics of Lean claim that the nature of the production system, with its focus on waste reduction, will reduce the slack needed to be flexible in a process, thus necessitating other production systems (such as hybrid production systems (Elmoselhy 2013)). The difference in view was intriguing. Both proponents and opponents had valid arguments. The impetus for this study therefore became a desire to examine the connections between Lean and flexibility in a process.

3.3.2 Method Design

The nature of the research impulse led to the conclusion that conducting a multiple-case study was appropriate (Yin 2009). It was decided to limit the case study to two cases and to put more emphasis on interviews and less on observation of a process. The reason was that it was deemed important to understand decisions made in the process. For this the semi-structured interview seemed the right tool (Bryman 2011), also considering procedural issues discussed by Kvale and Brinkmann (2009). For the definition of flexibility the choice fell on Upton (1994) as it was compatible with the intent of resource optimization within Lean.

Each case was assumed to have a defined XPS. The study was therefore designed to use the XPS (Netland 2012) of each case as a given and focused on how a process responded to an impulse or event that requires flexibility of some kind in the process on several different levels. Also important was the stated intent of the case to work with Lean. The XPS could later be used to interpret the interview responses to find connections between Lean and flexibility on a practical level. In practice, the detailed design of the study and the selection of cases were done simultaneously. The reason for this was that for the study it was important to be able to select events requiring flexibility, commonly occurring in the selected case. This choice was made so that it would be probable the respondents had first-hand experience of the consequences of change within a process. The design of the inquiry method was based on five commonly occurring events requiring flexibility, that both cases had in common. Using the XPS of each case could present issues in the analysis since each XPS was independent (different companies) of the other. However, it was decided that the XPSs were similar

enough for a valid comparison when looking into the details of the XPS and comparing the XPS to general Lean methods. Also, using the XPS of case A to analyze responses from the interviewees from case A was a choice that was intended to filter and interpret the answers of the respondents. It could not be assumed that the respondents had the same general Lean knowledge (and vocabulary). It was assumed that they were familiar with the Lean methods and vocabulary described in the XPS used in their own process.

There are an almost infinite number of events possible in a process. Each will trigger a range of responses. Common events that require flexibility within a process were chosen in the design, but it is conceivable that if other events had been chosen when designing the interview protocol, other responses could have been received. Based on the industrial experience of both authors, the events were chosen because they were probable or indeed likely for the cases selected, thereby increasing the likelihood that the respondents had knowledge of them and that the organization had standardized methods for responding to the events. Including events that occurred more rarely would have likely decreased the probability of first-hand experience of the respondents, and would as well have decreased the likelihood of the responses to these events being standardized or connected to the XPS of the process. In short, the design of the study was based on the assumption that connections between flexibility and Lean would more likely be found in common events than in uncommon events.

3.3.3 Designing the semi-structured interview protocol and observation protocol.

Interview protocol design was based on a literature review. The intention was to use commonly accepted definitions of flexibility and change to construct events that were fairly common for the cases, and then examine the consequences of these events from several different perspectives in the process. The idea was, depending on how the process chose to respond to an event, the consequences would be different for different areas of responsibility. The total sum of the responses would be of interest to judge the connection between the XPS and the flexibility of the process. Considering construct validity of the study (Yin 2009), five different common scenarios were used in the protocol design. The scenarios were chosen based on volume and product flexibility.

Scenario 1: Increase of volume (production volume)

Scenario 2: Decrease of volume (production volume)

Scenario 3: Change of sequence (the order of the products produced in the process)

Scenario 4: Introduction of a new product (introduce a completely new product in the process)

Scenario 5: Removal of a product from production (stop making the product at all)

Each of the scenarios required some level of flexibility. Depending on what area of responsibility the respondents had in the process, it was likely that the range of responses would be different. For instance, a manager had a different set of responses than an industrial engineer. Therefore the protocol was designed around three different functions in the process:

management, logistics, and industrial engineering. The respondents would each respond to the different scenarios and from their view point explain the consequences and actions taken in response to the scenario. Each of the scenarios were divided into sub-questions to give structure to the interview protocol. The questions were adapted to suit the particulars of the function they were aimed at, but all questions followed the same underlying logic. For further details see appended paper II. An observation protocol was designed simultaneously and structured around the gathering of facts in the process. The intention was to use the information given by the respondents during the interviews and then use observations to corroborate the information. If for instance one respondent named “Tool flexibility” as an important factor in “Volume increase”, the same tools would be observable in the process. Also, factors that contradicted the responses had to be observable. The intent was to increase the reliability of the interview data.

Selection of functions of the respondents was a critical factor in the design of the interview protocol. Several options were possible, but management, logistics and industrial engineering were chosen based on the intent of the study to focus on practical change in a main process. The reason for this limitation was the aim to find a meeting point between practical actions necessary to respond to a scenario and the application of Lean. Each scenario opened up a range of consequences and the functions of the respondents was chosen as those most likely to be involved in handling the change.

3.3.4 Choice of cases

The cases were chosen based on a number of factors. Firstly, the result of the processes, a sub-component in a larger product, were largely similar. This enabled a comparison between cases. Secondly, both cases were fairly large and both had defined Lean systems. Both cases were mature in their application, with several years of experience in the application of Lean in a process. There were some superficial differences in the XPS of each case, Essentially though, the systems were based on the same Lean principles, enabling comparison. The main differences between the cases were the speed and structure of the process. Though the processes were similar in principle there was a difference in how they were organized. The process in case A was organized around mutually dependent parallel processes, with a consolidation point after the end process. In case B, the processes were independent and specialized. It was therefore decided that the cases were similar enough to be comparable but different enough so that the results could be generalized.

3.3.5 Pilot study

Two pilot studies were conducted, one at each company. The pilot studies were done at processes with no direct connections to the processes selected for the main study but were of a similar nature and structure. The organization of the process of the pilot study, was in all important aspects similar to the one in the main study in both cases. This was deemed important because the focus of the study design were the semi-structured interviews based on the five scenarios. It was therefore important for the construct validity of the study (Yin 2009), to choose an area for the pilot study that was not just physically similar but also of a similar organization. The first study revealed problems with the protocol for the semi-

structured interview, as the respondents did not fully grasp what was asked of them. This was attributed to the academic language of the interview protocol, which was too far removed from the reality of the respondents. After reworking the protocol, a second pilot study was done to verify the integrity and logic of the protocol, as well as the appended observation protocol. The protocol was also timed to get an estimate of the time required for the main study.

3.3.6 Conducting the main study

The study took place over roughly one month. Two processes at each case were selected for the main study. One representative for each function for each group was interviewed, giving a total of six interviews for one case and five interviews for the other case. The difference in the last case depended on a function shared between the groups of that company. The division of labour between the researchers in the interview situation was that one was mainly responsible for the dialogue and the asking of questions and follow-up questions, and the other researcher focused on taking notes and handling the recording equipment. The notes were later used in the observation of the process. Each interview was recorded with the respondent's consent and the interviews were later fully transcribed for the analysis. The study design required initial questions of a general nature, such as the respondent's background, level of education, and experience. Each interview took roughly one hour and was held in a meeting room or location in close proximity to the process under discussion.

The general intent of the interviews was to find the response and experience of that function to each of the proposed scenarios. Since two independent representatives from each function were interviewed, comparisons of the responses could be made both within cases and between cases for each of the functions. With the exception of the last interview for the joint function at the second case, all interviews for one group took place the same day, so that respondents could not interact with each other. In the last case, practical reasons required rescheduling. After the interviews an observation was conducted in order to verify respondent responses. As much as possible, factual responses were verified. Also, the logic of respondent answers were considered given the pattern of the process.

Since observation of the process took place after the interviews of the three functional representatives of a group, the observation could be biased based on the information given by the respondents. However, the intent of the observation was to (as much as possible) look into facts given by respondents. Therefore, the observation protocol was also based around the gathering of independent process facts, such as line layout, equipment and information systems, takt time, and cycle time, which all served as a neutral base from which to observe the validity of the respondents' answers. The last interview was with a representative of a function shared between the groups of the second case. This interview was held at a time separate from the timing of the other interviews from that case, thus introducing the risk that the respondent was pre-informed about the content and structure of the interview, by those who had been interviewed before. No indication of any pre-knowledge of either the content or structure of the interview was indicated by the respondent during the interview.

The interviews also took place at a location removed from the process that was the topic of the discussion. The respondent was therefore talking about parts of the process not immediately available for verification or demonstration, thus increasing the chance of misinterpretation when taking notes. Therefore, each respondent was asked to (in simple forms) illustrate the process from his or her perspective. The illustration served as a bridge between interview and observation. Also, several respondents talked about the same process from different viewpoints. Such cross-referencing is seen to increase the validity of the response, as the answers were independent from each other and could be cross-references for internal logic. Either they supported each other or not. The total information given by the respondent was used when the process was observed, reducing the impact of one individual erroneous statement.

3.3.7 Informed consent

In accordance with reasoning by Bryman (2011), Helgesson (2006) and also Kvale and Brinkmann (2009) around interview situations, each respondent read and approved an informed consent form at the beginning of each interview. The informed consent form detailed the purpose of the study and informed that participation was entirely voluntary. It also stated that their response would be anonymised, and the nature of the process and the company studied would also be anonymised. Knowledge of the identities would be limited to researchers and their supervisors. The respondents were given time to read through the forms before signing, and before any further interviews were conducted.

3.3.8 Considering validity and reliability in the research design of study two.

The research was designed as a multiple-case study and explored the connection between Lean and flexibility in multiple model assembly lines. As the cases were specific, some thought had to be given to the external validity of the cases. Therefore the intent of the company to work with Lean as well as the XPS of the process were used as a base for the study. Even though the XPS of other processes might be different, the intent had to be the same although conditions varied. The second study was a mix of semi-structured interviews and observations with emphasis on the interviews and the observations as supporting sources. This gave the opportunity to triangulate information given by the respondents. During the interviews the respondents were asked to illustrate the process from their point of view, using simple boxes and arrows. This enhanced the reliability of the study as it gave a common visualization around which to discuss and ask questions. This also gave a schematic with which to conduct the observation. Reliability in the study was given by the interview protocol and the observation protocol. Also, considering the reliability of the study, all main interviews were transcribed and analyzed to find factors the respondents named as important for flexibility in response to the five scenarios. Inspired by Creswell (2009) and Kvale and Brinkmann (2009), the responses were organized into groups. The interviewers analyzed the answers independently and then jointly compared the results for a good match.

3.4 Analysis Method

Study data was examined using aspects from the frame of reference. The nature of Lean is too complex to use a linear scale to classify the findings. Therefore the color coding should be seen as a balance of factors dependent on the nature of the case and the nature of the aspect of Lean. The examination is summarized with a color and a brief explanation at the end of each section of the analysis.

Table 3. Color coding for the analysis

	Strong positive findings	Clear indications to the Lean aspect were found in all or a majority of cases. Several independent factors clearly gave the same indication in a case. Such indications could be that the exact same terminology was used independently by the respondents in the process as representatives of the lean support function. Responses during the interviews were clearly supported by observation of practice. Forms and information were clearly updated and could be connected to practice. Examples could be explained, demonstrated, and put into context of the XPS. The exact nature of the indication depends on context and aspect of Lean.
	Weak positive findings	Some direct or indirect connections to the Lean aspects were found in a majority of cases. Independent factors gave the same general indication in a case. Such indicators could be that the same general intent of a method or principle was given independently by the respondents in the process and the representative of the Lean support function. Responses during interviews had general support during observation but were either inconsistent or infrequent. Forms and information were present but not always updated. The structure was there but not always used. Examples were generally aligned with the intent of the XPS and could be explained by the respondent. Observation and the XPS did mostly, but not always, align. The exact nature of the indication depends on context and aspect of Lean.
	Vague findings	A few direct or indirect connections to the Lean aspects were found in a majority of the cases. Independent factors were infrequently aligned. Such indicators could be a general intent of the XPS that was only partially translated into methods. The respondents in the process used different terminology than the representative from the Lean support function. Examples could only vaguely be connected to the general intent of the XPS. Visualized information was missing or not generally used or not generally updated. Observation and the XPS were rarely aligned. The exact nature of the indication depends on context and aspect of Lean.
	Mixed findings	Clear connection in some cases and none at all in others. The mix could be where some groups are clearly positive and other groups have vague findings of the Lean aspect. Indicators can be a fully implemented method in one instance and a small trace in another instance. Typical indication if “efficient islands” are found.
	Conflicting findings	Contradicting connections found in the cases. For some aspects, the indications were clearly positive in some cases and clearly negative in others. An example of a negative indication is a response or observation that goes directly against the intent or letter of the Lean aspect. Further explanation of the indication, such as contextual factors, is needed.
	Insufficient data	The data is insufficient to draw conclusions. Only a minority of cases gave an indication or the indications were too general to draw any conclusions.

4 Empirical findings

This chapter describes the cases, the results of the studies, and establishes the foundation for further analysis. A thematic description of the observations, interviews, and the XPS of each case will be given. The anonymity of the cases and respondent are considered in the descriptions. Therefore the descriptions will be factually correct but identifying details are omitted.

Through empirical findings and analysis the cases will be referable by *S#C#*, meaning for instance *S1CB* should be read as *Study 1 Case B*. In some cases the referral will be *S#C#G#* where *Group 1* will be labeled as *G1*. The *S#C#G#* referral will be used when there are significant differences between groups within the same case.

4.1 Study 1 (S1) - Assessing a group's ability to create stability.

Based on a literature study, two interacting Lean methods, Standardized Work, and Problem-Solving, were chosen, as they act together to create stability in a process. In a Lean process, stability in the process is seen as a prerequisite for sustainable Continuous Improvements. Therefore, assessing a group's ability to create stability in its process can act as a measurement of the group's Lean maturity. Four cases were chosen for the study.

4.1.1 Case description of study 1 – Choosing companies.

The companies had a number of similarities and differences. None of them were in the same market and all of the products were different. They were all organized around teams or groups at the lowest organizational level.

4.1.2 Case A (S1CA) – A large material processing company.

The first case is part of a large internationally active material-processing company with a high degree of vertical integration. The value chain encompasses steps from the processing of crude raw materials to the fine processing of specific products. The sales are business to business and the end products are largely divers with very specific customer demands. The end products are not directly available to the end consumer, but are always incorporated or contributing to a final product made by another company. The company was situated at a huge site covering several square kilometers, with different processes situated in different buildings on the site, surrounded by large buffers of raw or partially processed material.

The study started with an interview with a representative for the central Lean support function of the company, with the purpose of understanding the XPS. The company had been working with the integration of Lean for a number of years with limited success. The XPS had been fully redefined twice and was in its third iteration. The first attempt to integrate Lean in the company had been with the help of external consultants, who also helped draft the initial XPS. The approach had been heavily based on quickly pushing tools and methods into the process and had caused dissatisfaction and resistance in the organization as *“people were angry because they felt steamrollered. As soon as the consultants left things went back to normal”*. After the initial attempt, the Lean integration was reorganized with a greater internal focus and continued to support the Lean islands that survived the first attempt. The entire XPS was

redefined again a few years ago, and the Lean support function was reorganized again. This time the plan was a gradual, step-by-step approach to the integration of Lean, based on the experience of the first years. A certain understanding of Lean as a system was evident in the examples given when touring the office of the Lean support function, where information boards displayed KPIs connected to the rollout of Lean in the organization, as well as deviations and 5S. The current project was the rollout of a new and well-defined problem-solving method, based on the A3 method, in the organization. The daily work of the Lean support function focused on holding trainings and workshops at the request of the organization. This approach was based on the experience of the backlash effect caused by pushing out tools and methods and “*forcing*” the organization to change quickly. However, a certain frustration was evident over the lack of impact and the slow progress in the integration. Though all representatives of the Lean support function were highly committed, support from upper and middle management was not always reflected in committed resources or time in the organization.

The raw materials process is highly capital intensive and ran around the clock the entire year except for a brief summer break for maintenance, installation of new equipment, and repairs. The raw materials process was several hundred meters long, with a yearly output of thousands of tons of crude material. The process served as the first part of a vertically integrated process, where each step led to a higher refinement and a higher specialization of the products.

From this point two separate refinement processes followed. The two refinement processes were independent of each other and both produced products that were near end customer specification.

4.1.2.1 Group 1 (S1CAG1)

The first refinement process (group 1) was a smaller process, a number of steps removed further down the chain from the raw materials process. The input material was highly refined and the purpose of the process was applying near final shape to the product. Tolerances of the near final product were a few thousand of a millimeter. The first process was physically small compared to the raw material process and only occupied part of a building. The entire process was easily visible from any point and there was no physically fixed position in the process. Work was done over the entire line by available personnel, sometimes together and sometimes individually, depending on the task. The process was run in a two-shift form with small teams each shift. The output of the process was measured in tons/shift. The groups shared a KPI board where the results of each shift were noted together with other statistics, such as machine up time, product quality, and scheduling. Process targets and strategic goals were noted, but those part of the board appeared neglected when looking at the date of the last change. If problems occurred in the process the response time could vary between ten minutes and a day depending on the availability of maintenance personnel. Standardized work was present at a defined level and the group had been working in a structured way with 5S. However, the described tasks had no times noted and “*it took the time it took*” according to the guide. The work standards were machine specific, not position specific. They described work that had to

be done at the specific location of the equipment and was not tied to a specific work position. The tasks were centered on running the process, setup, and operator maintenance. Safety in the process was highly important and had a separate standard. Training in the group was mostly done with in a master-apprentice system up to the level where the apprentice was able to work independently. Management decided when an employee was able to work independently, but the exact criteria were vague. There was a simple problem-solving method, but the method was not used consistently. Depending on the nature of the problem the method would be adapted in a pragmatic fashion. A new problem-solving method was being rolled out but had not been widely spread.

4.1.2.2 Group 2 (S1CAG2)

The second refinement process (group 2) was a medium-sized process, also a number of steps removed further down the chain from the raw materials process. The input material was roughly processed and the purpose of the process was applying a final shape to the product through heat treatment and material formation. Tolerances of the product were defined both by physical tolerances and chemical properties tested in a laboratory. The second process was two mirrored parallel process legs, in a long double U-shape and occupied an entire building. The entire process was divided into sections which could be monitored from one position/section. A position was generally fixed to a section of the process, with an area of responsibility that could stretch over the entire section, down to a few meters depending on the task. The process was run in a two-shift form with large teams (over ten employees plus support personnel) on each shift. The output of the process was measured in kilometers/shift. The groups shared a common KPI board where the results of each shift were noted together with other statistics. Smaller boards were connected to pass on information relevant to a certain section of the process. The information on the smaller boards was considerably more up to date and seemed more relevant than what was on the large common board. Targets and goals were sporadically noted on the common board. The process was guided by the size of the connected buffers and a logbook which was *“the only place where you could get an idea of whether we are falling behind or not”* according to the guide in the process, and ran in customer specific batches. If problems occurred in the process, signal lights connected to the section lit up in different color combinations depending on the severity of the problems. The response time of the maintenance personnel could vary unpredictably up to a day, depending on the availability of maintenance personnel, same as for group one. Standardized work was well described but the responsibility for keeping it updated was with the industrial engineer, not the line employees. The described tasks had no times noted except for preventive maintenance of the equipment. The illustrations used in the work description were clear and thought through. The work standards were machine specific, not position specific, same as for group one. They described work that had to be done at a specific location of the equipment and was not tied to a certain work position. The tasks were mainly centered on running the process, setup, and operator maintenance. Safety in the process was highly important, same as for group one. Training in the group was done with in a master-apprentice system up to the level where the apprentice was able to work independently. There was a two-level grading system and management decided how an employee was graded. There was no problem-

solving method used and problems were solved in a gung-ho fashion. “*We don’t have time to write papers, we solve the problem instead!*” was the reply from the guide when asked. The new problem-solving method being rolled out was unknown in group two.

4.1.3 Case B (S1CB) – A food processing company.

The second case is a large food processing facility where the final product is sold business to business. The main brand of the product is established during the processing and no further refinement of the product is done before it reaches the end consumer. The business customer is a retailer of the final product. Apart from making products sold under brands controlled by the company, products were also produced for other companies and sold directly to them to be resold under other brands. The company had extensive laboratories and research facilities where new products were developed and tested before they were launched. The company was situated in a large industrial building with the entire process under one roof. The company is part of a larger group of internationally active companies with various products, controlled by a central headquarters. The difference between the companies in the group lay mainly in their specialization on product type, as each product, even when the raw materials were basically the same, required highly specialized equipment and the process steps could be entirely different. For this company, customer demand and production was highly seasonal, problematic with regards to leveling of the process. During the high season the facility ran around the clock with temporary personnel, and during the low season a normal two-shift form was used. Production was then based on prognosis and limited only by the available storage facilities and tied up capital. The central headquarters is responsible for the definition of the XPS and each company of the group is responsible for the refinement and application of the XPS to suit the particular conditions of their process. During the initial contact, the XPS was explained as “*Lean with a twist*” by the central Lean support function.

The Lean support function was only indirectly connected to the central headquarters' Lean support function and acted as an intermediary between the corporate level of the XPS and the local level. The function acted as a support function for the entire plant. The resources for the local Lean support function were limited and much of the integration of Lean had to go through management. The purpose of the Lean support function was to act as a trainer and also to adapt the general XPS principles to methods that were relevant to the company. As the company manufactured food, the definition of value adding was interesting to explore. Value was added when changing the properties of the product during the various process steps, such as heating or deep freezing. The image of the customer was complex, as the retailers had specific demands and the end consumers had other demands. Since the product was food, there were also what was defined as “*Semi value adding*” defined as the fulfilling of demands given by law and regulations, which did not add anything for the end consumer, but was necessary to keep permits and certifications. The XPS was being slowly integrated, in fits and starts, in the system over a number of years, and was limited by the amount of resources that could be allocated. International competition in the business was keenly felt and cost focus resulted in low available resources as claimed by the respondent.

The plant had four parallel process lines that were principally the same but had slightly different equipment installed. As it was a food processing plant, before the tour of the facilities could begin there was a standardized course in hygiene procedures, such as obligatory hand-washing procedures, and protective clothing and headwear was assigned. Two groups were followed, each responsible for one line in the facility.

4.1.3.1 Group 1 (S1CBG1)

The first line was over 100 meters long and consisted of several process steps that either mixed the raw materials, mechanically processed the raw materials or through temperature affected the products' properties. The produced volume was measured in tens of thousands of products per hour. The group was fairly large, around 20 employees, but divided into smaller groups depending on process step. The final part of the process was the most labour intensive and required the largest sub-group. The initial mixing steps of the process involved the second largest group, with much measuring and weighing of the raw materials. The line in between was mostly automated with only a few maintenance personnel monitoring process parameters and doing maintenance. The line was long enough and divided in compartments so that there was no line of sight between one section of the process and the next. This required personnel to phone for assistance if there was a problem. The line had an active KPI board and the process parameters, equipment availability, and process scrap were prominent together with targets and action lists. All of which were followed up on a shift-to-shift basis. The information on the boards was reasonably up to date with a number of closed deviations and actions on display as well.

Training of new personnel depended on the sub-group and was done in a two-step apprentice system, where a new employee followed an experienced employee until able to work independently. The maintenance personnel were considered to have the most complex job, as they were responsible for the setup of the process when switching products and monitoring the equipment. Interestingly enough, the process was not immediately stopped if a product deviation was found, but the process flow was diverted into big scrap bins. The reason was given as the nature of the process, where stopping the line could cause fire hazards as well as considerable cleaning (taking hours) before production could be reassumed. Time to response if a deviation was found was anything from immediate to several minutes depending on where in the process deviation was discovered. Standardized work was machine centered, not position centered for the most part, with a few exceptions at the end of the process. For instance, all products were x-rayed to discover any equipment slivers or scraps hidden inside the product. Though this was mostly automatic, the process was tended by a position. The product was frequently tested by the team leader using a standardized protocol for taste, texture, and visible appearance. There were some objective indicators, but mostly the procedure was left up to the subjective judgment of the team leader.

4.1.3.2 Group 2 (S1CBG2)

The second line was followed during the shift change in the afternoon. It was remarkably similar to the first group with the same organization and process. The most important difference was that the process was dedicated mainly to one product variant, so the new product setup was done much more infrequently. A few differences were noted in the execution of standardized work, but more interestingly the maintenance system was being redefined with more emphasis on operator preventive maintenance. The system for follow-up was a t-card system with a different card for each maintenance task. The cards were displayed on a large board and had different colors on each side. Each shift the cards were turned by the team leader and the color for “Not done” was visible. Each responsible operator was supposed to turn a card to display the color for “Done” when a maintenance task was completed. Together the cards gave a quick picture of the maintenance status for the entire line section for that shift. Process yield was slightly higher than for the first group, which was explained to be due to a more infrequent switching of products. The most important other difference compared to the first group was that a new problem-solving method was being trained. The team leader could demonstrate several documented resolved deviations and was apparently proud of the ones where the team leader had been responsible. The method was a variation of the eight-step problem-solving process defined by for instance Toyota, except with more emphasis on the root cause analysis than is common. The method was demonstrated as establishing cause and effect trees instead of doing a straight five why analysis. The method was less defined when it came to generating possible countermeasures and relied on “Brainstorming” as the main method. Overall this was by far the best defined *operational* problem-solving method found during the case studies. The only problem with this method, expressed by the team leader, was the amount of time it took and the difficulty of getting a dedicated problem-solving team for the duration of the method.

4.1.4 Case C (S1CC) – A large international manufacturing company.

The third case is a large, internationally active manufacturing company. The products are both aimed at the business-to-business and business-to-user markets, with a large range of variation in the products. The product can vary in both physical size, as well as specification, to the extent that from the viewpoint of the manufacturing process, each final product can be regarded as a separate individual. This challenges the entire value chain as the work content in the manufacturing of a product can vary by several hundred percent. This puts a strain on both planning and balancing in the manufacturing process. The value chain is highly integrated when it comes to the key components of the products. The entire production site is fairly large covering a few square kilometers with facilities for research, development, process, and manufacturing in the same area.

The processes that were followed in the study were situated approximately in the middle of both the production site and the value stream. Although both processes were manufacturing components in the same building, they were not connected in any direct sense. Both processes were part of separate lines in different parts of the building and could be regarded as sections of a larger process.

The XPS of the company was fairly mature and had remained unchanged on a principal level for many years. A central Lean support function was responsible for the development and maintenance of the XPS, but the integration of the XPS in manufacturing was the responsibility of local Lean support functions. The local Lean support functions had a great deal of autonomy and a fair amount of committed resources. Even though the outer appearance of the XPS was unchanged, several details in the execution of the system were under redevelopment, as the company had found limitations in the potential of the old methods. This means that a functioning and successful XPS had to be reinvented without changing the image of the system. Several key aspects of the system were being changed and the changes rolled out from the central Lean support function to the local support functions. This presented an interesting opportunity to study what was defined by a representative of the local Lean support function as, *“It works and we have to change it anyway. This is difficult”*, referring to changes in the execution of the XPS.

4.1.4.1 Group 1 (S1CCG1)

The first group was responsible for the first of five sections of a manufacturing process about seventy-five meters long and straight. The entire process was visible from any given point, though there was much equipment and tools hanging from beams and rather large material buffers surrounding the process. The product that was being manufactured was fairly large and had to be transported in the process with a continuously driven conveyor system. The process was measured in hundreds of products per day. The sections of the process were divided into manufacturing stations where between one or two employees were working on the product. Work was done in a two-shift system with a major shift during daytime and a smaller shift with reduced output during evenings. This shift form was a reaction to changes in volume demand. The evening shift could be quickly ramped up to increase volumes if needed. Instead of ramping down the total speed of the process, the day shift held the same speed and output rate as if the production was running at full capacity. The evening shift worked at lower capacity. The reason given was that management did not want to lose the *“feel”* of a fast work pace in the process. Experience had shown that a slowing of the pace overall also brought with it quality and safety problems. *“Balance is a delicate thing”* as stated by the manager of the process.

The groups were of medium size with under ten employees in a group including the team leader. The work done was mostly manual with the help of tools, although some automated or semi-automated equipment was used, mainly for ergonomic reasons. The reason given for this by the team leader was that the versatility of manual labour was seen as necessary to cope with the variety of the products. Also, the shifting work content meant that a dynamic rebalancing of resources was necessary to avoid bottlenecks due to differences in workload. Overall, the difficulty of achieving an efficient work balance and productivity issues were seen as important challenges for the group. In expressing this the team leader showed a remarkable consistency of terminology when describing the challenges for the group compared to the representative from the Lean support function. The generally stated principles were translated down into terms used frequently by various respondents. Response

time if a deviation was discovered was measured in seconds and the team leader was mainly responsible for initial response and decisions. The standardized work of the process was highly developed and position centric. It was structured around two levels with an upper level describing the work sequence and a lower more detailed level describing the details of the work. For some unexplained reason, time setting was missing from many of the observed standards. The group were responsible for writing and updating the standardized work and were regularly relieved from their positions in the process by the team leaders to do this. This was observed at several instances both in the group and pointed out with other groups. This was seen as a normal procedure by the employees, who thought of it as obvious and of little note when asked. “*We need time to write*” was the laconic response. The group had visualized the KPIs on a standardized board system where every group used boards structured exactly the same, as evident during the initial walkthrough. On these boards, relevant key figures for the group were displayed and updated frequently during the day. Once a day the figures were reported upwards in the hierarchy in aggregated form.

The problem-solving methods used were fairly advanced, but not consistently used. Depending on the severity of a deviation, simpler methods would be used. Initiating problem-solving was a decision made by the local manager together with a team leader. In some cases deviations were ignored, “*We already know about that problem, no point in recording the occurrence again*”, as claimed by the team leader. The problem-solving methods were different from those defined centrally both in form and slightly in emphasis and logic. The difference was attributed to the independence of the local Lean support function and seen mainly as positive, although not important. Problems deemed to fall outside the ability of the group to solve, were escalated during the daily process meeting and handed over to a supporting function. Typically maintenance or industrial engineering who in turn had to get back to the group with a proposal. Interestingly, the group still felt a sense of responsibility for the problems that had been escalated and were active in asking for solutions. Contact with the supporting functions seemed to be professional with no apparent laying of blame and a seemingly joint sense of purpose as observed when attending a meeting. However, no sense of resource follow-up or long-term verification of countermeasures was found.

4.1.4.2 Group 2 (S1CCG2)

The second group observed was situated in a different part of the same building, manufacturing a completely different product than the first group. The manufacturing line was built in a 150-meter long U-shape. Since the component was smaller (roughly 25% of the first group's component) and lighter in comparison, the equipment and carrier systems were lighter and smaller as well. This also meant there was less space round the component with the consequence that only one employee worked at each station. Even if the total number of employees on both lines was roughly the same, the line of the second group was twice as long. The result was greater visibility in the process but also longer distances for transport. The process volume was measured in hundreds of products per day.

The size of group two was about the same as for group one with the same organization and shift form. The KPI boards were exactly the same at group level, although some KPIs were slightly out of date. This was explained by the team leader as due to absenteeism and a lack of resources, “*We had to choose*”, and regarded as an abnormal situation. The same structure of escalation and aggregation of information as for the first group was in place, but for a completely different management hierarchy. Standardized work was regarded with a great sense of pride in the group and the descriptions had the same two-level structure as for the first group. The main differences were found in the details of the second level with more images and a more detailed description of the work including time setting, compared to group one.

The problem-solving methods used by the group were locally invented and even named after the charismatic manager that had invented them. They were also different from the methods proposed by the local Lean support function and in some senses incompatible in logic and form. Interestingly enough, there was a sense of pride indicated by the team leader as this down-to-earth problem-solving method was seen as superior to any other problem-solving method. This sense of ownership of the method seemed to lead to more initiated problem-solving and a greater understanding of the method itself, than for the first group, but the method used was rather crude with simple root-cause analysis and little support in fact gathering and solution generation. Still, the method, crude as it was, was known and used by the group and also fairly quick to use. The escalation structure used by the group was the same as for the first group with the same attitudes and ownership. Both groups shared the same maintenance organization but management and industrial engineering were different.

4.1.5 Case D (S1CD) – A heavy equipment manufacturer.

The fourth case of study 1 was a heavy equipment manufacturer. The products are sold either business-to-business or business-to-user. The variation in the products is less than for case C. And the pace of production was slower. The challenge for the process lay in the behavior of the market where long periods of high demand was followed quickly by periods of low demand following overall patterns in the global economy. Since production lead time was fairly long, there were problems with the prognosis and planning of capacity as discussed with a representative of the local Lean support function. The international competition was also seen as problematic, especially Asian competitors. The process site was spread out over a large area with large buildings separated by long distances. In the main building there was a high level of vertical integration for key parts and the end product from the production site was shipped as components to other sites internationally, or put in storage as spare parts.

The XPS of the process was centrally defined with minor local adaption at a practical level by the local Lean support functions. The local Lean support functions had a lower degree of independence compared to case C and there was a central Lean auditing system in place as indicated by the representative of the local Lean support function. This was seen as mainly positive, but a lack of understanding on the part of the central Lean auditors caused some frustration. The local Lean support function had a fair amount of resources. This was needed

as the entire plant was being reorganized to better suit the demands of flow and pull inherent in Lean. The XPS itself bore similarities to the system used by case A and was fairly recent in form. It had replaced an older system that could be seen as less cohesive in design. The XPS was fairly detailed enabling a central audit system. Interestingly each principle of the XPS had a defined “owner” in the upper management group, giving a clear mandate to the organization.

4.1.5.1 Group 1 (S1CDG1)

Due to availability only one group was followed in Case D. The process and product was similar although slightly heavier than in the first group of case C. The pace of production was measured in tens of products per day. Since the pace was slower than for case C, the nature of SW was different with a larger work content described in a more general fashion. Also the process was more compact, covering tens of square meters with pre-processes in close proximity. Group size was small, around five people to a group, but could be increased if the demand for the product increased. The carrier system was of a floor-based Stop-and-Go nature, with the product standing still during manufacturing. The shift form was currently only one shift due to a lack of orders. Some personnel were on loan to other departments. There was the potential to increase production volumes within the current shift form, before going to other shift forms. The description of work was done in two levels with the sequence described in the first level and how the work was to be done in the second, more detailed level with illustrations chosen by the employees to illustrate crucial points in the process. However, not all tasks were detailed in such a fashion. The standards also used symbols to depict quality or safety issues in the work description. If support was needed or deviations were found, the employees had a button to push, which would alert support via a text message. The response time could vary depending on workload and distance from support. Exact figures were not available, but were thought to be from 30 seconds and upward.

The KPI board of the group displayed commonly defined indicators. Not all of them had targets and a few of the long-term indicators were not updated. The information was reported daily or in a shift-based fashion, depending on the number of active shifts. There was a centrally defined and well structured method of PS which could be exemplified during observation of the process. The process was based on a combination of a 4 M fishbone analysis and a 5W2H system to describe the deviation. Training in the method was not widespread, resulting in only a few active problem-solvers. No direct follow-up of resources spent on the problem-solving was evident. There was a visual recognition system in place where successful PS was displayed as examples of other processes. The process in general also showed signs of rapid improvements, which the respondent attributed to the pace of application of Lean which was said to be fast. In some cases the restructuring of the process was still ongoing. In other cases the organization was planning for the next step based on the experience from the initial change, as explained by the guide.

4.1.6 Findings of study 1 – Creating stability is complex.

The important conclusions of the first study are on two levels. Firstly, looking at the results of the study certain conclusions may be drawn. Assessing the Standardized Work of the different

cases show different levels of standardization depending on the nature of the process. In both manufacturing cases, all three groups studied had utilized SW at two levels. The upper level gave a description of “What” and “Sequence” and referred to a second more detailed level where the “How” and “Why” of the operations were described. In contrast, the process industry cases both only described one level of SW, where the “What” and “How” of an operation was described. The “Sequence” of the operation was highly dependent on the equipment of the process and therefore implied in the SW rather than explicitly enumerated. Also, since the operations could be done at various locations of the process equipment (it was large), the standard was machine centric whereas the manufacturing standards were position centric.

Since all cases had evolved their own version of SW independently from each other, certain general conclusions may be drawn. Manual labour connected to manufacturing most likely requires a more detailed work sequence. The reason for this is probably that levels of freedom and number of choices are much greater in manual manufacturing than in a process industry with process equipment. The process equipment defines the sequence and conduct of an operation as the operator serves the equipment. Therefore the level of detail in SW can be different between manufacturing and process operations.

The ownership or indicated sense of responsibility was also higher in the manufacturing cases than for the process cases. The reason could be that the result of the process was (literally) in the hands of the operators in the manufacturing cases and any deviations could be directly or indirectly traced back to the efforts made by one individual at a given time. The operators of the process industries were one step removed from the result of the process. The result was given as a consequence of the process equipment and the operators served the equipment. Thus the direct line between labour and consequence was broken and deviations were harder to trace. Neither did the process industries have a reference system directly connected to the demands of the customer. Therefore it became correspondingly more difficult for the process operators to have a sense of “Am I falling behind or not?” in their work.

When it came to PS, the results were less clear. All groups that participated (except one) had a clearly defined problem-solving system, but they used the methods in various, and sometimes conflicting, ways. Even within the same company, the groups would have different methods and work in different ways. Sometimes the connection between the method used and the centrally prescribed method for PS was tenuous indeed. The groups, for vague reasons, chose to work with other methods. This indicated that the amount of impact the central support function had on the practice of PS in the processes was not sufficient. The frustration indicated by the representatives from the central support functions revealed that they were not unaware of this phenomenon, but felt unable to do anything about it. Since this was a phenomenon prevalent in all cases and groups (including the one that claimed to use no PS system, central or otherwise) a general conclusion can be drawn. The institution of a central Lean support organization is not by itself enough to guarantee a calibrated and coordinated approach to Lean methods, as indicated by the lack of adoption of central PS methods. However the SW methods had a higher adoption rate and were more in line with the centrally

prescribed methods. Therefore there could be a difference in the nature of the methods, as the central approach to spreading the methods in the organization was basically the same. This could be a topic for further research.

Secondly, looking at the results of the first study, the attempt to operationalize a Lean assessment method at a group level of a process gave results comparable between processes. The method was based in Lean theory and focused on a prerequisite for Continuous Improvements. A group's ability to create stability in the process can be seen as an indicator of the maturity of the group. Since the method was based on the intent of the Lean method, it was fairly devoid of internal jargon and the group level of a process acted as a common denominator regardless of the purpose of the process. Though further research is needed, the foundation of an assessment method is there. As it turns out, the most interesting results were revealed not only through study of one group or case, but also in comparison between cases. The conclusion is that the method of assessing Lean used in study one can be seen as a complement to the methods proposed by for instance Rother and Shook (2004), Karlsson and Åhlström (1996) or Bhasin (2011a), as it provides an operational perspective on a process, thus providing an additional view on the Lean maturity of a process. For further details and analysis, please see appended paper I.

4.2 Study 2 (S2) – Exploring the correlation between Lean and flexibility.

Based on discussions and literature, the question of the second study was to understand the connection between Lean and flexibility in mixed-model assembly lines (MMAL). Much research claims that Lean is flexible by nature. Other research claims it is not flexible and there is a need for other production systems to address this. Regardless of position, it would seem reasonable that there are some connections between Lean and flexibility, positive or negative. These connections should be detectable if one studied companies that worked with Lean and also had the need for flexibility. Two cases were chosen for the study.

4.2.1 Case description of study 2 – Choosing companies

The two companies chosen for the case study are not in the same markets and the end products were largely dissimilar. Some assembled components that were part of the end products were selected for the purpose of the study. Size, weight, and purpose of the components were similar enough to enable comparison. At the same time, the chosen assembly strategies were dissimilar, giving range to the study. Both cases were organized around teams or groups at the lowest organizational level, and both had a XPS with several years of experience.

4.2.2 Case A (S2CA) – An international company that makes large equipment.

The first company of the second study is part of a large internationally active company which makes large equipment. The products are varied but mainly aimed at other companies in various businesses. The part of the process that assembled parts of the equipment could be seen as an internal sub-supplier to the rest of the company. Case A had been working with the application of Lean for a number of years and had a well-defined XPS with a supporting organizational structure, as well as a stated intent to work with Lean. The definition of

flexibility in the company was less evolved and flexibility was more or less a non-issue on the principle level. On a practical level, fluctuating demand and variation in customer specification was a real concern. Two processes were selected for the case study. The processes were parts of larger processes in driven assembly lines. The products assembled in the two processes were fairly large and of comparable complexity and volume. The two processes were semi-dependent and operated independently from each other up to a certain point. The respondent represented different functions in the two processes, management, industrial engineering, and logistics. They were each asked questions about their response to changes in the process.

4.2.2.1 Increasing volumes for case A

If there was a need to increase assembly volume due to some change in demand, the management replied that the response would depend on the size of the increase. Also, the duration of the increase was seen as important and affected the chosen response. Several options were available at short notice. Changes in shift forms and working hours was one immediate option that did not require long preparation. Information was seen as important but, *“as long as the right guys are involved it is not a problem”*, indicating that personal competence is important. If the volumes continued to increase, some sort of rebalancing and change of takt time would be necessary, but also required more effort and more preparation. Such responses also brought with risks for quality and equipment availability. An increase in productivity was also seen as an option. If the increase in demanded volume exceeded technical capacity, the response would be more complicated and require collaboration with other functions, investments, and a longer lead time. The response from the industrial engineers was similar. Some initial changes could be made to equipment speeds and elimination of bottlenecks. There was some slack in the line balancing that could be eliminated. Changes in shift forms was also mentioned as an option, although it fell outside of the industrial engineers' area of responsibility. An increase in the speed of the driven line was also seen as necessary, although it would require a rebalancing of work. Rebuilding the system to handle volumes beyond technical capacity was possible but required much planning and was also seen as expensive. The response from logistics was more linear in nature. An increase in volumes meant an increase in personnel and traffic in the plant. Interestingly enough the competence of the personnel was seen as a challenge. *“If you are experienced you are able to predict what will be needed next. You learn the patterns”*. New personnel did not have this skill, and, as it was based on personal experience, it was difficult to train. *“It takes about two weeks to become familiar with an area. We don't want people to be stressed. That would invite dangerous behavior if they try to catch up”*. Lack of space for logistics to handle an increase in volumes as well as the distance to the suppliers, were seen as problems if volumes increased more.

4.2.2.2 Decreasing volumes for case A

From a management viewpoint a decrease in volume was less problematic. The normal response would be a change in shift form and a reduction in personnel, depending on the size and duration of the decrease. In one case it was mentioned that a decrease in volume gave

more time for training and time off. In other cases people would have to be reassigned. This could prove problematic if “*people end up where they don’t want to work*”, according to one manager. There was also the possibility of running the assembly with gaps in product flow in order to decrease output, but retain assembly speed. Otherwise, the line could be rebalanced. From an industrial engineering point of view, a reduction in produced volume was seen as a minor event. If the process was rebalanced it would trigger moving some equipment, but this was no big issue and required no great effort. The technical capacity of the process was not reduced, but kept as a potential for future increases in volume. The logistical response followed the same pattern with a decrease in personnel as the main response.

4.2.2.3 Change in sequence for case A

Changing the order of the planned production was seen as routine by management. It was a common occurrence and the main challenge was the notification time. If the product had already begun to be assembled, the change in sequence was problematic because the line was not designed around that kind of flexibility. With a longer notification time there were no problems at all from a management view. As long as the information was correct and the notification time sufficient there were no effects, apart from that the team leader had to know when to introduce the moved parts back into the flow. From the industrial engineering point of view this had very little effect. All the equipment in the process could be set up for a new variant almost instantaneously. As long as the information in the system was accurate there was no further effect. There were some mixing rules that had to be followed, but those were the responsibility of the planning department and of little concern. Logistically the effects became greater as the change required a rearranging of prepared materials and also an area to store the rearranged parts until needed. As long as the notification was given in time, this was normal procedure, but the reintroduction of parts in the flow required manual decisions and could be problematic if procedures were not followed, as the exact events depended on what variant was changed in the sequence.

4.2.2.4 Introduction of new parts in the process for case A

From a management point of view there were several important factors to be considered. Firstly, depending on the nature of the new part, new assembly equipment might have to be installed with all the risks of disturbance in the current process, risks for lowered OEE and other problems that might occur. Secondly, personnel would have to be trained and new standards written. If the change was extensive an entirely new assembly line balance might be necessary, as the consequences of the new standard might spill over into adjacent areas of the process. This was also seen as a complex event from an industrial engineering point, depending on the nature of the introduced part. For major introductions there was almost certainly a need for a designated project leader. Smaller introductions were handled with much less consequence on a day-to-day basis. For logistics, the consequences were smaller than expected. As long as there was room enough at the process and there was enough storage, this was no big deal. The most important effect was that the update of the information in the IT systems had to be correct. But the work was the same regardless of the nature of the part, if it fit into the range of operation for the logistic equipment.

4.2.2.5 Removal of a product from production for case A

This was seen as a very simple issue for management. As long as the information sent to the assembly group was correct, it was simply a case of vacating a place by the assembly line. For the industrial engineers, the consequences were slightly greater, as in some cases equipment might be made redundant and would have to be removed from the line. Either to be stored as backup, used somewhere else in the process, or scrapped. For logistics this was no problem at all but seen as positive, as the space beside the line that was freed allowed for better placement of other parts. The only work involved was to either send the old parts back to central storage or hold them for spare parts.

4.2.3 Case B (S2CB) – A company that makes slightly larger equipment.

The second company of the second study is part of an international company which makes large equipment of a different nature and purpose than Case A. The end products are hugely varied and are aimed at different businesses. The part of the company used for the case study made parts for the end equipment. It was a central sub-supplier to the rest of the company. Case B had a well defined and mature XPS, as well as considerable experience in the practical application of Lean. There was a clear and stated intent to work with Lean in the process, which was also reflected in how the process was physically organized. Flexibility was not formally defined on a principle level, same as for case A, but the same practical consequences were evident in the production. Two processes were followed in the case study. They were physically smaller than for case A and organized differently and produced lower volumes, although the assembled products were entirely comparable to case A both in complexity and size. The products were assembled in separate and independent processes, meaning that one could be shut down with no effect on the others. The processes shared logistical resources. With the same logic as for case A, the respondent represented different functions in the two processes, management, industrial engineering, and logistics. They were also each asked questions about their response to changes in the process.

4.2.3.1 Increasing volumes for case B

From a management viewpoint, the response to an increase in volume depended on the size of the increase, the duration of the increase and the notification time. Smaller increases were within the capacity of the system and handled with an increase in manning and in some cases a change in shift form. There was an unutilized capacity in the current system that would be put to use. New employees would have to be properly trained so as to not introduce quality defects, but otherwise this was not seen as a big problem. *“We use an apprentice system, where the new guy will be certified by me as soon as his trainer thinks he is ready”*, as claimed by one of the managers. Further increases would require a rebalancing of the process and possibly new equipment. There was an operational prognosis process where these issues were discussed and it was deemed unlikely that an increase in volume would come as a surprise. For industrial engineering, the size of the increase was important as different equipment had different capacity. If the increase was within the capacity range of the equipment this was seen as a minor issue, perhaps only requiring moving equipment or some small modification. If the demanded capacity exceeded or was close to the capacity of the equipment a much longer notification time was required to either develop solutions or purchase and verify new equipment. Also an increase in volume might be problematic from a maintenance point of view. *“More stuff will break. Running the equipment harder also means that there is less time for maintenance”*. Logistics saw no major difficulties, as an increase in demand resulted in an increased manning mirroring the increase and shift forms of the assembly line. There was also a capacity issue concerning forklifts. *“We would need more (forklift) batteries by the entrance. They would run out quicker if we drove more”*, as claimed by the logistics manager.

4.2.3.2 Decreasing volumes for case B

A reduction in assembled volume was not problematic from an organizational point of view up to a certain point. A redundancy of personnel would mean a rebalancing of resources within the entire plant, with new tasks assigned to the permanently employed personnel. This would also mean that people would have to be retrained. Reduction of the temporary staff was seen as unproblematic. Changes in shift form were also an option. The response from industrial engineering mirrored the response from management and there were no technical challenges to the reduction of volume in assembly. The reduction of manning in logistics would mirror the reduction at the assembly line, with corresponding rebalancing of the remaining work.

4.2.3.3 Change of sequence for case B

A reshuffling of the assembly sequence was a common event and equipment in the assembly process required no additional work. From a management point of view the correct information to the assembly was seen as more important than the physical effects of a change. The design of the assembly process made a change of sequence easy. Technically there was no problem. Logistically the challenge was the retaking of the parts that were designated for particular individual components. The amount of work depended on the type of component

rescheduled. Also, the consequence might be that new material had to be gathered or rearranged quickly depending on how much ahead of the assembly the logistic preparation was.

4.2.3.4 Introduction of new parts in the process for case B

Depending on the type of introduction, some kind of verification and test assembly had to be made. *“Everybody has to be trained. As long as we have time for that, the project will be successful”*. Training is seen as necessary by management in order to verify new standards and to train personnel. Industrial engineering remarked on the lead time for investments in new equipment. In many cases the old equipment could be adapted but if that was not possible a longer process was necessary. If the line had to be rebuilt it also introduced difficulties but as long as the checklist for rebuilding was followed it should not be unmanageable. From the logistics side it was important to establish the kind of supply necessary for the new part. Should it be a Kanban part or not, for instance? Also, rearranging existing materials at the assembly process could be problematic depending on the type of introduction. A good material preparation process was seen as essential.

4.2.3.5 Removal of a product from production for case B

The removal of obsolete parts from the assembly process was seen as an easy change by both management and industrial engineering. As long as a definitive decision for the removal of the part had been done, equipment could be scrapped, put in storage or reused somewhere else in the process if it was made redundant. It could be surprisingly difficult to reach a definitive decision. *“Sometimes customers change their minds and decide they still need the product”*. Much of the equipment was generic and used in the assembly of many different variants. Therefore, scrapping of equipment was not common. For logistics it was simply a matter of removing the part from circulation and deciding what to do with the remaining parts in storage.

4.2.4 Findings of study 2 – Flexibility is a property of a solution in Lean production.

The second study resulted in several conclusions. There were many ways to respond to a change in demand or if the circumstances changed in a process. Since both companies were experienced in Lean, it would have been reasonable to find connections between the XPS of each company and the flexibility factors discovered. The connection should either be positive or negative. The results were neither. Some of the flexibility factors were “Lean” in accordance with the XPS of the case but most were not. There seemed to be no pattern in the results. Sometimes a response to a scenario could be seen as Lean and at other times it could not. This lack of a pattern seemed to be the same regardless of what function was examined. This (to the researchers) somewhat startling conclusion led to a reexamination of the interview material. Flexibility, the act of change in response to an outer incentive, seemed to be a *decision* on the part of the respondents. There was nothing “automatic” or “built in” when choosing a solution to an adaption problem. Since both cases work with XPS and an

intention to be Lean, a prominent feature in both XPSs was problem solving. When choosing how to solve problems, flexibility can be seen as a property of that solution. Flexibility is therefore a built-in potential in a solution. Logically this made sense. During observation of the cases, various aspects were observed where solutions to particular problems were given flexible features. For instance, fixtures built to accommodate a range of different properties in the product. As long as any new product was within these boundaries, flexibility was easy. But this built-in flexibility, the choice of solution, was waste if the feature was never used. Therefore, some levels of flexibility had no effect on the efficiency of the process and others did. It all depended on the right solution when solving a problem. Another example observed were the shelves. In a given situation, from an efficiency (5S) perspective, one shelf served as well as another. Therefore, in that situation, both solutions were equally “Lean”. But when there was a need for change, a shelf on wheels was more flexible than a fixed shelf, requiring less effort to adapt. From this it would be easy to conclude that all equipment should be flexible in a process. This could however increase the complexity of the process and counteract reliability of the equipment and also potentially increase cost. Therefore, logic dictates that flexibility in a process has to be within certain constraints in a Lean process if it is not to be costly and complex. For further discussion and details, please see appended paper II.

Apart from the connection between Lean and flexibility, the same data was used to understand flexibility in multiple model assembly lines. Although the cases were different and operated under different conditions, the mechanisms for achieving flexibility were basically the same since assembly system constituents were the same. The main difference lay in scope, temporal factors and modularity. Concluding the third paper, to achieve flexibility of volume, product mix, operational flexibility, and the introduction of new parts/removal of old parts, other internal flexibility mechanisms had to be considered. For further details and analysis, please see appended paper III.

4.3 Concluding the studies – The pieces are there but the picture is missing.

The first study examines the operationalization of an assessment method based on the connection between Standardized Work and Problem-Solving, with the intent of creating process stability. This as seen as a prerequisite for Continuous Improvements within a process. If a process tries to improve quicker than its ability to stabilize the results and operation, the entire Lean introduction can be in jeopardy. Thus the ability to create stability on the group level of a process can be used as one measurement of the Lean maturity of the process. The second study focused on the connection between Lean and flexibility in a process exploring how a process that is working with Lean would respond if subject to external events or changing demands. The study found that there was no direct connection between Lean and flexibility. They seemed independent of each other in a direct sense. It was found that solutions that were equally efficient could have different grades of flexibility. The connection between Lean and flexibility was therefore of an indirect nature where flexibility could be seen as a built-in potential in a solution. Thus flexibility reduces waste potential in

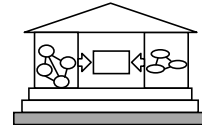
the system. The cost of changing goes down. This can be done in many ways and there are many kind of solutions to the same problems. Therefore, if a potential for flexibility is built into a solution and that potential is never used, the flexibility is in itself a waste since it has cost resources to develop and is never utilized. Choice of proper flexibility and range of flexibility can be seen as a strategic management choice, as the consequences can be great for the process.

Both studies examine the properties of parts of Lean as an interdependent system. What was not obvious when designing the studies was the deeper connections of Lean as a whole. Each study stands on its own, but the connections between them, apart from the obvious principle of Continuous Improvements, were not easy to understand. Both studies were connected to behavioral aspects as well as management aspects. Understanding the interconnections and dependencies simultaneously on a technical and human level would be necessary, to be able to connect the studies into a functioning whole. The results of the studies by themselves were not enough to achieve this. Therefore it is seen as necessary to build a larger frame of reference for this thesis and to return to the material gathered during the studies with new views and perspectives.

5 Analysis

Returning to the data from the two studies, this chapter will use the aspects defined in chapter 2 for this analysis. Even though the center of gravity was different in the two studies, the studies were based on the same logic and should therefore be comparable. The studies have both been centered around human work at a group level. Each view and aspect from the frame of reference is explored in the data, to establish how well the integration of Lean in the studied cases were connected in Lean theory.

5.1 Analysis of the studies using the Historical view of Lean



H1. Work can be objectively studied and described in a work standard.

Support	Comment
Strong positive findings	Indications in all cases

The XPS of all cases of both studies show a uniformity when it comes to describing work on a principle level. All XPSs have Standardized Work stated as a principle, although details differ. In some cases, it is described as a higher-level principle, in other cases it is described as a lower-level principle and part of another principle.

H2. Standardization of work enables synchronization of effort.

Support	Comment
Weak positive findings	Contextually dependent Less support in process industry. More support in manufacturing industry

In the manufacturing cases of study 1 and 2, work is done in direct sequence. The effort of one position is directly followed by the work of the next position in an assembly line. The line itself can be technically different, but the synchronization of work is the same. This is less clear in S1CA and S1CB where work can be done unsynchronized, dependent on the process equipment. This could be connected with the greater emphasis on maintenance in the process line compared to the manufacturing line. So in conclusion, there is a contextual factor. Standardization of work *can* enable synchronization of work, but is by itself not enough.

H3. Continuously experiment to find solutions to pragmatic problems.

Support	Comment
Mixed findings	CI in XPS Different methods used. Range from some to weak support for experiments. Not much experiment within flexibility range.

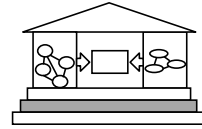
For both studies and in all cases, the XPS stated some drive for continuous improvements, although phrasing might differ. In details and in practice there were differences. In Study 1 all groups used different methods for improvements and problem-solving. For some groups there was a formally defined system that was followed and could be verified through observations and examples. Other groups claimed to “not bother” with formalities, as they “just went out and solved the problems” (S1CAG2). The Lean support function uniformly (with the exception of S1CC) expressed some frustration over the lack of acceptance of the centrally defined problem-solving methods, regardless of whether the groups used another system or none at all. In all groups of the study there was little evidence of experimentation to find the best solution. Finding any solution at all seemed to be enough. In study 2 the focus was to solve flexibility problems. Also, in this study the range of experimentation to find the best solution seemed small. Solutions were chosen based on experience and established practice. However, this result could be caused by the design of the questionnaire where scenarios were chosen because they were common occurrences. If the questions had been focused around uncommon events that require flexibility, it is possible the results would have been different. This is supported by the assessment of S1 where no group indicated they followed up on resources spent during a problem-solving. This indicates that even though some experience would perhaps be gained (as indicated in S2), the event was not followed up and evaluated.

H4. Results lead to practice. Practice leads to principle.

Support	Comment
Mixed findings	Some support of practice leading to principle Contextually dependent

When talking to the representatives from the Lean support functions of the different cases, some differences started to emerge in the details. Especially the process industries (S1 case A and B) defined operator maintenance as part of the normal work description, even though it was not directly value creating. Both cases (S1CA and S1CB) had arrived at basically the same definition of what should be described in SW, even though the operations were completely independent of each other and the processes different. The nature of the process was found to influence the definition of SW, as indicated by the difference in SW between S1CA and S1CB, compared to S1CC and S1CD.

5.2 Analysis of the studies using the Foundational view of Lean



F1. Stop a process when a problem is detected and correct the problem.

Support	Comment
Conflicting findings	Highly context dependent Response time depends on workload. In one case process not stopped at all.

Different approaches were found in both studies, both in principle and also in practice. In cases that worked with manufacturing, principles were clearly defined and part of the quality system, the application of F1 differed in the manufacturing cases. The manufacturing process with the highest work load also had the most well-defined application of F1, whereas the manufacturing process with a lower work load had a less well applied F1, as indicated by observation. This indicates that the workload of a process will affect what the process perceives as a problem. In the cases of S1CA and S1CB, the idea of F1 was more difficult to implement. For S1CA, for those who processed material the detection of certain problems with the product were decoupled from the process, leading to a delay between occurrence and being able to stop the process. The conditions for S1CB were even worse. In food processing, it was hazardous to stop the process due to a risk of fire in one part and congestion of the food in process in another part. S1CB accepted tons of scrap rather than stop the process. This leads to the conclusion that the application of F1 is highly context dependent. In process industries the distance between detection and occurrence necessitates the prevention of problems before they occur, which could be an explanation of the emphasis on maintenance as discussed in H4 above.

F2. True understanding of a situation is based on direct observation combined with deep reflection.

Support	Comment
Weak positive findings	Not done in a structured way

In both cases in the second study, representatives of the management, logistic, and industrial engineering functions explained their responses to different changes. In none of the cases did they indicate deeper reflection. In one case (S2CB), the manager indicated that changes were opportunities to increase productivity, especially when decreasing or increasing production volume. This required some thought. Otherwise the changes could be classified as mechanical. Competently performed but no clear indication of either observation or reflection. Study 1 had a slightly different focus, where both decisions of process follow-up and training of personnel were made based on a competence matrix. In those cases, the performance of the employee was observed and assessed as an organized part of a manager's work. Based on study 1 and study 2 it may be concluded that observation and reflection occurred as an organized part of a manager's work during daily operation. However, as indicated by study 2, it was not done in a structured way when the process changed significantly.

F3. See the end customer as an integral part of the production system.

Support	Comment
Strong positive findings	Strong contextual factor Depends on ability to level demand and seasonality

In both studies the customer (the end consumer) was referred to during the majority of the interviews. In the first study, when talking to the lean support functions, the customer was seen as defining value in the process by all representatives giving support to F3. In application, the image was more diverse. The manufacturing industries had integrated the perceived need of the end customer into the process, mainly through a takt system but also through numerous quality measurements. In the process industries, the connections were less clear. In S1CA, the process batches were run according to customer order but the time factor was less defined than for the manufacturing cases. For the food processing (S1CB) the connection was, surprisingly, even more distant. This was due to a strong seasonality of customer demand, according to responses during the interviews. Since the company was not able to level customer demand, it was forced to decouple the process from customer demand even further than the other process company, though aware that this was less efficient than a tighter connection to customer demand. This indicates there is a strong contextual factor affecting the application of Lean when it comes to methods of integrating customers into the production system.

F4. Use the Non-Cost Principle to find opportunities for improvement. Then do Kaizen!

Support	Comment
Vague findings	Known but not important in decisions and choices.

The first study was focused on the connection between SW and PS. The questions were focused on the stability of the process and not as much on the productivity improvement in the process. Therefore only indirect conclusions can be drawn from the first study. The XPS of all the cases in the first study adhere (explicitly or implicitly) to the Non-Cost Principle. Some understanding of the principle was in evidence with the representatives of the Lean support function. However, the Non-cost principle was described as one of many and not indicated as the main driving force in the system except in a general way. Thus F4 found few indications in the first study. In the second study, there was indication when interviewing managers in the first case (S2C1) of understanding of the direct connection between the Non-Cost principle and Kaizen, as they indicated changes (flexibility) as opportunities to work with productivity as well. However, the driving force was the change itself (the need for flexibility), not the Non-Cost principle. Thus the Kaizen could be seen as opportunistic and secondary. There was little indication of understanding of the Non-Cost principle given by the representatives of the other functions. This leads to the conclusion that F4 is little understood on an implementation level or an application level. Clearly it is not used as a major driver of Lean, as by the intentions of Taiichi Ohno (Ohno 1988; Shingo 1989).

F5. Train people to think as well as to do.

Support	Comment
Weak positive findings	Methods are done in the most resource-efficient manner without much reflection

This was of particular interest in the first study, as training is an integral part of SW. However, the support of F5 in the first study was weak, as indicated by the frustration claimed by the representatives of the Lean support functions. Especially S1CA had restarted its Lean initiative several times in different versions. Typically the spread of Lean into the organization was done through the distribution and training of centrally defined methods for Problem Solving and Standardized Work (among others). The training was done by others than direct managers and the methods taught were treated as separate from the process, a sort of add-on, not integrated into the system of the process. One example of this is the responsibility for the maintenance of the descriptions of the SW. For both S1CA and S1CB, it fell to the industrial engineer to maintain and write the standard. For manufacturing the responsibility was with the operators. But even in that case it was often one designated operator that wrote all the standards. This was indicated by the signatures of the authors on the standards, where one person often wrote the majority of the standards for an entire line. People are taught a method, the method is executed in the most resource-efficient manner, seemingly without understanding the deeper purpose of the method.

F6. Leveling and operational stability is largely enabled through elimination or reduction of work associated with switching of tasks.

Support	Comment
Strong positive findings	Even though switching of tasks was quickly done, the potential for productivity gains was largely untapped.

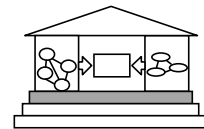
Evidence of this could be found in all cases in both studies. For the manufacturing cases, the switching of tasks (change of variants) in the lines was close to instantaneous or required very little effort. Usually it was completed within fractions of a Takt time, as indicated by observation and interview in study one and two. The switching of tasks within process industries was more of the type batch and queue, but even then much effort had gone into making the switch as efficient as possible. This was indicated by the modular design of the equipment that was changed and the interviews where the respondents described the challenges connected to a running change in S1CB. For S1CA, large parts of the line had to be shut down when changing the process, but this was largely standardized and well practiced. This indicates a strong understanding of the application of F6 within the process. Interestingly enough the understanding of the implementation of F6 was lower, as the productivity gain enabled by F6 was largely untapped for all cases. More so for the process industries than for the manufacturing industries as indicated by F4 above. Thus the application of F6 could be seen as a sub-optimization rather than a true understanding. At least the connection between elimination of setup work and that of leveling and operational stability was not well understood.

F7. All processes should be continuously improved.

Support	Comment
Weak positive findings	Strong implementation: mixed, weak application.

All XPSs used in the cases (different wording but clearly indicated) defined Continuous Improvements as an integral part of the production system. In the first study, the representatives of the Lean support functions mentioned this as an important part of the system and demonstrated concepts that would support this, such as suggestion systems and improvement systems. Thus the implementation of Continuous Improvement could be seen to be strongly supporting F7. In application the results were more diverse. S1CD had a strongly integrated suggestion system with visual depictions of the improvements made on a yearly basis at a central position in the process. This was also indicated by the clear support of the system from management, as well as the factual KPIs of the process. In S1CC, the system was more understated. Improvements were measured at a group level and aggregated up to management level but the total results were not visualized. The pace of improvement in S1CD was also faster than for S1CC, but this could also be attributed to the fact that S1CD was newer to Lean than S1CC and thus had more “easy” improvements to make. S1CB had a system similar to S1CD, but it seemed to be less utilized, although the PS system was well developed. S1CA had no formalized system apparent in the process, though their Lean support function explained how it should work. All in all, the diffusion of the Continuous Improvement system was mixed, lending some support to F7.

5.3 Analysis of the studies using the Evolutionary view of Lean



E1. A great sense of urgency is normally required to drive the evolution into a Lean production system

Support	Comment
Conflicting findings	Depends on alignment between management message and application.

There were differences in the sense of urgency demonstrated by the cases. As indicated by the interviews with the representatives of management in S2CB and the representatives of the Lean support function of S1CD, there was a sense of “worry” or “urgency” in the implementation of Lean. This was supported by looking into the results of the process. A few years back the results were not adequate and competition was fierce. After the decision to implement Lean was made, upper management committed to the implementation in action and words, conveying a sense of “hurry up” to the rest of the organization. When speaking to operators it was clear that the message had permeated down through the organization. This in contrast to S1CA, where representatives from the central Lean support function were aware of the urgency but were also frustrated by the lack of ownership in the organization. Some managers adopted Lean creating “efficient islands” (Modig and Åhlström 2012), but in general there was a weak sense of urgency in the organization. This was true despite the fact that external competition was at least as fierce as for S1CD. The lack of commitment was

observable in the slow pace of change in the process as well as from passing comments when talking to operators during coffee breaks. It seemed to be someone else’s problem and did not really affect them on a personal level. The rest of the cases fell somewhere in-between with for instance S1CC displaying some pace in the implementation of Lean, despite being highly profitable. The higher the alignment between the message of the management and what was said by the operators in the process, the higher the pace of application of Lean, it would seem.

E2. Evolution can be driven by internal reflection, not just external circumstances

Support	Comment
Weak positive findings	Reflection depends on the process' current development phase and was not found to be continuous.

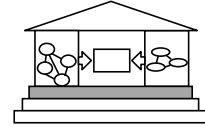
Interestingly, despite the lack of “sense of urgency” demonstrated by S1CA there was a strong sense of reflection and commitment demonstrated by the central Lean support function. The XPS of the company was into its third iteration and some organizational changes had been made. The external circumstances had not changed but the internal approach had evolved. The same behavior could be seen in S1CC. Although the XPS was successful and the process was profitable, the pace of change was deemed to be too slow and the application (not the implementation) of the XPS was under development. This aligns well with the message by Taiichi Ohno, of rediscovery of the one's own process (Ohno and Mito 1988). Internal reflection was not demonstrated as clearly in the other cases. They seemed to be in other phases in their development cycle, with a greater focus on the application of Lean than an evaluation of the progress.

E3. Continuous learning and adaption of practice is at the heart of any successful Lean implementation.

Support	Comment
Strong positive findings	Even though each case was different, all displayed a strong intent to learn. Deeper reflection (Hansei) not done.

As indicated by for instance Hines et al. (2004), Lean implementation can be described as having several different stages. The transition between the stages requires an adaptation of behavior in the process, which should be based on experienced-based learning. More or less in all cases, there was some evidence of this behavior, but on different levels. In S1CA and S1CC, the adaptation was done at the central Lean support function, resulting in a change in the implementation of the XPS. In S1CB and S2CB, the learning was on a more local level, as indicated in the observation of the processes, resulting in changes in the application of the XPS. Especially in S2CB, the organization of the production was, in many places, being adapted to enable smoother flow. In S1CB the practice of problem-solving methods was under development to support deeper analysis. There was some concern of the analysis taking more time than the previous method, but also an expectation that the time for analysis would go down as the method became more practiced and established. Even if there were clear indications of a will to learn, deeper reflection, Hansei (Liker 2004) was not done and the learning was on a practical level.

5.4 Analysis of the studies using the Tools and Methods view of Lean



ToM1. *The leveled customer demand initiates the process*

Support	Comment
Weak positive findings	Nature of market demand affects practical solution of leveling. Customer behavior as well as products and processes strongly influenced application.

In both studies, the majority of the cases indicated that the process was initiated by a customer order. The exception was S1CB, where the high seasonality of the customer demand required production over much of the year to be shifted towards building stock. In the season of demand, the shift form was changed to increase production as well as delivering from stock to cover the fluctuation in demand. Interestingly enough, this decoupling of customer demand and process output from S1CB functioned as a leveling of production. It would have been uneconomical, given the bottlenecks and grade of investment in the process equipment, to truly match customer demand during the different seasons. This indicates that ToM1 is connected to certain conditions of demand patterns. An enabling factor in this is also that the product from S1CB has few variations. The customization required in other production is largely absent for S1CB. When looking into the leveling of the other cases there are some attempts to even out fluctuations. When examining the second study, both S2CA and S2CB indicates using an initial order stock to achieve basic leveling. For larger fluctuations other measures were taken, such as rebalancing, shift changes, and technical adoptions. The pattern of customer demand was in both cases dependent on other factors, such as different economic cycles for different markets. Both companies were globally active and could use this as a leveling factor as well. For S1CA, customer demand initiated the process as the product mostly was made according to a specific specification, but it was produced in batches and the time from order to delivery could be considered long. It can be concluded that there was a large level of understanding of ToM1 in all cases, but that differences in customer behavior as well as products and processes strongly influenced how ToM1 was applied. Only in one case was the initiation of production partly based on speculation and prognosis. Mostly customer demand initiated the process, but the methods of leveling the demand to achieve efficiency ranged from weak to nonexistent.

ToM2. *Through Standardized Work, the impulse of the customer is converted into the results of the process.*

Support	Comment
Strong positive findings	Depends on distance between effort and process result. Nature of the process affects application of SW

The distance between the work described in the standardized work and the results of the processing seem to affect the connection between SW and the result of the process. For S1CA and S1CB who are both process heavy, the SW was more centered on describing the operation and maintenance of the processing equipment. The connection between effort and result of the process was only indirect. For the remaining cases, the distance between the tasks described in SW and the results of the process were smaller. There was a direct connection between work and result due to the nature of the manufacturing processes. Thus it may be concluded

that the connection between the work described in the SW and the results of the process, is largely dependent on the nature of the process.

ToM3. Value, as defined by the external customer, largely defines what quality is in the Lean process.

Support	Comment
Strong positive findings	Translation of customer value into quality measures may vary depending on process but was present in all cases.

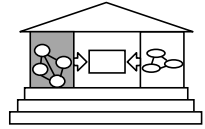
This was clearly evident in both studies and all cases, but manifested itself in different ways. Since SICB was processing food, a measure of quality demonstrated during the observation and interviews was the “taste test”. At regular intervals, the team leader would remove a sample of the product and taste it. It was not clear how this was calibrated but as stated by the team leader “*You soon learned how it should taste*”. In S1CA, the product was tested chemically as well as mechanically to verify that the product was in accordance with the customer's specification. This was done in several stages and mainly in a laboratory. For the manufacturing cases, quality was verified in several stages. This was clearest in S1CCG1, where the product was not only verified visually and mechanically, but also put in a test bench to verify that the properties of the product matched specification. In all these examples, the customer values in the product, whether it be taste, chemical properties or specification, was clearly translated into operational procedure.

ToM4. With a basis in Standardized Work, deviations were found in the results of a process in relation to “Value”, as defined by the customer, and also in the relationship between value-adding time and waste, in the effort spent producing the result.

Support	Comment
Conflicting findings	Some values are important, productivity less so. Unclear results.

The results of the studies are contradictory. This is clear when it comes to the issue of quality as discussed in ToM3 above. But when it comes to the relationship between value-adding time and waste, the productivity of the process, much of the result of the second study showed that it was not necessarily a concern for the processes. Some representatives of functions in S2CA mentioned that it is opportune to increase productivity when other changes are implemented. However there was no mention of this in a direct sense. This might be a result of the design of the studies, where the first study looked into how groups create stability in the process and the second study was focused on the connection between flexibility and Lean. Supporting this is the XPS of each case, where the reduction of waste is either clearly in the XPS, or implied in the principles of the XPS. If the XPS had been strongly applied in the process, it is reasonable that the ToM4 would have been clearer in the studies.

5.5 Analysis of the studies using the Systems view of Lean



S1. An XPS must not only describe the parts of the production system, it must also describe connections and dependencies in the system.

Support	Comment
Vague findings	Only indirect connections were described in the XPS. Little understanding of the nature, dependencies, and direction of the connections.

The connections and dependencies of the XPSs were in no case made explicitly clear by the visual depiction of the XPS. In some cases, the visual depiction of the XPS could be interpreted as showing implicit connections to Problem-Solving, as indicated by the stated priorities in the XPS. In all cases, the representative of the Lean support function was asked to illustrate the connections and dependencies he or she knew of in the production system. Even if all of them regarded the XPS as a system, awareness of the nature of the connections seemed low. Illustrations of the connection of the XPS varied both in scale and content depending on the discussion. No conclusions could be drawn other than that it would seem that the understanding of the XPS as an interconnected system was low at all levels of the organization. Surprisingly this was also true of the representatives of the Lean support function. Therefore S1 found very little support in the cases. This is indirectly supported by the state of application of Problem-Solving methods applied at the group level. No indication of a systematic approach when finding countermeasures to problems could be found. This can be seen as an indirect indicator that the level of awareness of the connections of the applied XPS was low as well.

S2. The parts of a Lean system must be, through implementation and application, traceable back to the “Non-Cost principle” and connected to the “nature of demand”.

Support	Comment
Weak positive findings	“Nature of demand” seemingly more important than Non-Cost principle.

Some support of S2 was found in some cases. For S1CC the Non-Cost principle was stated as a cost priority in the system. Other XPSs had other direct or indirect indicators and the representatives of the Lean support functions all indicated an awareness of the principle at an implementation level. The exact phrasing could vary but the intent was there. However, at the application level of the process the connections were less obvious. As indicated in the second study, much work was done and many solutions applied without direct connections to the Non-cost principle. As always when lack of an indication is used in the analysis, caution is necessary in the conclusion. It is possible that another design of the study would give different responses from the respondents. But given the fundamental nature of the Non-Cost principle, it is reasonable that it would be referred to, directly or indirectly, if deemed essential to the organization. This is indirectly supported by the lack of follow-up on problem-solving resources, uniformly indicated in the first study. Interestingly, the second study showed an awareness of the “nature of demand” at the operational level of the process. It was common for the representatives of management and in particular, logistics, to refer to outside influence and conditions when discussing need of flexibility in the process.

S3. Operation of the XPS should be based on an understanding of the sources of waste in the system.

Support	Comment
Weak positive findings	Operational awareness of unevenness (Mura) though not stated in the XPS. No system awareness except for waste (Muda). Connections and interdependence unclear.

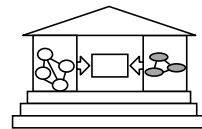
In the discussion with the Lean support function, a clear idea of waste as a concept was evident in most cases. Mainly in the form of Muda, where references to the seven traditionally defined wastes were common (see foundational view, Taiichi Ohno, above). Often other waste was included in the definition, such as “waste of human ideas” or “potential”, for instance. In one case (S1CC), there was an awareness of Mura and Muri, as well and in one case there was an awareness of Mura, although not by that name. In practice the demonstrated awareness was less clear. The observation of the process done for study one and two revealed several solutions and also references to the seven traditional wastes. Interestingly enough there was little reference to Mura (when filtered from process jargon) in the interviews with different functions and representatives, but in practice there was some indication of awareness. For instance, the logistical system of S2CB was under development to accommodate larger variation of variants and a higher fluctuation in workload through the introduction of “Kit-picking”. Both S2CB and S2CA had designed fixtures and conveyor equipment to handle variation in the process. End-process buffers were however common for all processes, especially S1CB. There was an operational awareness of the problem that seemed to be unstated in the explanation of the XPS. The main exception was the two cases from the process industry, where Mura was incorporated in the process through equipment design. There seemed to be little awareness of Muri in any process, either at the implementation or application levels of the processes. Overburdening was seen as undesirable but was not incorporated into the application of the XPS, nor obvious in the discussion. Inefficient measures were referred to in the interviews of the second study, instead of avoidance or solution of the problem. Some mention of maintenance frequency was made by the process companies. In one case indirectly by the manufacturing companies (downtime for carriers, S1CC). No indication was given of an understanding of the connections between Muda, Mura, and Muri (see Figure 5 in Systems view of Lean, above) for any case, even when they were aware of the problems. This is indirectly supported by observation, as each particular solution was largely disconnected at a concept level for the other solutions. The impression was more local pragmatism than overarching principles.

S4. The application of the XPS is done in stages, which should be based on the conditions of the process, the dependencies of the XPS, and the experience of the employees.

Support	Comment
Insufficient data	No conclusion can be drawn.

In some cases, the XPS of a case was useful to understand the sequence of application on a general level. S1CC had a design of their XPS that was organized to give a sense of implementation sequence, but only on a very general level. This was indicated in the interview with the representative from the Lean support function. For S1CD, the XPS itself was not illuminating. One had to go into the explanation underlying the XPS to get a sense of sequence. For the other cases, the sequence of implementation and application was not explicitly considered. For S1CB, the issue of stages or sequence came as a revelation to the representative of the Lean support function. In that sense the study could be criticized since it affected the subject. But since Lean is learnt in stages, some interference by the studies may be seen as unavoidable. Little of the stages of Lean integration was indicated when interviewing respondents actively participating in the processes. This was indicated by its absence in the responses. If the plan for application and its stages had been commonly known, it is feasible that they would have been referred to during the interviews. Instead the majority of the answers were in the present tense or past tense, giving little indication of awareness of a future development in the XPS at an operational level. Some caution is appropriate in this conclusion, as the design of the study might influence the respondents. A different design might have given different results. Consequently, at best this conclusion can be valued as an indication.

5.6 Analysis of the studies using the Philosophical view of Lean



P1. Lean methods have to both fill their intended purpose and surface problems and in doing so, foster consciousness.

Support	Comment
Insufficient data	Some awareness at the Lean support function, but seemingly not in the operations. Practical focus on current problems.

In the first study, some awareness of the duality of filling a purpose and revealing problems was discussed when interviewing the representatives from the Lean support functions. When talking to managers and team leaders less awareness was apparent. Especially when talking to first line managers, when focused on training methods in the first study, purpose was described as the transfer of ability in a practical sense. For the process industries training was through a master-apprentice system, where a new employee followed a senior employee or a team leader until able to perform the task on his or her own. No mention of any attitude-fostering aspect of the training in any case. Some support of this could also be seen in that the problem-solving methods were diverse with little follow-up (learning) built into the PS system. No conclusion can be made about P1, but the overall impression of the first study was more one of pragmatic solution focus and less of reflection, fostering, and awareness. The same conclusion and reservation applied to the second study. Little evidence of deeper

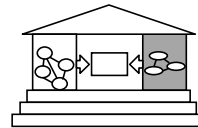
reflection and reasoning was found. Most representatives of a function (Management, I.E., Logistics) were focused on the solutions of the flexibility scenario, relevant within their area of responsibility. Little thought to the Lean system was evident. When discussing training as a consequence of change in manning, focus was mostly on pragmatic aspects.

P2. The application of a Tool or Method in Lean must be aligned with the purpose of all the Tools and Methods, as well as the intent of the Lean system.

Support	Comment
Weak positive findings	Alignment better in process with more experience with Lean.

There were differences in the alignment between the application of the methods of Standardized Work and the purpose of the system between the cases. The statements about standardization and Andon made by the Lean support function were less in evidence, when observing a process with less experience with Lean, than a process that had started later and had more experience. The best alignment was found in S1CC, where both team leaders could explain the methods using the same vocabulary as the Lean support function. At the other end of the scale was S1CA, where alignment was almost non-existent. Especially in PS methods there was a difference between the Lean support function and the explanations given by the guide during observation. The implementation of Lean in S1CA was in its third iteration, and there was still misalignment, indicating difficulty in the dissemination of purpose and intent of the system.

5.7 Analysis of the studies using the Cultural view of Lean



C1. There has to be a sense of reciprocity between the employees and the management.

Support	Comment
Insufficient data	Some indirect indication. More research needed.

Little clear sense of reciprocity between the employees and the management was found in the studies. If the purpose of reciprocity is to generate a feeling of “we are all in this together”, to avoid alienation between management and employees, the best indication of C1 was found in remarks given by operators in S1CA, who indicated a clear opinion of “us and them” when talking about management. S1CA is also the case where Lean has been restarted twice in the company. However, drawing cause-effect conclusions from this is not possible. Some support for the feeling of alienation can be concluded from the frustration of the central Lean support function regarding the difficulty of gaining acceptance for Lean in more than isolated islands in production. Further research is necessary.

C2. Involvement and a sense of responsibility is required for continuous improvements. Participating in improvements gives a sense of involvement.

Support	Comment
Strong positive findings	Personal commitment and pride evident with employees actively engaged in Continuous Improvements and Problem-Solving

This was clearly the case for S1CB and S1CC where respondents demonstrated a clear sense of involvement and pride when describing the improvement work they had participated in. For S1CB one respondent was being trained in new problem-solving tools and demonstrated a great personal commitment to the methods, demonstrating on line the effects of actions taken as a consequence of the analysis. In S1CC one respondent went to great lengths to explain the connection between the KPIs of the process and the long-term goals for the group, displaying understanding and commitment to the productivity targets for the group. Several initiatives were explained from the suggestion list. In S2CB a representative from Industrial Engineering enthusiastically discussed several solutions in the process, in order to increase flexibility when handling variant products. Overall it seemed that the respondents who were energetic and enthusiastic in their explanation displayed more commitment and gave more detail in their explanations than respondents who were only mildly interested and thus less involved.

C3. A culture of immediate reaction to correct deviations.

Support	Comment
Strong positive findings	Difference between manufacturing cases and process industry cases. Several strong contextual factors found.

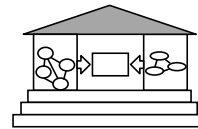
For all the manufacturing cases there was strong support for the implementation of C3. In application there were contextual differences. For the process with the quicker flows the “immediacy” of the stop was realized, for the slower processes urgency was less. This was indicated by observation in the process as well as explanation by the respondents. There were some differences in what the corrective action was. Depending on the nature of the deviation, it could be simply to correct the deviation at that particular product. In a minority of cases the corrective action triggered a deeper problem-solving process. Mostly it was explained by “*we are already aware of this problem*” by the team leaders. Therefore it can be concluded that for the manufacturing cases, the corrective action was mostly focused on the immediate correction of the specific deviation and less on long-term actions. The process industry cases handled deviations differently. There was less urgency and a longer time between deviation occurrence and discovery. In the case of food processing, deviations were diverted into scrap bins without immediately stopping the process. This choice was explained due to the nature of the process which could not be stopped without fire hazards and other consequences. This was further indicated by the focus on preventive maintenance and process control rather than deviation-handling procedures in the Standardized Work. To conclude, there are several contextual factors connected to C3. The speed of the process, the nature of the product, and the nature of the process were all found to affect the application of either “immediacy” or the nature of the corrective action.

C4. A culture of creative discontent drives Continuous Improvements

Support	Comment
Vague findings	KPI targets could be found, but little evidence of structured actions. No method of logically connecting KPI targets and actions was evident.

Since this conclusion captures the intent to never be satisfied with the current state, the drivers to challenge the normal situation of a process must be examined. In all cases the indication of long-term goals and challenges were evident when examining the KPIs at group level on the results board. However, the goals and targets were sometimes in disarray as some targets were updated and current and other targets were not updated. The mix between updated targets and those not updated could be found on the same board. No patterns could be discerned. In a few cases there was an action list connected to the KPI targets. Also, in such cases there was a mix of updated and living actions and “dead” lists. In no case was there a clear method of making a connection between the actions and the targets and KPIs. The analysis in most cases seemed shallow. The few exceptions were cases where the action was obvious and required no analysis.

5.8 Analysis of the studies using the Management view of Lean



L1. A sense of personal accountability and competence in methods.

Support	Comment
Mixed findings	Differences were found at a personal level. Some link to experience level in Lean of the process. Perceived range of control affects sense of accountability.

Various levels of personal accountability could be found during both studies. In general there was a sense of responsibility at the management level. In some cases the perceived range of control over influencing factors was low. Though management admitted to responsibility for the results, factors that could be influences compared to factors that depended on events outside the managers' control, affected the sense of accountability. In general, the managers of the manufacturing cases seemed to have a greater competence in the methods of Lean compared to managers in the process industries. In some cases the manager explained the KPI board and, when discussing the action list, the range of solutions seemed more mature in the manufacturing processes. However, the sample was too small to draw any definitive conclusions.

L2. Self-development attitude.

Support	Comment
Weak positive findings	The more knowledge in Lean, the more evident the attitude that self-development was necessary. Also, greater curiosity came with greater knowledge.

The greatest display of curiosity and need for self-development was given by the Lean support functions. After the formal interview, the discussion would continue and there seemed to be great curiosity about what other companies were doing. System aspect of Lean was

discussed, although at various levels depending on knowledge. The impact of the Lean support functions in the process was in most cases not that great. So even if there was a commitment to learn more, the dissemination of knowledge was not strong in most cases. There was a similar indication when discussing at the management level in some cases. In other cases there was a lack of curiosity and a sense of complacency at the management level. A similar pattern could be observed at the team-leader level. The pattern seemed to be roughly linked to the experience level in Lean in general, with some exceptions at a personal level. The group at S1CA with the least experience displayed the least level of curiosity.

L3. The drive to continuously improve has to be coupled with respect for people.

Support	Comment
Strong positive findings	The principle was considered when planning changes, but there was a misalignment in the understanding of Respect for People between management and employees.

In all cases in both studies the Respect for People principle of Lean was referred to several times at management level and at the Lean support functions. This was an important principle and often included in the XPS of the process. Interestingly, the principle was also sporadically referred to at an operational level as well, but in a negative sense. “*Is this Respect for People?*” was heard in discussions when discussing an aspect of the operation that was displeasing or a decision that was not popular. The objection was heard in processes with more Lean experience. The more immature processes did not seem to be aware, or at least did not refer to the principle, even though discontent with decisions was evident there as well. Therefore it can be concluded that there was a misalignment between the management view of Respect for People and some employees' perception of the principle in the more experienced processes. In the less experienced processes, employees gave little indication of awareness of the Respect for People principle at all.

L4. There is an established sense of True North in the organization.

Support	Comment
Weak positive findings	Awareness at management level not always translated into direction at operational level

The indications of L4 were varied. When speaking to managers in S2CA and S1CB, there was a clear sense of heading and a sense of strategy when talking about planned changes. The same was evident when talking to the Lean support functions in the first study. All were aware of a direction and an intent. On an operational level, the sense of True North was less evident. The team leaders in S1CB indicated a worry about competition in the business “*The (competing) plants in eastern Europe are much larger and more efficient*”, but there was no sense of overall direction or what the management intended to do about the situation. In S1CA, the managers and the Lean support function were all aware of the competition and market situation, but this was not translated into direction or action in either group studied. In particular one group worked in a process deemed “unprofitable” with an “unstable” quality situation. Little concern for this or the direction of development was found in the group. The future was up to management and the industrial engineers. Little sense of personal commitment was evident when talking to the group during a coffee break.

5.9 Concluding the total analysis

Summarizing the analysis gives a condensed image of each view of Lean and leads up to the discussions and conclusions of the thesis.

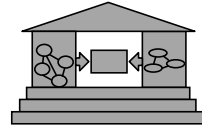


Table 4. Concluding the Historical view of Lean.

Historical view of Lean	
H1. Work can be objectively studied and described in a work standard.	Strong positive
H2. Standardization of work enables synchronization of effort.	Weak positive
H3. Continuously experiment to find solutions of pragmatic problems.	Mixed
H4. Results lead to practice. Practice leads to principle.	Mixed

Table 5. Concluding the Foundational view of Lean.

Foundational view of Lean	
F1. Stop a process when a problem is detected and correct the problem.	Conflicting
F2. True understanding of a situation is based on direct observation combined with deep reflection.	Weak positive
F3. See the end customer as an integral part in the production system.	Strong positive
F4. Use the Non-Cost Principle to find opportunities for improvement. Then do Kaizen!	Vague
F5. Train people to think as well as to do.	Weak positive
F6. Leveling and operational stability is largely enabled through elimination or reduction of work associated with switching of tasks.	Strong positive
F7. All processes should be continuously improved.	Weak positive

Table 6. Concluding the Evolutionary view of Lean.

Evolutionary view of Lean	
E1. A high sense of urgency is normally required to drive the evolution into a Lean production system.	Conflicting
E2. Evolution can be driven by internal reflection and not just external circumstances.	Weak positive
E3. Continuous learning and adaption of practice is at the heart of any successful Lean implementation.	Strong positive

Table 7. Concluding the Tools and Methods view of Lean.

Tools and method view of Lean	
ToM1. The leveled customer demand initiates the process.	Weak positive
ToM2. Through Standardized Work the impulse of the customer is converted into the results of the process.	Strong positive
ToM3. Value, as defined by the external customer, largely defines what quality is in the Lean process.	Strong positive
ToM4. With a basis in Standardized Work, deviations are found in the results of a process in relation to "Value", as defined by the customer, and also in the relationship between value-adding time and waste, in the effort spent producing the result.	Conflicting

Table 8. Concluding the Systems view of Lean.

Systems view of Lean	
S1. An XPS must not only describe the parts of the production system, it must also describe the connections and dependencies in the system.	Vague
S2. The parts of a Lean system must, through implementation and application, be traceable back to the "Non-Cost principle" and connected to the "nature of demand".	Weak positive
S3. Operation of the XPS should be based on an understanding of the sources of waste in the system.	Weak positive
S4. The application of XPS is done in stages, which should be based on the conditions of the process, the dependencies of the XPS, and the experience of the employees.	Insufficient data

Table 9. Concluding the Philosophical view of Lean.

Philosophical view of Lean	
P1. <i>Lean methods have to both fill their intended purpose and surface problems and in doing so, foster consciousness.</i>	Insufficient data
P2. <i>The application of a Tool or Method in Lean must be aligned with the purpose of all the Tools and Methods as well as the intent of the Lean system.</i>	Weak positive

Table 10. Concluding the Cultural view of Lean.

Cultural view of Lean	
C1 <i>There has to be a sense of reciprocity between employees and management.</i>	Insufficient data
C2. <i>Involvement and a sense of responsibility is required for continuous improvements. Participating in improvements gives a sense of involvement</i>	Strong positive
C3. <i>A culture of immediate reaction to correct deviations</i>	Strong positive
C4. <i>A culture of creative discontent drives Continuous Improvements</i>	Vague

Table 11. Concluding the Management view of Lean.

Management view of Lean	
M1. <i>A sense of personal accountability and competence in methods</i>	Mixed
M2. <i>Self-development attitude.</i>	Weak positive
M3. <i>The drive to continuously improve has to be coupled with respect for people.</i>	Strong positive
M4. <i>There is an established sense of True North in the organization.</i>	Weak positive

Since all cases have several years of experience in the integration of Lean as well as a stated intent to actually be working with Lean, they all have a remarkably similar way of operating the Lean integration. All of them have established Lean support functions and visualized XPS:s as a method of communicating the system in the organization. All cases have groups or teams (although the exact denomination may vary) with a stated intent to improve the process as well as to operate the process. All cases have a stated upper management commitment to Lean.

The analysis above provides a consolidated image of all the cases in both studies. Commonality and differences in the cases can be found and explored when comparing the situation in the companies with the aspects of Lean theory. This consolidated image may open up new avenues of research (see future research below), but more importantly the current state provides a snapshot of the state of Lean integration for the manufacturing industry and process industry studied. Consequences and implications will be further examined in discussions and conclusions below.

6 Discussion and conclusions

Lean as a topic of research is well established and has received considerable attention over several decades. The methods and tools of Lean are well studied and established. Even so, there are avenues and perspectives of Lean that are less examined and discussed. This chapter aims to cover a few of them.

6.1 Research question

The intent of the research question was to examine how to describe the current state of a Lean integration based on the lowest organizational level of a process.

Table 12. Aspects of Lean in relation to the findings.

		Strong positive findings	Weak positive findings	Vague findings	Mixed findings	Conflicting findings	Insufficient data
Historical view of Lean	H1						
	H2						
	H3						
	H4						
Foundational view of Lean	F1						
	F2						
	F3						
	F4						
	F5						
	F6						
	F7						
Evolutionary view of Lean	E1						
	E2						
	E3						
Tools and Methods view of Lean	T1						
	T2						
	T3						
	T4						
Systems view of Lean	S1						
	S2						
	S3						
	S4						
Philosophical view of Lean	P1						
	P2						
Cultural view of Lean	C1						
	C2						
	C3						
	C4						
Management view of Lean	M1						
	M2						
	M3						
	M4						

Based on a fairly comprehensive view-based model, an analytical framework was established. A total of eight views giving a total of 32 aspects were established and organized in relation to each other (see Figure 1). Lean view aspects were used as a frame of reference to examine the consolidated case-study material and to establish a description of the current state of attempts to integrate Lean (see Table 12). The research question was:

RQ: *How to understand the integration of Lean in a process?*

The answer to the RQ is found in the summarized support of Lean view aspects found in the case material.

Strong positive support in the Lean view aspects

Support	Instances	Comments
Strong positive findings	9	Strong indications found in simple applications or fundamental ideas

The analysis found nine aspects in the Lean view, which found strong positive indications in the examined material. Common factors for the instances seem to be that they were of a simple and straightforward nature. The aspects that found strong indications, described an implementation of Lean applicable without much analysis or thought, as they seemed compatible with established practice in the process. The dissemination of the aspects in an organization in a process is affected by contextual factors in several instances. In some cases there was a misalignment between knowledge of Lean and application of Lean. For instance in M3, management commitment was not always translated into understanding at an operational level. This indicates that the translational mechanism between knowledge and ability is of importance in the integration of Lean.

Weak positive support in the Lean view aspects

Support	Instances	Comments
Weak positive findings	11	Connections and dependencies between parts of Lean not well established. Generalization and spreading of solutions are important.

The analysis found 11 aspects in the Lean view that found weak positive support in the examined material. Common factors for the instances that were weak positive seem to be that connections and dependencies between different parts of the XPS were only partly established. In some cases the connection and dependency were well understood, in other cases the connections were less well established. For instance P2 indicated a weak link between the application of a Lean tool or method and the overall purpose of the system. Also, S2 indicated a weak link between application and the Non-cost principle. This was also evident when examining problem-solving practices in general, where experience gained during PS was generally not spread to the rest of a process. This indicates that the mechanism for generalizing and spreading solutions to establish connections between different parts of a Lean is of importance.

Mixed support in Lean view aspects

Support	Instances	Comments
Mixed findings	3	Individual attitude is important, both at the operational level and at the management level.

The analysis found three aspects in the Lean view, which found mixed indications in the examined material. Common factors for the instances were personal commitment and ownership. To go beyond what currently works and challenge a situation would seem a bigger obstacle than simply solving problems based on process deviations. This also requires a relearning of established skills for new contexts. This relearning indicates that the integration of lean can be described as a loop where each iteration requires rethinking established principles and procedures.

Vague findings of Lean view aspects

Support	Instances	Comments
Vague findings	3	Lack of focus in the integration of Lean.

The analysis found three aspects in the Lean view that were not at all or only vaguely found in the examined material. Common factors for the instances were interestingly enough, traceable back to the Non-cost principle and the understanding of Lean as a system. This indicates a lack of focus on the intent of a Lean introduction. This lack of focus could be a contributing factor to the inefficiencies of a Lean introduction.

Conflicting findings in the Lean view aspects

Support	Instances	Comments
Conflicting findings	3	Specific context can counteract a Lean principle.

The analysis found three aspects in the Lean view that were contradictory in the examined material. Common for the instances, was a strong contextual dependency. In some cases the principle was compatible with the conditions of a process, in other cases it was not. An example is F1 where the process in one case was not stopped at all if deviations were found due to the nature of the process. This indicates that the specific context of a process in some instances counteract the application of a Lean principle. The specific context of a process therefore is found to be of importance to the introduction of Lean and a source of possible paradoxes and dilemmas.

Not enough data to draw a conclusion for Lean view aspects

Support	Instances	Comments
Insufficient data	3	Too few indications in material

The analysis found three aspects of the Lean views where the data was too sparse to draw conclusions from the examined material. The Lean view aspects are based in Lean theory and it would have been reasonable to find connections in the reviewed material, However, few indications were found. Further research or other indicators have to be established.

Answering the RQ

To be efficient in the introduction of Lean, a process has to have the ability to assess the current state of a Lean introduction. The introduction of Lean would have to be understood from several different angles simultaneously and as a system. Simply looking at a single view or just a few, would yield an image of the Lean introduction that could be limited and lead to the wrong conclusions. For instance, if only the tools and methods view is considered the management view might be forgotten and tools and methods applied without thought of development and direction. Or if the Lean systems view is considered without also regarding Lean as a culture, the application of Lean could turn into “Mean” as the humanistic angle is not considered. The analytical framework gives one such system of views. Based on the examined material, it would seem that the companies have a number of common strengths in their introduction of Lean, when it comes to the straightforward parts of a Lean integration. The weaker support in the comparison could be explained by the difference in experience and context. Commitment and ownership on a personal level could explain some of the contradiction and Lean views that are unsupported in the material. It would seem that the comparison of cases revealed several aspects of the process of Lean introduction that have to be considered if the introduction of Lean is to be efficient.

The industrial contribution

Putting the current state in relation to the resources spent on the integration could answer if the resources are being used for the right issues or not. By taking all views into consideration at the same time, the process can assess the integration of Lean as an interdependent system. The use of several simultaneous views to examine the same process therefore gives a reasonably good snapshot, which can be taken of the Lean integration at any given instance. This description of the current state highlights factors that are strong and factors that need attention. Using this analysis could enable the Lean support functions to assess the progress of Lean integration and to redirect efforts from the issues of Lean integration that are strong, to parts of the integration requiring more attention. This would increase efficiency in the integration of Lean as resources would not be wasted where they were not needed.

The academic contribution

All of the views taken in the frame of reference are based on studies, both contemporary and historical. The academic contribution is therefore the establishment of the relationship between the different views (figure 1), where a particular angle or view of Lean research can be put in relation to other views. Because Lean is an interdependent system, each view can affect every other view, directly or indirectly. It is therefore interesting for researchers to place other studies in a framework to understand the strengths and weaknesses of the studies from a systemic perspective, and to find new avenues of exploration for one’s own studies.

6.2 Concluding remarks

Being able to establish a comprehensive current state of a Lean integration process is important. This highlights strengths and weaknesses in the current situation and can be used to evaluate if resources are spent appropriately. The current state analysis also brought several other issues into focus, when examining the case-study material during the analysis.

- There were misalignments between knowing about Lean principles and the ability to apply those principles. This was evident in the differences between the terminology used by the Lean support functions and the terminology used by some of the other respondents. It was also evident when looking into the execution of the Lean methods, where there occasionally significant differences between groups within the same company. As a common strategy to integrate Lean in steps (Shingo 1984; Liker and Meier 2007) it is conceivable that training and coordination of a Lean integration could present a challenge.
- How the experiences gained during the attempt to introduce Lean in parts of a process are to be generalized and spread to the rest of the organization, to avoid wasting resources, by reinventing the wheel. This generalizing procedure was identified as of key importance to Toyotas success (Fujimoto 1999). The problem of experience not being spread, was generally evident in all cases. Experience gained during the solving of particular problems was generally not spread to other parts of the organization, the so-called Yokoten (Liker and Franz 2011). Nor was there a deeper evaluation of problem-solving procedures common, the so-called *Hansei* (responsibility and self-reflection), seen as necessary for organizational learning (Liker 2004). Normally, if the problem went away, that was enough. More thorough follow-up and learning was typically not done. This was evident in the differences in problem-solving methods for groups within the same company, as well as the absence of a formalized problem-solving system for one group in one case.
- The risk of incompatible Lean systems in a process, caused by piecemeal introduction. This was evident in the different strengths of some of the groups. For instance, one group was strong in preventive maintenance and another in standardized work. Each group therefore had its own development arc, introducing the risk of incompatible XPS methods. Each group might be efficient if assessed locally, but the risk is the creation of incompatible “efficient islands” (Modig and Åhlström 2012) that lead to an inefficient system in total.
- The strong force of process-specific context has to be taken into consideration. There were several instances in the analysis where the context of the process had a strong impact on process methods. In some cases the methods contradicted the letter of the Lean principle if not the intent. Personal attitudes, organizational culture, and management ownership can also be regarded as a process context, as the introduction of Lean replaces something else. This can be attributed to the difference in Lean genes and Lean instep (Rövik 2000). Therefore the effect of process context in a Lean introduction process must be clear.

All of these issues affect the integration of Lean and because Lean is dynamic by nature (i.e. Continuously Improving), a study of the current state of a Lean integration, although necessary to assess potentials and problems, is not enough. The issues above can be seen in a current state analysis, but not fully explained. Therefore, the process that leads up to the current state and will lead to further development will also have to be understood. This realization leads to future research in chapter 6.4.

6.3 Quality of research

A number of aspects can be considered regarding quality of research in this thesis. The research process in general, is a seductive process. As a researcher, especially a novice one, it is easy to become enamored with the subject of one's research. Research by nature seems to be driven mainly by curiosity, the impulse to understand a phenomenon or to gain new knowledge. In general this can be a positive experience, especially if new to a subject. In most aspects it is therefore a good thing, but there is also the risk of unconsciously losing objectivity and analytical distance. This is of course a risk in this thesis as well. Especially considering the previous experience of this author. To counteract such tendencies, rigor of scientific method is necessary as well as practice. Easier said than done, which is perhaps why learning how to do research takes time.

In case studies as defined by Yin (2009), pre-knowledge of a subject is regarded as positive because the researcher is not only required to record data but also interpret data during collection. This because analytic judgments may be necessary during the study. Pre-knowledge also involves risk, as there might be an unintended bias towards what is already "known" by the researcher. Such bias might manifest itself during the research design, as skewed questions, in the gathering of data, and in the analysis. This has to be carefully considered, as the author has a fair amount of knowledge and experience in the subject of Lean. It was therefore essential for this thesis to search for cases outside the author's range of experience. Unfamiliarity might counteract unconscious bias to some extent. Also, method transparency increases the validity of the studies, as it should be easy for a reader to understand the choices made during the design, execution, and analysis of the studies.

The choice of cases could be problematic. Since the studies are limited in both number and scope, far reaching conclusions and sweeping generalization should be done with caution. It can be argued that the conclusions are generalizable to some extent, but the studies could and should be extended with new cases from other fields. Such fields could be welfare organizations, Non-Governmental Organizations (NGOs), service providers, or even academia where Lean is being introduced. All of these have their own conditions and challenges and should therefore give new interesting angles to the research. Also, Lean theory can only ever be underdetermined by empirical evidence (Sismondo 2010). The search for a "best fit" is intuitively aided by a greater number of cases, but in truth there are always other avenues of explanation that can fit the data. Some caution in establishing cause and effect and drawing conclusions is therefore necessary simply because of the nature of case studies.

In many organizations Lean has not been successful. Proponents of Lean, for example Womack and Jones (2003), or Liker (2004), claim that Lean is universally applicable and that failure in the application is for instance due to a lack of understanding. There are however many researchers, for instance in Sederblads (2013) anthology, where the claim that Lean is universally applicable in any process has met with considerable criticism. Even if much of the criticism is based on misunderstanding or a lack of knowledge, the research behind it is worth a look. Hines et al. (2010) for instance claims that much of the criticism of Lean is correct, but that Lean is implemented in stages. Depending on which stage the introduction is in, different problems will occur.

Whatever one's viewpoint, a certain amount of humility with the proponents is called for as the integration of Lean often fails to live up to expectations, despite years of effort. The integration would, if nothing else, seem to be a rather messy and inefficient affair, where numerous resources are spent based on faith and promise. This entire thesis hopes to contribute to a slightly more efficient integration process in the future.

6.4 Future research

Though Lean has been the subject of intense studies over the last four decades and it would seem that the subject has been thoroughly examined, much remains to be explored. The most important avenue of exploration is a direct consequence of the current state analysis. Knowing a situation is important, but to understand many of the indications it would seem there is a need to understand the process that has lead to the current state. The integration process itself would need further exploration and definition. There is also a need to establish the effects of different conditions on a Lean integration process.

Also, despite many years of research, somehow many fundamental definitions of Lean, axioms underlying the system, remain unexplored. An apparent example is the definition of value in a process. Much has been written about the traditional seven wastes and some has written about Muda-Mura-Muri and the connections between them. The inverse of waste and value should therefore be easy to define. However, it would seem that the definition of value is rather vague. One possible topic for future research would therefore be to redefine value and explore the consequences. Perhaps this too is why Lean is difficult to integrate in many processes. The underlying definitions are simply incompatible with the process and the wrong problems are therefore being solved.

Another possible avenue is to explore the consequences of the analytical framework proposed in this thesis. There are many industries and processes as suggested by Arlbjørn and Freytag (2013), that can be examined to enhance the generality of the conclusions. There are many more possible choices. One thing is clear however:

We can all look forward to many more years of exploration.

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