Practical Implementation of Lean at Small and Young Companies

A DISSERTATION PRESENTED
BY
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TO
THE DEPARTMENT OF MECHANICAL ENGINEERING

IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
MASTER OF SCIENCE IN ENGINEERING
IN THE SUBJECT OF
MECHANICAL ENGINEERING

LUND UNIVERSITY
LUND, SWEDEN
JUNE 2018

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Abstract

Introduction: This thesis aims to investigate how a small and young company can implement the management philosophy Lean. The thesis is designed as a literature study with two objectives. The first objective is to identify what Lean is and what its underlying tools, methods and principles are. The first objective is accomplished in the results chapter. The second objective is to investigate how these tools, methods and principles can be implemented at small and young companies. The second objective is completed in the analysis chapter.

Method: The database LUBsearch has been used to search for relevant scientific articles. Peer Review were used to verify the quality of the articles. Two books and a lecture from Lund University were also used.

Results: The results display several methods, tools and principles that can be used when implementing the Lean philosophy e.g. Just-in-Time, Autonomation and Kaizen.

Analysis: The analysis evaluates the tools from the results. An investigation on how Lean can be implemented at small companies and at young companies is conducted. Lastly, the tools, methods and principles that are well suited to be implement at young and small companies are implemented at a real company.

Conclusion: The conclusion discusses the evaluations of the Lean tools and the practical Lean implementation at the real company. The majority of the evaluated tools and methods are proved to be applicable at small and young companies. The truly difficult aspect of implementing Lean at a young and small company turned out to be making people use the Lean tools, methods and principles.

Keywords: “Lean SME”, “Lean Small Company”, “Lean Manufacturing”, “Practical Lean Implementation”, “Lean Young Company”.

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Abbreviations

DESIGN FOR MANUFACTURING AND ASSEMBLY	DFMA
FAILURE MODE AND EFFECTS ANALYSIS	FMEA
FIRST IN FIRST OUT	FIFO
JUST-IN-TIME	JIT
KEY PERFORMANCE INDICATOR	KPI
MAKE ONE – CHECK ONE – MOVE ONE ON	MO-CO-MOO
MULTINATIONAL COMPANY	MNC
NON-VALUE ADDING	NVA
ONE-PIECE FLOW	OPF
PRODUCTION SECURITY MATRIX	PSM
QUALITY CONTROL CIRCLES	QC-CIRCLES
QUALITY FUNCTION DEPLOYMENT	QFD
ROOT CAUSE ANALYSIS	RCA
SMALL AND MEDIUM SIZED ENTERPRISE	SME
SINGLE MINUTE EXCHANGE OF DIE	SMED
STATISTICAL PROCESS CONTROL	SPC
TOTAL PRODUCTIVE MAINTENANCE	TPM
TOTAL QUALITY CONTROL	TQC
VALUE STREAM MAPPING	VSM

TO MY LOVING FRIENDS AND FAMILY.

Acknowledgments

THIS THESIS PROJECT WAS MADE POSSIBLE WITH THE HELP OF A FEW PEOPLE. A thank you to everyone at the Company for welcoming me into your group. A special thanks to Professor Ståhl, whose books and lectures introduced me to the subject of Lean. Finally, a very special thanks to Ebba for her support and feedback.

何の問題もないことが最大の問題です
Having no problem is the biggest problem of all.

Taiichi Ohno

1 Introduction

WHEN A YOUNG COMPANY IS ABOUT TO BEGIN PRODUCTION FOR THE FIRST TIME, they can benefit greatly from having a clear production and management philosophy. Based on the chosen philosophy, the company can begin to design its production and management systems so that they have a clear structure from the beginning. Implementing a well proven philosophy facilitates for all stakeholders as they get a clearer sense of the company's direction and a broader understanding of why and how decisions are made. A clear philosophy also makes it easier for the company to further develop its processes, as the philosophy can be used as a template for further expansion.

This thesis investigates how the Japanese management philosophy Lean can be implemented at small and young companies. The investigation focuses mainly on Lean tools meant to be applied within production but also contain elements from other company areas as well.

This introduction chapter introduces the philosophy Lean and state the objective of this thesis. The material and method chapter explain how information to the thesis was gathered and validated. The results chapter display how the Lean philosophy can be applied using selected Lean tools, methods and principles. In the analysis chapter, a detailed examination on important aspects to consider when implementing Lean at a small and young company is presented. The analysis chapter also includes a practical Lean implementation project at a start-up company in Sweden. Finally, in the discussion chapter, a discussion about the outcome and about the thesis is held.

1.1 Objective

This thesis has two main objectives. The first objective is to identify what Lean is and what tools, methods and principles can be found within the philosophy. The first objective is accomplished in the results, chapter three. The second objective is to investigate how these tools, methods and principles can be implemented at small and young companies. The second objective is fulfilled in the analysis, chapter four.

1.2 Delimitations

This thesis investigates and describes Lean tools, methods and principles. The tools, methods and principles are only described briefly and are not investigated to deep extents. The thesis also investigates how the Lean tools, methods and principles can be implemented at small and young companies via a literature study and a practical study. The literature study investigates what forgoing researchers learned from Lean implementations at small and young companies. The practical study follows a practical Lean implementation at one small and young company. The results from the practical study cannot be said to be conclusive put should be seen as an indicator for how Lean can be implemented. Delimitations concerning the material used can be found in chapter 2, Material and Method.

1.3 Introduction to Lean

In modern manufacturing enterprises, focus is today aimed at reducing costs and minimising waste. The manufacturing enterprises are striving to produce products at a lower cost, with a better quality and in less time. Leading the way in the attempt to achieve these goals is the Japanese automobile manufacturer Toyota Motor Corporation with their merited production system called the Toyota Production System, TPS. Underlying the TPS is the philosophy Lean, which was coined in the book *The Machine That Changed the World* by Womack, Jones and Roos in 1990 [1].

Lean revolves around minimising waste and increasing value-adding time [2]. This means that a company must always strive to eliminate unnecessary activities in all its operations. In doing so the company can produce faster, better and cheaper than its competitors. [3]

The Lean philosophy is built up by different methods, principles and tools. The tools, methods and principles can be used differently depending on the circumstances. Several of the Lean methods and tools overlap in terms of goals and execution. [4] In chapter three, results, a selected number of Lean principles, methods and tools are presented.

1.4 History of Lean

In the 1930's the founder of the Toyota Motor Corporation, Kiichiro Toyoda, wanted to adopt and improve American production techniques. In 1938 he coined the term Just-in-Time, see section "Just-in-Time", and the first pieces of Lean started to fall into place [5]. A short time afterwards the two engineers and Lean pioneers Taiichi Ohno and Shigeo Shingo was brought into the company and soon began implementing their ideas into the production system [6]. Taiichi Ohno introduced the Kanban system, see section "Kanban", and Shingo began developing the autonomation concept, see section "Autonomation" [7]. The Just-in-Time concept was at first only used internally in the company but in

1963 Toyota started to introduce the concept to their subcontractors [8]. After a short while the subcontractors started to see productivity gains [9].

In 1960 the lead-time of a car produced at Toyota was six weeks [10]. Ten years later Toyota had managed to get that number down to two days as a result of refined Lean techniques [11]. Around that time prices of cars began to drop. Johnson [10] illustrates the correlation between the development of different manufacturing factors and the introduction of different management concepts well, see Fig. 1.1.

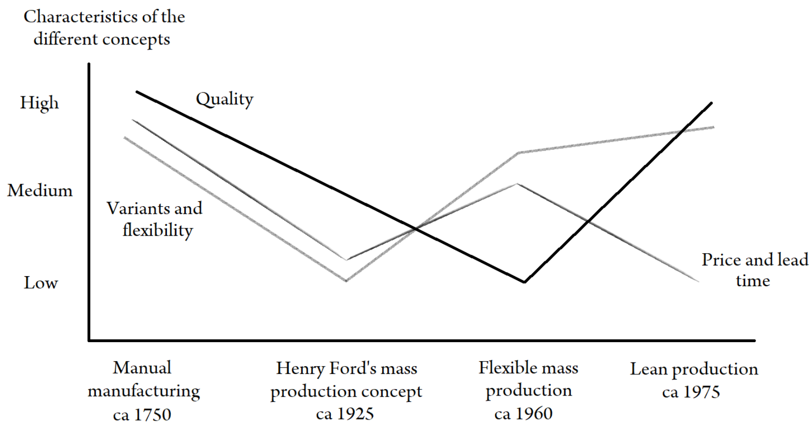

Figure 1.1. Development of different factors in correlation to industrial concepts, Johnson [10].

In 1976 it was evident that the Lean philosophy was spreading as other companies were showing increased stock turnover as a result of them having implemented the Just-in-Time concept [12]. It was also possible to see that the companies had increased flexibility and a wider selection of products [9]. From 1955 to 1989, the Japanese car industry increased its share of global car production from under 1% to just over 28% [4]. In 1982, Toyota merged its manufacturing company and its sales company. Because of this, the Just-in-Time concept spread to other departments were the concept would prove to be beneficial as well [11]. Today Lean philosophy is practised all over the world. Not only within manufacturing, but in all kinds of fields and industries.

1.5 Varying definitions of Lean and JIT

Lean is a term that has been used and experimented with by many different companies and researchers. For that reason, there is confusion about what the term really means and what it contains [13]. Even in Japan, were the concept originated, there is no clear consensus on what Lean stands for. Within Japanese industries the most frequently used words are "Just-in-Time", "Stockless production" and "Zero inventory" [14]. Although the term Lean is a bit ambiguous, some argue that there is a "fairly" uniform view on what the Lean sub-concept of Just-in-Time or JIT stands for [13]. Below follows a brief introduction to, and comparison of, what five different sets of researchers has to say about JIT.

Voss & Clutterbuck [15] says the following about JIT:

> *"Just-In-Time is not a single technique. It is more appropriate a philosophy of manufacturing, in which a variety of techniques - approximately 100 have been identified - support the objective of waste free production to meet known orders."*

Voss & Clutterbuck summarise JIT by presenting four different fundamental areas of activity, see Fig. 1.2.

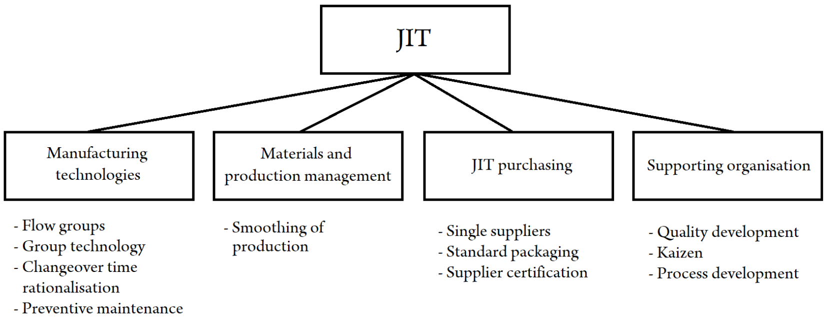

Figure 1.2. Components of JIT, Voss & Clutterbuck [15].

Hay [16] argues that elimination of waste is the common denominator for all components of JIT, see Fig. 1.3. Hay continuous and says that quality is very important. However, he does not go deeper into quality aspects as they are already well established in the West. Hay underlines the importance of flow as one of five key principles within JIT. Flow refers to the principles related to how the process moves between operations. Lastly, Hay argues that the involvement of all personnel is an important part of JIT, which the other researchers do not. However, employee involvement is difficult to measure as it already is a significant part of Japanese working culture. When implementing JIT in the West, it is important create this engagement of personnel since it is not as self-evident.

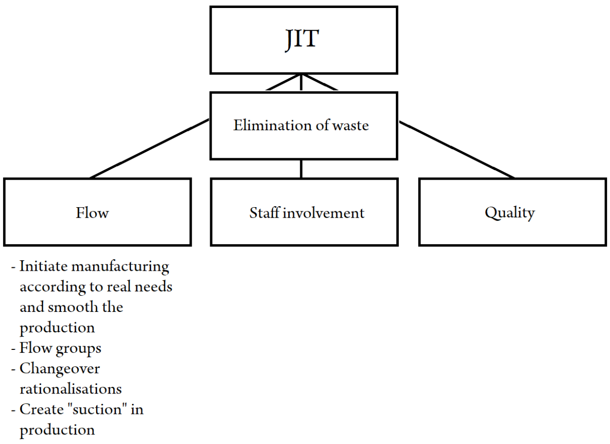

Figure 1.3. The JIT concept and its components, Hay [16].

Monden [17] have investigated the Toyota Production System, TPS and argues that the TPS is based upon JIT and Autonomation each with their own sub components, see Fig. 1.4. Autonomation stands for, according to Ståhl, systems that prevent the production of incorrect details [13]. Autonomation is, according to Monden, andon and machines that automatically stop a process when they detect a malfunction [17].

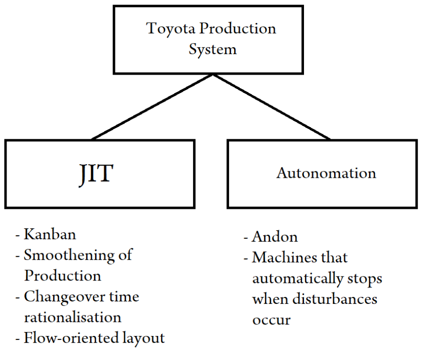

Figure 1.4. The Toyota Production system, Monden [17].

O'Grady [18] describes the JIT philosophy with 4 propositions:

- Tackle the primary issues
- Eliminate waste
- Seek simplicity
- Develop systems that detect problems

With the first point, O'Grady believes that one should address the primary problems and not the symptoms. The second point concerns the reduction of transport by arrangement of flow groups and by eliminating quality and control stations by transferring responsibility to the operator. The third point concerns striving to achieve simplicity through simple product flows and simple material and production control e.g. Kanban. The fourth point involves creating support systems for the abovementioned points so that problems can be detected and fixed [18]. In the West it is common to use buffers and thus "hide" problems [13].

The similarities between the four sets for researchers are that they all mention methods and techniques that are well used in the West today e.g. Kanban, QC-circles, see section Quality Control Circles. The difference between them is that they highlight the importance of the supporting systems to different extents. This might be explained by the fact that supporting systems was not seen as an important part of Lean before the 1990's. [13]

The fifth researcher that will be mentioned is Ericsson [19]. Ericsson's model of Lean highlights the links between the methods within Lean. Ericsson aims to distinguish three elements; philosophy & goals, methods and support systems. He also divides a company in to two sections; the managing section and the developing section, see Fig. 1.5.

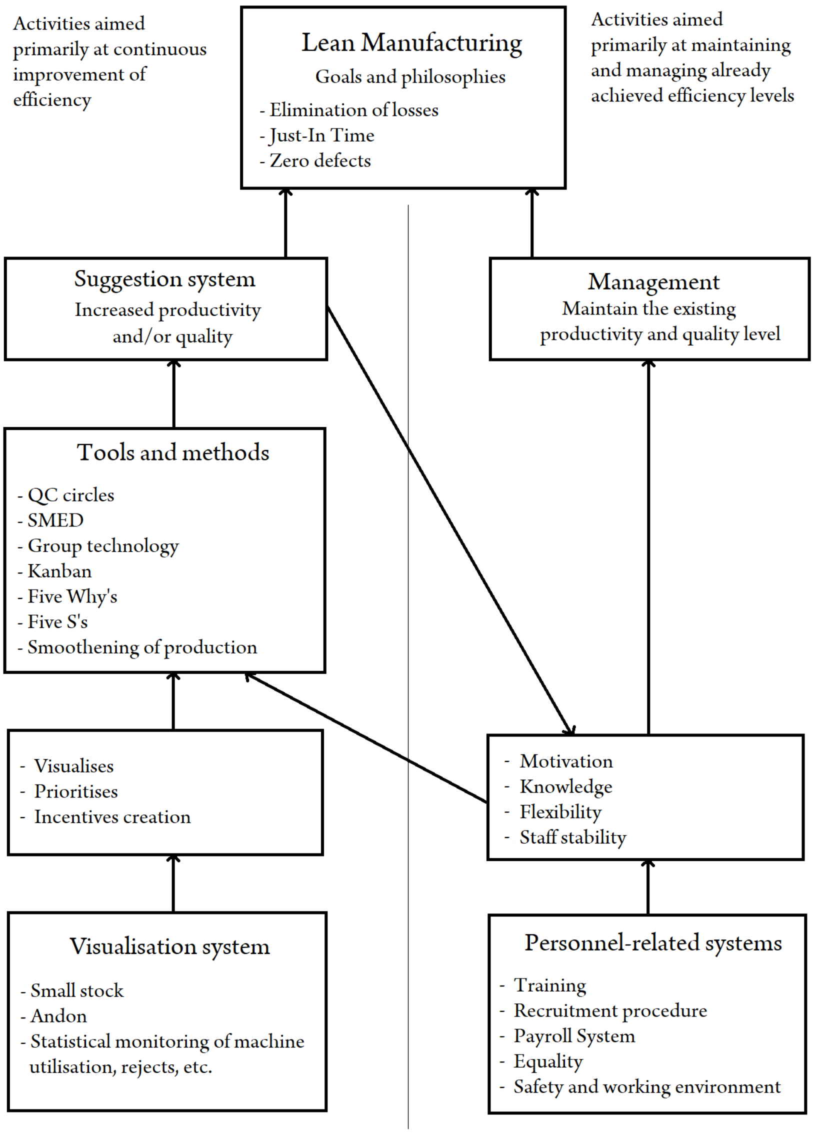

Figure 1.5. Ericsson's model of the dynamic interaction within Lean Manufacturing, Ericsson [19].

Ericsson's model displays the continuous improvements, see section "Kaizen", that occur because of the dynamic interaction between the two company sections.

By looking at these five sets of researchers it becomes evident that even a sub-concept of Lean, JIT, can be interpreted in many different ways. For this reason, one can never refer to a "true" Lean. Instead one has to accept that the meaning of the term may differ depending on the situation.

1.6 Japanese glossary

When talking about Lean and the Toyota Production System it might be of interest to know some related Japanese words. Black & Phillips highlights the following words [3].

Kaizen: The Japanese word for *improvement* and a central term within Lean.

Muda: A word meaning any human activity that occupy resources but doesn't create any real value.

Mura: The Japanese word for *unevenness*. Mainly used when talking about uneven flow in processes.

Muri: A term used to describe the act of overloading a segment in the process or carry out unreasonable amounts work.

Jidoka: A term describing *the decision to stop a process and immediately fix a problem when is occur rather than waiting to solve the problem later*. Jidoka is a central part within Lean.

Gemba: Refers to the part of a process where value is being added to a product.

改善の4つの目的があります。 より簡単に、より速く、より安く　これら4つの目標は、優先順位の順に記載されています。

There are four purposes of improvement; easier, better, faster and cheaper. These four goals appear in that order of priority.

Shigeo Shingo

2

Material and Method

THIS THESIS IS DESIGNED AS TWO LITERATURE STUDIES. In a literature study, the goal is to respond to the objective by looking at previous literature that have investigated the same subject. The objectives of the two literature studies is presented in "Objective", see section 1.1. The material that has been selected can be found in "Material", see section 2.3. This thesis also contains a practical study in which different Lean tools are applied at a real company. The practical study describes how different Lean tools and methods were implemented at the company.

2.1 Search strategy

The scientific articles used in this thesis have been found via LUBsearch, which is a database at the Lund University library. The requirement for the scientific articles is that they are relevant with regard to the keywords "Lean", "Lean Production", "Lean Small Companies", "Lean SMEs" and "Lean Young Companies". The articles should also be trustworthy. For this reason, scientifically reviewed, so-called "Peer Review", articles have been used as a selection criterion. Several of the selected articles are written for different audiences and have different angles on Lean and its uses. This helps to create a nuanced image of the subject and gives the thesis a broader width.

2.2 Selection criteria

When selecting material for the thesis the following selection criteria have been used.

- The material is directly related to business development.
- The material concerns Lean or any of its underlying concepts.
- The material should complement each other i.e. they do not investigate the same thing.
- Scientific articles should be reviewed according to Peer Review.

2.3 Material

The material for the first literature study, presented in chapter three "Results", consists of six scientific articles, two books and one lecture. The lecture was held by Lean Specialist David Nyberg at Lund University [2]. This thesis's most referenced books are *Industriella Tillverkningssystem* by Professor Jan-Eric Ståhl [9] and *Lean Engineering* by JT. Black and Don. T Phillips [20]. Jan-Eric Ståhl is a professor at Lund University, Sweden. JT. Black is a professor in industrial and systems engineering at Auburn University in Alabama, US. Don T. Phillips is a professor emeritus at Texas A & M University in Texas, US.

The material for the second literature study, presented in chapter four "Analysis", consists of eleven scientific articles. The used articles were mainly focused on aspects to consider when implementing Lean at small and young companies. To the extent possible the used articles were selected as to not investigate the exact same subject.

2.4 Source criticism

The articles used are all scientifically reviewed by experts in their area before publishing, so-called "Peer Review", which should guarantee a certain quality and objectivity. But even in scientific literature there may be wills or links to individual market participants. Thus, it cannot be excluded that there are underlying motives in the articles. Several companies try to claim that their version of Lean is the right one. This should be kept in mind when examining the material. The Lean philosophy has been developed and used by many companies and researchers. For this reason, there are several interpretations of the concept.

Although this dissertation attempts to create a breadth in the matter, it should be made clear that this thesis only provides a basic introduction to the subject.

私たちは、さまざまな先入観を毎日破壊することなく失敗する運命にあります
We are doomed to failure without a daily destruction of our various preconceptions.

Taiichi Ohno

3

Results

THERE ARE MANY REASONS TO IMPLEMENT LEAN. One reason might be to lower costs. Another reason to improve quality. A third to shorten delivery times [21]. A way of implementing Lean is to apply certain tools, methods and principles, preferably in combination with each other. In this chapter the results from the literary study are presented. Different Lean related principles, tools and methodologies are introduced and briefly explained. It is important to understand that Lean is a way of thinking rather than a set of tools. However, utilising the principles, tools and methods is a great way to adopt and comprehend the Lean philosophy [21].

3.1 Lean principles

This section presents several central principles within the Lean philosophy. Many of the principles originates from the Toyota Motor Corporation.

The Toyota Way

The Toyota Way is a list of ground rules used at Toyota Motor Company. The list in meant to inspire a certain mindset within all personnel at the company. Here follow the Toyota Way. [2]

Continuous improvements:

- Challenge – create a long-term vision and face challenges with courage and creativity.
- Kaizen – Improve the operations continuously to create innovation and development.
- Genshi Genbutsu – *Go and see*. Go to the source and find the facts to make informed and correct decisions. Develop after that consensus and fulfil the goal at fastest possible speed.

Respect your surroundings:

- Respect – Respect others. Do everything you can to understand each other, take responsibility and strive to create a mutual understanding.

- Teamwork – Stimulate personal and professional development, share possibilities for development and maximise the individuals' and the group's performance.

Toyota's 14 principles

The Toyota Motor Corporation has also established 14 principles. These 14 principles share a similar purpose as the Toyota Way and aims to inspire employees to think in a certain way. Here follow the 14 principles, divided into four sections. [2]

Philosophy:

1. Base decisions on long-term thinking, even if it has a negative impact on short-term goals.

Processes:

2. Create process flows that brings problems to the surface.
3. Let the demand govern, avoid overproduction.
4. Smoothen the workload.
5. Stop processes to solve problems to make sure that the quality is right from the beginning.
6. Standardised operations are the basis for continuous improvements and for personnel involvement.
7. Make operations transparent to make sure that no issues remain hidden.
8. Only use reliable, well proven techniques that fits the employees and the processes.

Co-workers and partners:

9. Develop leaders that truly knows the organisation, who lives by the Toyota philosophy and who teaches others to do so as well.
10. Develop outstanding persons and work teams that follows the philosophy of the company.
11. Respect partners and subcontractors by challenging them and helping them become better.

Problem solving:

12. Go and see with your own eyes to fully understand the situation.
13. Make decisions slow and with unity – execute them quickly.
14. Become a learning organisation through tireless and constant improvement.

Lean Leadership

A good leader, according to the Lean philosophy, carries certain traits and ways of working. According to Nyberg these traits can be summarised as follows [2].

A Lean leader:

- Goes to where it happens, see Gemba.
- Sees learning as part of his or her work.
- Do not look for a scapegoat.
- Avoids departmental thinking and prioritises the company as a whole.
- Encourages questioning.
- Uses facts as much as possible.
- Possesses great patience.

3.2 Lean tools and methods

Lean has a variety of underlying tools and methods that all contribute in reaching the positive effects of Lean. The tools and methods can be implemented into the organisation separately. However, the truly great positive effects of Lean occur when multiple tools support each other. Within western industries it sometimes happens that a company only incorporates one or two of the Lean tools. This usually results with the tools not having the positive effects promised by the Lean concept. [13]

Most of the Lean tools originates from the Toyota Production System. A company do not need to implement the entire TPS in order to reach Lean, a selection of tools can be enough to gain the positive effects. The tools are often simple to understand. The problem is knowing when to implement them and when not to [22]. In the following sections a wide variety of Lean tools and methods are presented.

Just-in-Time

Just-in-Time, JIT, is one of the most important components of Lean. JIT can in brief terms be described as *having the right thing, in the right amount, at the right location, at the right time*. In other words, JIT means that a company strives to deliver and receive everything at a precise time and thereby avoid building up stock. JIT decreases the storage cost and decreases the lead times so that the company can respond quicker to market demand [22]. JIT also reduces disturbances and variations in processes. The goal of JIT is to completely eliminate unnecessary stock. Stock often hides disturbances in the process e.g. a faulty component gets placed in stock with non-faulty components and is only later discovered. According to the JIT concept any problem should be dealt with immediately. Having no or low stock highlights problems in the processes. The problem can hence be addressed properly and without delay. This leads to gradually increasing quality and productivity.

Disturbances can according to Ståhl be divided into three categories; machine standstill, cassations and alteration of processing time [23]. Minimising stock helps locate where these disturbances occur in the process.

Shingo says that *We most judge stock as an absolute evil* [6]. In Japanese industry, inventory is by definition bad. This mindset has a clear connection to the JIT philosophy.

In order to implement JIT successfully some argue that certain circumstances must be present. Miller & Vollmann says that JIT can only occur when there is a stability in the production flow [24]. Oishi presses on the necessity of short set-up times, few breakdowns and low rejection rates [23].

From an economic standpoint JIT creates an increase in profitability, according to DuPont analysis, see Fig. 3.1.

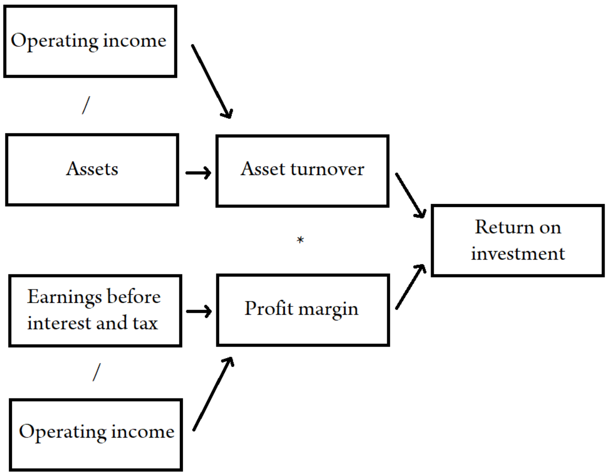

Figure 3.1. Graphical representation of DuPont analysis.

The increase in profitability is a result from the increased capital turnover, which in its turn is a result from the increased inventory turnover. Having increased inventory turnover is a direct effect of implementing JIT. JIT also increase the profit margin as costly losses and disturbances are reduced. Studies in Japan has showed that the profit margin tends to keep increasing as quality and productivity increases. However, increased inventory turnover has not proved to increase capital turnover in the same extent. An explanation might be that companies tend to substitute inventory capital for facility capital. [23]

JIT sometimes get discredited for being "sensitive to disturbances". This however is JITs biggest strength as it highlights hidden problems. [25]

Autonomation

Autonomation is a concept developed by Shigeo Shingo. The idea with autonomation is to create systems that detect production abnormalities and stops the process when they arise. Many of the systems are designed to simulate and automate human reasoning. Hence the word autonomation, automation with a human touch. [26]

According to Black & Phillips a truly autonomated system both detect *and* correct problems that it encounters. A system that handles both those tasks would however, in most cases, become very complex and expensive. [26]

Autonomation is in Japan synonymous with Jidoka; *the decision to stop a process and immediately fix a problem when is occur rather than waiting to solve the problem later.* The mindset of Jidoka is often the difference between a company that implements Lean successfully and a company that do not. [26]

Taiichi Ohno argued that JIT and Autonomation are the pillars which Lean is built on [8]. Black & Phillips extends Ohno's theory and they add that if JIT and Autonomation are the pillars upon which Lean is build, the foundation that the pillars rest on is the pursuit of *waste elimination* [26].

Kaizen

Kaizen stands for continuous improvements and is a collective name for small improvements in quality and productivity in a company's processes. Kaizen is an important part of Lean as striving to improve is central to the Lean mindset. Kaizen improvements are in general small and continuous and should not be confused with innovation. Innovations are larger technical improvements that often require large investments. The relationship between improvements and innovations with and without Kaizen is described by Imai, see Fig. 3.2 and Fig. 3.3. [22, 27]

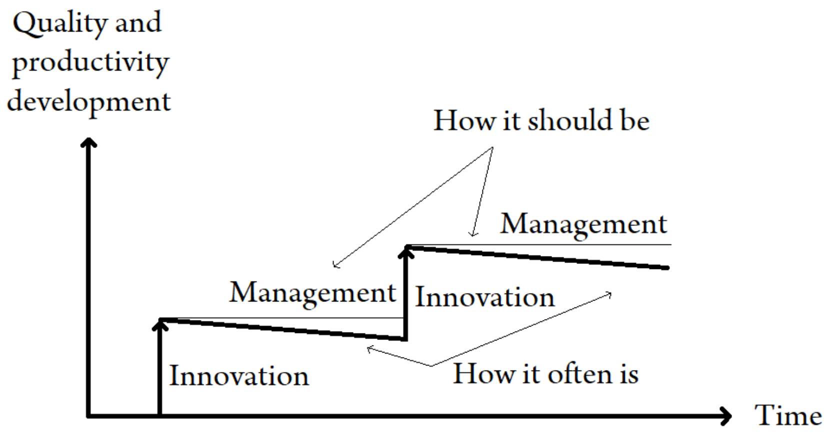

Figure 3.2. Improvement of quality and productivity without Kaizen, Imai [27].

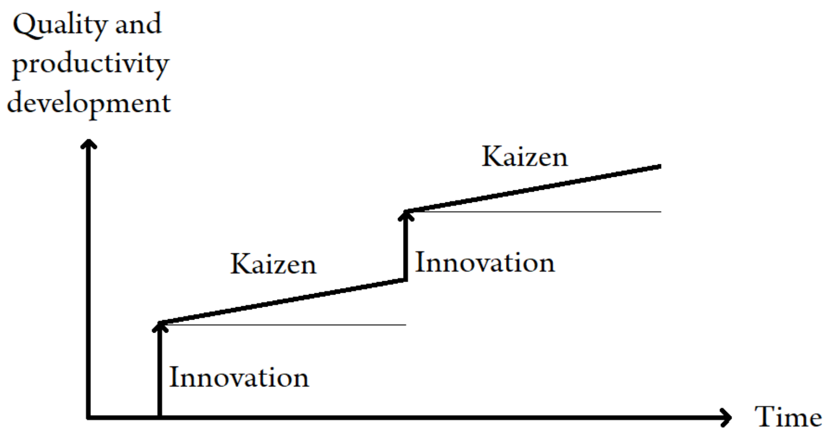

Figure 3.3. Improvement of quality and productivity with Kaizen, Imai [27].

Within Kaizen one might come across the expression Kaizen Event. A Kaizen Event is when a team of workers change and improve something in a selected process. A Kaizen Event where the improvement is introduced immediate and quick is called a Kaizen Blitz. [3]

Ståhl argues that continuous improvement only can be achieved if the development department and the managing department are part of the same organisation. [21]

Design for Manufacturing and Assembly

Design for Manufacturing and Assembly, DFMA, or sometimes divided into Design for Manufacturing, DFM, and Design for Assembly, DFA, is a method that helps minimise cost of manufacturing and assembly. The method aims to apply a cost minimising mindset when performing product development. The method consists of a couple of steps. The first step is to minimise the number of inbound components. The second step is to improve the assembly properties of the remaining components. Performing these steps should result in a decrease in the number of components and in a decrease in assembly and manufacturing costs. Applying DFMA should, to some extent, help create a more producible product. [22]

A problem in many industries today is that product developers at many times lack sufficient knowledge about manufacturing. This might be a result of the product developers often being separated from production. Using DFMA is an efficient way of bridging this gap. [22]

Quality Function Deployment

Quality Function Deployment, QFD, is a tool used to improve product development. When using QFD the product developers translate customer requirements into technical specifications. Stricter and well-adjusted specifications during product development lowers the need to make changes later in the processes. Lowering the amount of changes saves the company both money and time. Less changes also lowers the lead time which enables the company to serve the customer quicker. QFD brings a quality aspect into product development and is hence increasing efficiency. [22]

Failure Mode and Effects Analysis

Failure Mode and Effects Analysis, FMEA, is an analytical technique used to ensure that potential flaws in a process or product has been considered and addressed. To find the risk factors and their potential causes one performs a six-step impact assessment. Here follow the six steps. [3, 22]

1. Create a form that is divided into construction and process analysis.
2. Evaluate the product or process based on risk of error, effects of the error and possibilities for error detection.
3. Quantify the evaluation on a numbered scale.
4. Multiply the three values, high numbers indicate risk factors.
5. Develop measures of improvement.
6. Implement the measure and perform a new FMEA to assess the changes.

Kanban

A Kanban system consists of cards, so called Kanban-cards, that are sent backwards in a process to indicate when something needs to be produced. To exemplify, if Station C need a new part to perform an operation it sends a card backwards to Station B who then creates the part and sends it to Station C, see Fig. 3.4. [3]

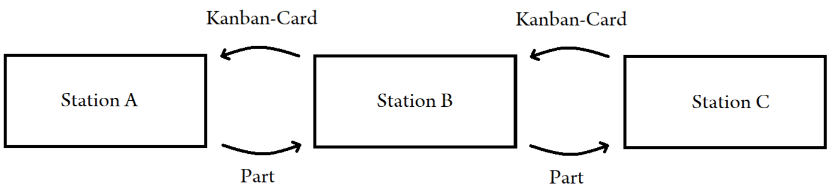

Figure 3.4. Visualised Kanban Process.

When the Kanban system consists of a multi-step chain the result is a pull-effect. The pull-effect is an important part of JIT and allows for controlled inventory management and production. [3, 22]

Taiichi Ohno came up with the idea when he visited a supermarket. At the supermarket the shelfs where continuously refilled as the customers collected their groceries and hence creating a "suction". [8]

Total Productive Maintenance

Total Productive Maintenance, TPM, is a systematic way of working that creates disturbance-free processes at low costs through the involvement of company personnel. To create disturbance-free and stable processes the company must reduce cassations, machine standstill and pace loss. If these three disturbance sources are reduced the company can liberate resources to work with process improvement instead of process repair. By doing so the company can increase its competitiveness. [22]

One way of creating stable processes is by improving overall equipment efficiency, OEE. This can be done by reducing the following six sources of loss. [22]

1. Equipment failure.
2. Changeovers, tool change and adjustments.
3. Idleness and small stops.
4. Pace losses.
5. Defects in the form of rejects and adjustments.
6. Rejects at start up.

Another important step within TPM is that operators get to know their equipment, learn to recognise errors and to correct these errors. With operator maintenance, the maintenance department can focus on specialist maintenance. [22]

The last part of TPM worth mentioning is that knowledge gained in one department should always be spread to other departments so that they can improve as well. [22]

Statistical follow-up on productivity and quality

Using statistics to follow-up on productivity and quality development is an important part of TPM. Statistics of e.g. machine standstill, quality index or productivity should be presented to all the concerned. Having reliable statistics almost always helps management to make informed decisions. Displaying statistics can also help employees understand how well a station is functioning and why certain decisions are being made. [22]

Suggestion systems

As part of Lean and working with continuous improvement, it is often of use to create a suggestion system. Using the suggestion system, employees can leave suggestions for improvements. At Toyota suggestions are reviewed once every month. The saving effect of the proposal indicates how much compensation that should be given to the suggestion creator. [17]

The Five S's

The Five S's refers to five Japanese words. These words aim to inspire employees to keep an efficient and organised workspace. The words are as follows. [3, 22, 28]

- Seiri, translates to *sorting out what is necessary and what is not*. Keep e.g. machines and documents that are not being used away.
- Seiton, *straightening and setting in order*. Keep order and mark where different things are to be stored so that they can be found easily when needed.
- Seison, *sweeping and shining*. Clean your own workplace.
- Seiketsu, *standardise*. Standardise the developed work process based on the three above points.
- Shitsuke, *sustaining*. Follow the rules at the company and sustain what has been achieved.

The Five Whys
The Five Whys is a method developed by Taiichi Ohno to avoid treating symptoms and instead treat the source of the symptoms. Ohno propose that one must always ask oneself *why* five times to know if the problem has been dealt with correctly. [8]

Zero Defects and Zero Inventory
Within the Lean philosophy there are a couple of goals that should always be sought to achieve. Two of those goals are zero defects and zero inventory. Zero defects aim at creating systems that does not produce any cassations. According to Black & Phillips this can be achieved in three ways. Using the Poka-Yoke method, correct quality problems at the source and using Pareto diagrams together with root-cause analysis. [3, 29]

The second goal, zero inventory, aims at having no excess stock anywhere in production. These two goals can never be fully achieved but should be seen as something to strive towards. [3]

Poka-Yoke
Poka-Yoke is a Japanese term meaning *mistake-proofing* or *defect prevention*. Poka-Yoke refers to designing a process in a way so that mistakes physically or procedurally cannot occur. A poka-Yoke solution can for example be a device that automatically stops a machine when it realises something is wrong. [3]

Pareto diagram
Pareto diagrams are used to structure different problems located in a company's processes. The diagram lists possible causes to a problem in a bar graph, the height of the bars represents how large a percentage can be attributed to the respective cause. Using pareto diagrams the company can identify which causes contributes the most to a problem in the process. An example with bearing failure can be seen in Fig. 3.5. [22, 2]

Figure 3.5. Pareto-diagram, Ståhl [22].

Ishikawa diagram

The ishikawa diagram, sometimes called fishbone-diagram, is a tool that helps visualise how different events result in a problem occurring. The diagram uses different lines to derive different events. Using the ishikawa diagram the company can identify the causes that contributes in creating a problem. An example with a lecture can be seen in Fig. 3.6. [2, 22]

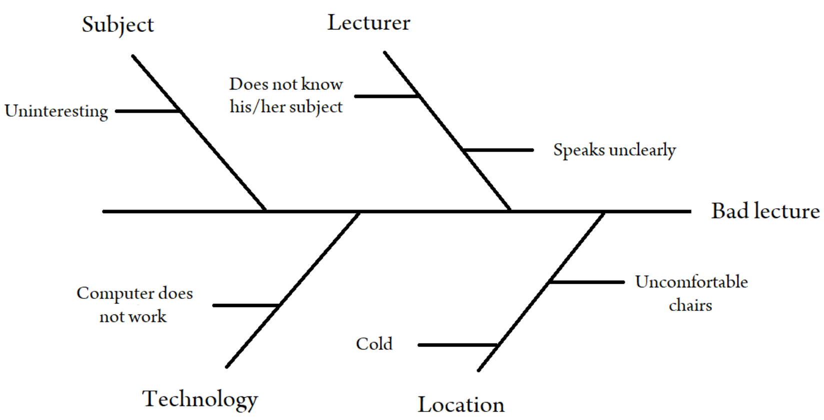

Figure 3.6. Ishikawa diagram, Nyberg [2].

Knowing the causes to a problem, the company can start to create a suited solution. A frequently used Ishikawa diagram is the 7M diagram, see Fig. 3.7. [2]

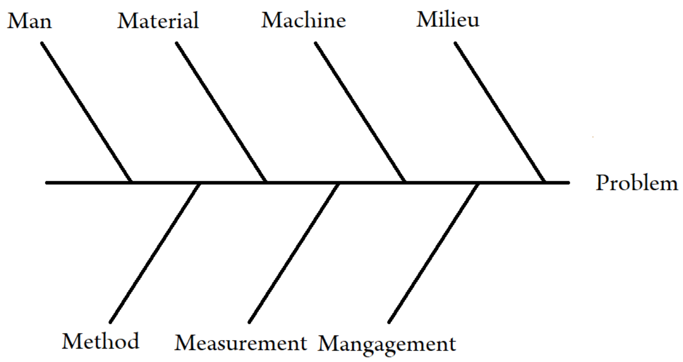

Figure 3.7. 7M diagram, Nyberg [2].

Root Cause Analysis

Root Cause Analysis, RCA, is a method used to eliminate recurring problems. When performing an RCA, one looks for the underlying cause to the problem. Only after the root cause is identified is the curative action developed and implemented. [3]

Statistical Process Control

Statistical Process Control, SPC, or Statistical Quality Control, SPQ, are tools that helps control variations in selected parameters. The parameters are plotted against time. Alarm limits detects trend deviations in the parameter variations, see Fig. 3.8. [22]

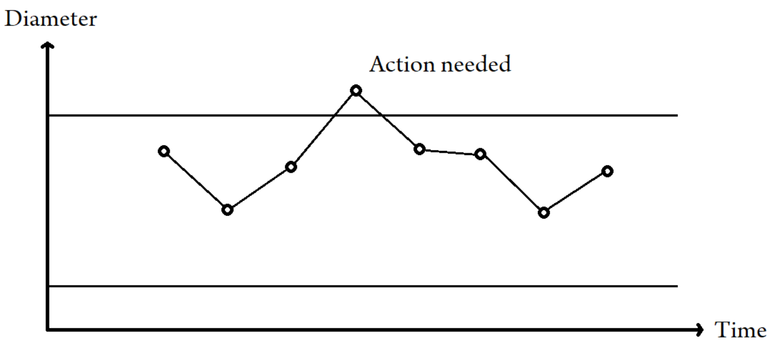

Figure 3.8. Results from SPC in a diagram, Ståhl [22].

Ishikawa and Pareto diagrams can be used to figure out which parameters to use. SPC has a wider applicability than controlling processes or quality and can be useful in several other situations. [22]

Quality Control Circles

Quality Control circles, QC-circles, is a concept where five to twelve persons meet in a group and solve different problems within productivity, quality, security or work environment. The members of the group alter depending on what problem should be solved. If the problem is related to a specific process, then only employees working with that process should be assigned to the QC-circle. The QC-circle members should preferably only solve problems related to the process that they themselves are working with. The members may use other Lean tools to solve the different problems. [22]

Total Quality Control

Total Quality Control, TQC, also called Integrated Quality Control, IQC, is a concept where everyone in the entire organisation has a comprehensive understanding of quality control, its methods, benefits and prospects. TQC share many similarities with JIT, SPC and QC-circles. TQC eliminates quality problems which leads to reduced need for buffers. Buffer reduction in its turn enables JIT. [3, 22]

Group technology

Group technology is a methodology where one looks for refining processes for different components that share similarities in terms of execution. Refining processes that are similar gets grouped into families and placed close to each other. This way similar processes are performed similar and at a joint location. By using group technology thinking one can increase efficiency significantly. [22]

Single Minute Exchange of Die

Single Minute Exchange of Die, SMED, is a concept developed by Shiego Shingo. The name SMED originates from the idea that changeover of manufacturing equipment must be completed in less than ten minutes, i.e. a one-digit number of minutes. The goal of the concept is to convert internal changeover time to external changeover time and by doing so lower the overall time of a changeover. Internal changeover time refers to the time of an interventions being made whilst the process is at a standstill. External changeover time refers to the time of an intervention being made whilst the process is running. [22]

Andon

Andon refers to information boards that are displaying the current status of the company e.g. production parameters. The boards usually show machines at standstills, broken machines or/and production statistics. The information is often displayed with both colour and sound signals and should be visible to all the concerned. The boards can also be used to assist operators, as an operator can call upon attention via the board when a problem occur. [22, 30]

Small stock

Striving to always lower the stock is an important part of JIT and Lean. Processes often contain sources of disturbances that buffers hide. Reduction of buffers highlights costly disturbances and without extra storage the problems become more urgent to address. Ohno said that employees should *feel the pinch* and immediately start working on a solution to the problem [8]. Continuously fixing problems increases the overall productivity and improves the quality of the products. Ståhl argues that small stock creates a short-term weakness but a long-term strength as manufacturing becomes more refined. [22]

One-Piece Flow

One-Piece Flow, OPF, is a production method that aims to transfer one component at a time smoothly through the production line without stopping in storages in-between. Using OPF systems the company can decrease lead time, increase productivity, improve quality and reduce cost. An OPF system is visualised in Fig. 3.9. [2, 3]

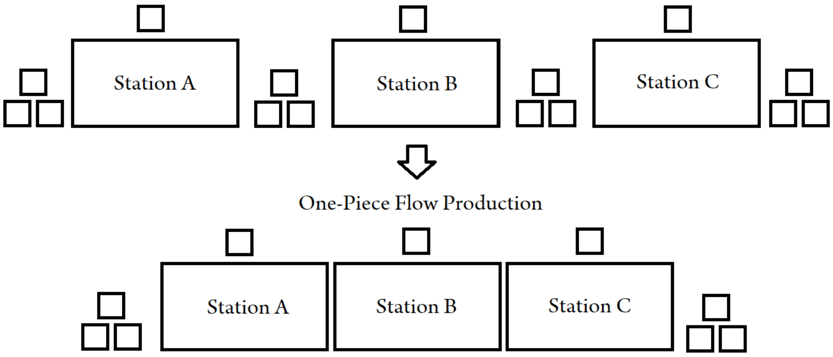

Figure 3.9. Converting to a One-Piece Flow system, Nyberg [2].

Value Stream Mapping

Value Stream Mapping, VSM, is a method used to map the flow of material and data. VSM can be performed on any process within a company. The goal with VSM is to find non-value adding activities and *muda* between processes. The improvement opportunities that comes with VSM are often great, however, executing a VSM often require extensive resources. Occasionally performing VSM usually eases planning in the long-run. [2, 3]

Key Performance Indicator

Key Performance Indicator, KPI, is a value that reflect the current status of a company. KPIs are e.g. days without an accident, internal rejects/reworks, on-time delivery or produced units per operator. KPIs are an important tool for analysing progress made within a company and a frequently used tool within Lean. [2]

The Seven Wastes

According to Taiichi Ohno there are seven wastes that every Lean system should be looking to eliminate. The seven wastes are as follows. [2, 3, 8]

1. Overproduction.
2. Idle time.
3. Transports.
4. Excess processing.
5. Excess inventory.
6. Wasted motion.
7. Poor quality.

Gemba Walk

A Gemba Walk is a concept in which one investigates a process to find *muda* or other improvement opportunities. Where it is possible, improvements are made and, in the end, hopefully the only thing left is value adding activities, *gemba*. [3]

MO-CO-MOO

Make One – Check One – Move One On, MO-CO-MOO, is a way of controlling the quality of produced parts. The idea is to inspect a product after each step of the manufacturing process. After an approved inspection the part is moved forward to the next step in the process. MO-CO-MOO is a way of improving quality, finding problems and ensuring that a product is functional. [3]

Decouplers

A decoupler is an intermediate step between two manufacturing stations or machines. A decoupler can be a transportation section or an inspection station. Using decouplers is an important step in the introduction of MO-CO-MOO capability. [3]

Make-to-Final Inventory

In context to the JIT concept, it might sometimes be of use to store finished products before sending them to the customer, even though it goes against the goal of zero inventory. Storing finished before send-off is within Lean called Make-to-Final Inventory. Make-to-Final Inventory is a way of satisfying on-time customer delivery. [3]

Process sheet

A process sheet is a set of instructions used within manufacturing. The instructions are often specified to a specific batch, lot or run and are usually describing operation parameters, settings for equipment and any associated tools or supplies. [3]

3.3 Other tools

In this section, three additional tools are briefly described. The tools share similarities with Lean but do not derive directly from the Lean philosophy. The three tools can easily be implemented alongside the other tools within Lean.

Six Sigma

Six Sigma is a program using statistical analysis to reduce variations within production. The concept was developed at Motorola in 1987 and is today frequently used at companies all over the world. The name Six Sigma originates from a statistical model where a maximum of 3 or 4 errors can occur in a million possibilities of error within the limits of ±6 standard deviations. The model is illustrated in Fig. 3.10. [31]

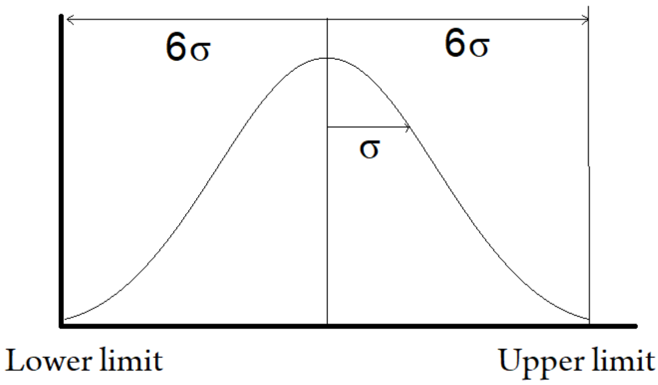

Figure 3.10. The statistical model behind Six Sigma, Ståhl [31].

The model is a goal to strive towards in order to reduce issues caused by variation. Working with process control enables the possibility of finding ideal process data and thereby improve machining time, minimise standstill and improve quality. [31]

In Six Sigma it is not uncommon to use the method DMAIC to improve the processes. DMAIC stands for Define, Measure, Analyse, Improve, Control. [29, 31]

Ståhl argues that Six Sigma initiatives often are top-down controlled with Six Sigma experts coming in and investigating selected processes. For this reason, Six Sigma is not well suited for companies with a flat organisational structure. [31]

Production Security Matrix

The production security matrix, PSM, is a tool used to identify areas where improvements can be made. The PSM registers production hold-ups and categorises the different causes and the time each hold-up required. After enough data has been gathered the PSM reveals which problems in the process that are causing the longest total hold-up times. Using that information, the company can decide on their next improvement project. The basic structure of the PSM is illustrated in Fig. 3.11. [32]

	Result parameters				
Factor groups	Quality parameters Q	Standstill parameters S	Pace parameters P	Environment parameters M	Σ Factors
A. Tools					
B. Working material					
C. Process					
D. Personal and Org.					
E. Wear and maintenece					
F. Special factors					
G. Peripheral					
H. Unknown factors					
Σ Result parameters					

Figure 3.11. The Production Security Matrix basic structure, Ståhl [32].

Model for manufacturing economics

The final tools that should be mentioned is Ståhl's economic model for manufacturing cost. The model contains most of the key numbers within manufacturing economics and displays how they all affect the total cost of producing a component, see Eq. 3.1. [33]

$$
\begin{aligned}
k_i = {} & \frac{k_A}{N_0}\left[\frac{1}{n_{pA}}\right]_a + \frac{k_B}{N_0}\left[\frac{N_0}{(1-q_{Qi})(1-q_B)}\right]_b + \frac{\kappa_C \cdot k_{CP}}{60N_0}\left[\frac{x_{pi}t_{0i}N_0}{1-q_{Qi}}\right]_{c1} + \\
& \frac{\kappa_C \cdot k_{CS}}{60N_0}\left[\frac{x_{pi}t_{0i}N_0}{1-q_{Qi}} \cdot \frac{q_{Si}}{1-q_{Si}} + x_{sui}T_{sui} + \frac{1-U_{RB}}{U_{RB}}T_{Pb}\right]_{c2} + \\
& \frac{k_D}{60N_0}\left[\frac{x_{pi}t_{0i}N_0}{1-q_{Qi}} \cdot \left(1+\frac{q_{Si}}{1-q_{Si}}\right) + x_{sui}T_{sui} + \frac{1-U_{RB}}{U_{RB}}T_{Pb}\right]_d + \\
& \frac{1}{N_0}(K_{AUH}+K_{CUH}+K_{GUH})_e + \frac{1}{N_0}(K_{HL})_g + \frac{1}{N_0}(K_{Tno})_h
\end{aligned}
\qquad \text{Equation 3.1.}
$$

The previously mentioned Lean tools or methods often has a clear connection to the different economic key numbers found in the model e.g. SMED to the changeover time T_{sui}. Using the model makes it easy to follow-up on changes made to the system or to simulate the possible effect of a proposed change. [33]

Continuous improvement is better than delayed perfection.

Mark Twain

4

Analysis

IMPLEMENTING LEAN AT A COMPANY IS NEVER EASY and there are many risks to consider before applying the concept. This chapter investigates how Lean can be implemented at small and young companies in general and at a young company in Sweden in particular. Evaluations of the tools, methods and principles proposed in the results chapter are made, both by me and by the heads of the investigated Swedish company. A thorough analysis of how Lean can be, and has been, implemented by other researchers is also made. From the conclusions, drawn from the evaluations and the previous research, a plan to implement Lean at the investigated company is formulated. Lastly, the plan is applied at the company and the results of the practical Lean implementation are discussed.

4.1 The Company

This thesis investigates a small company founded in February of 2017. Due to confidentiality reasons the company in question is referred to as the Company. The Company is located in Sweden and produces electronics-heavy extreme sports devices. The Company has about 20 employees and was during the time of this thesis project in the stage of launching its first product. The Company had no previous established management philosophy and was keen on implementing the Lean concept.

The Company can be divided into four major departments; mechanics, electronics, production and operations. Each department has their own way of working and therefore some of the Lean tools, methods and principles are only implemented at some of the departments. Other tools are implemented across the entire company and some tools are not be applied at all. Which tools that were applied at the Company and which were not is presented sections 4.4 and 4.5.

4.2 Previous research on Lean implementation

The Lean philosophy is usually implemented at large companies with plenty of resources. However, implementing the concept at a small and young company is not as common. This section investigates how others have implemented the Lean philosophy.

Lean implementations at small and medium sized enterprises

Small and medium sized enterprises, SMEs, is defined by the European Commission as a company that has less than 250 employees. Small companies have between 10 to 49 persons employed and medium sized companies have between 50 to 249 employees. SMEs make up 99,8% of all enterprises within in the EU27 and 65% of all employees in the EU27 work at SMEs [34]. Despite this, there is not an abundance of research on Lean implementation at SMEs.

Matt & Rauch [34] say that the SMEs are identifying the ever-increasing competitive pressure and are altering their operations as a proactive way of coping. Matt & Rauch argue that this willingness to change and improve processes is a good starting point for Lean implementation. They continue and says that smaller organisations are usually more flexible than their larger counterpart and that small enterprises are generally more adaptive and innovative both in terms of their products and in terms of their production. This speaks in the SMEs favour according to Matt & Rauch. Matt & Rauch also say that smaller companies are ordinarily less bound by tradition, have less bureaucracy and shorter communication lines. For this reason, implementing something new at a small company usually goes faster than at a larger company. Lastly, Matt & Rauch argue that the often-occurring informal nature of smaller businesses is something that should make a Lean implementation easier.

However, many researchers argue that Lean implementation at smaller companies often harbour significant difficulties. [34] These difficulties are further discussed in the next section.

Barriers upon Lean implementation

SMEs that try to implement Lean often encounters barriers that hinder a successful implementation. This section discusses barriers that have been encountered in previous research on Lean implementation at SMEs.

Matt & Rauch [34] carried out a study to analyse Lean implementations at small companies. They conducted ten interviews and came to the following conclusions:

- In many of the companies the Lean tools, methods and principles were not well known.
- The companies often tried to make production efficiency gains by using larger lot sizes, instead of using e.g. production setup time optimisation.
- Lean thinking i.e. a waste minimising mind-set, is often only used within production and not spread throughout the companies.
- The companies seldom initiate Lean implementation on their own initiative.
- There is often a lack of knowledge within management.
- It is often hard for small companies to find qualified personnel.

Xu et al. [35] argues that large companies can provide the required resources and experts' know-how to successfully and fully implement Lean. SMEs often lack these resources. Xu et al. does however argue that SMEs can learn from successful Lean implementations at large multinational companies, MNCs.

For this reason, they conducted a survey in Singapore at eight MNCs to find common denominators for successful Lean implementation, which could hopefully be applied at local SMEs. They interviewed key stakeholders and investigated the MNCs' operations. They found the following most common success factors:

- Commitment from top management.
- A Lean implementation program that aligned with the MNCs long-term goals and vision.
- Visual communication of progress achieved by Lean.
- Well defined and closely monitored KPIs.

Xu et al. took the knowledge they gained at the MNCs and used it when implementing Lean at four local SMEs. From the Lean implementation at the SMEs they learned that the SMEs often faced similar challenges as the MNCs. They listen the most common challenges faced by the SMEs. The challenges were as follows, most common first: [35]

1. Lack of will to change culture.
2. Lack of manpower.
3. Failing to find an appropriate approach to Lean.
4. Lack of Lean concepts.
5. Lack of management support.
6. No discernibility of Lean benefits.

Xu et al. also noticed that most of the SMEs did not establish operational KPIs. This made it very hard to measure and visualise the outcome of the Lean implementation. This in its turn discouraged the development of a Lean culture at the SMEs. [35]

Berlec et al. [36] investigated 20 research papers on barriers that may hinder Lean implementation. They tried to find common themes within the publications and to some extent conclude what usually creates problems in the process of implementing Lean. One of the researchers that they investigated presented four key factors that are critical for successful implementations of Lean at SMEs:

- Management and leadership.
- Finance.
- Skills and expertise.
- Company culture.

According to that researcher all the above-mentioned points are vital to address to successfully implement Lean. A second researcher presented four major reasons to why companies fail to implement Lean. The four reasons are: [36]

- Management is not committed to or does not understand Lean.
- Management does not understand that culture change is needed to make the implementation successful.

- The company do not have the right people in the right positions.
- The Lean philosophy might not be the right fit for the company.

A third researcher argued that successful Lean implementation depends on a nation's culture as well as on the company's culture. [36]

Having summarised their investigation, Berlec et al. conclude that management support is outstanding as the most critical success factor in Lean implementations. 55 % of the examined papers mentioned the importance of management commitment and support. As of this, Berlec et al. argue that when a company and all its employees are about to go through substantial organisational change it is important to have the proper human resources, especially within management. They argue that it is important to detect and address unsupportive management as soon as possible. They also say that having a successful pilot project eases the Lean implementation as the employees can see the benefits of Lean with their own eyes. Lastly, they argue that it is important not to keep employees in the dark and to inform them of the Lean goals they are expected to achieve. In this way the company can adapt to the new Lean culture faster. [36]

Belhadi et al. [37] argues that SMEs have a hard time coping with many barriers at the same time. To avoid having to tackle all the barriers at once, they decided to rank the different barriers based on their urgency to be overcome. In this way the company can address the barriers in a stepwise manner.

Belhadi et al. investigated 14 research papers and found 20 barriers that can occur when Lean is being implemented. They also interviewed a Lean expert about frequently occurring barriers. They placed the discovered barriers into five key categories. All the barriers and how often they were mentioned in the publications can be seen in Tab. 4.1. on the next page. [37]

Table 4.1. Barriers of Lean implementation and how often the barriers are mentioned in scientific publications, Belhadi et al. [37].

Ref.	Categories/failure factors	Sources (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(a)
SB	*Strategic barriers*															
SB1	Lack of management involvement			X	X	X		X	X		X	X	X	X	X	
SB2	Unclear objectives		X		X				X			X				X
SB3	Short-term vision	X		X		X			X	X		X	X	X		
SB4	Poor decision-making process									X						
TB	*Technical barriers*															
TB1	Insufficient information system								X				X		X	
TB2	Lack of time and financial resources	X		X	X	X		X	X		X			X	X	
TB3	Poor facilities and layout configuration						X									
TB4	Lack of understanding of process	X				X		X					X	X		
CB	*Cultural barriers*															
CB1	Lack of skilled resources	X					X							X	X	
CB2	Fear and resistance to change	X			X	X		X			X	X	X		X	
CB3	Lack of formal training for workers			X	X			X	X		X	X	X		X	
CB4	Lack of empowerment of employees		X	X		X		X	X	X		X	X		X	X
MB	*Market-related barriers*															
MB1	Instability in production schedule		X				X	X								X
MB2	Lack of influence over suppliers						X			X			X			
MB3	Product variety		X					X			X					X
MB4	Lack of external support from government, suppliers, customers, and outside consultants									X						
KB	*Knowledge-related barriers*															
KB1	Lack of adapted methodology of lean implementation											X				
KB2	Use of wrong tools and methods									X		X				
KB3	Lack of understanding of lean								X				X			
KB4	Lack of an adapted measurement system		X	X		X							X		X	X

Note: [a]Factors identified from the discussions with lean experts

After the barriers were established Belhadi et al. looked for solutions to the barriers. They performed a literature review and found 17 sets of solutions to the barriers. Using the TOPSIS method, Belhadi et al. ranked the different barriers and the different solutions. The five barriers that are most important to prioritise were as follows, most important first: [37]

1. Lacking management involvement; Belhadi et al. argues that the fact that this barrier is the highest rated is fully justified as it leads to many other problems. Problems such as lack of resources, dysfunctional top-down or down-top communication and perhaps even absence of employee commitment.

2. Failure to adapt a Lean implementation methodology; Belhadi et al. say that many SMEs try to use the same implementation frameworks as their larger counterparts. This often results with the SMEs struggling, as they do not have the same prerequisites. Eventually the SMEs might even give up on Lean entirely. For this reason, Belhadi et al. argue that Lean implementation programs need to be modified to fit the SMEs' needs and characteristics.

3. Short-term vision; Belhadi et al. say that at many times SME managers want to see quick results. This often leads to an insufficient long-term vision. Only having short-term goals is therefore a significant barrier for Lean implementation as it promotes poor decision-making.

4. Fear and resistance to change; Belhadi et al. say that the employees at SMEs sometimes opposes changes. The employees might for example fear that the cost saving aspect of Lean may jeopardise their jobs. Belhadi et al. argue that managers and owners of SMEs are, in contrast to larger corporations, more worried about the risk that comes with changing their operations. For this reason, many Lean implementation projects fail as the employees and managers are not willing to change their mind-set.

5. Lack of Lean understanding; according to Belhadi et al. the Lean philosophy is not always interpreted correctly by SMEs. This can be a barrier for successful implementation. Belhadi et al. say that not understanding Lean correctly can for example lead to misapplication of Lean tools and other poor decisions.

The five most important solutions to the barriers ranked by Belhadi et al. were as follow: [37]

1. Commitment and participation of management; the highest ranked solution. Belhadi et al. say that for Lean to be implemented successfully the SMEs' managers should display clear and decisive leadership. The managers should participate in and monitor ongoing implementation projects as well as develop good connections with the employees so that they get the right training, resources and communication tools to implement Lean successfully.

2. Finding simple measurement and KPIs; according the Belhadi et al. measurements is vital for any company trying to implement Lean. SMEs usually have limited resources and can therefore not monitor a large amount of complex KPIs. For this reason, Belhadi et al. argue that it is important to find simple indicators that can help the company follow-up on, and review, achieved improvements.

3. Develop a learning culture; Belhadi et al. say that SMEs should strive to promote understanding of Lean thinking and its tools. Doing this, instead of mimicking methods used by other organisations, creates an organisational learning culture, according to Belhadi et al.

4. Early development of Lean culture; developing a Lean culture early is important argue Belhadi et al. This can e.g. be achieved through training of employees by a Lean expert.

5. Provide time and resources for change; for Lean to be implemented successfully both time and resources need to be provided according to Belhadi et al. The SME needs to have patients and stay true to its long-term vision. Belhadi et al. argue that it does not need to be a massive investment, but the required resources should be dedicated and made available.

Proposed implementation methodologies

Lean implementation can be done in many ways. This section focuses on two methods for implementing the concept at SMEs. They two methods presented in this section mainly serve as inspiration for the practical Lean implementation plan developed for the Company.

The first methodology is presented by Amine et al. [38]. Previous frameworks for Lean implementation has, for the most part, been adapted to large companies and for this reason Amine et al. decided to create a framework suited for SMEs. They performed several case studies and developed a new framework tailored to SMEs. The new framework that they developed consists of three phases; a pre-implementation phase, an implementation phase and a post-implementation phase. Each phase in their framework is presented in detail below: [38]

Pre-implementation phase: First, management need to commit to the implementation project and begin establishing objectives and goals. The goals and objectives should be aligning with the strategic policy and long-term vision of the company. Management should after that establish a "Lean team". The Lean team do not need to consist of many individuals but should be a multifunctional team. After the Lean team has been selected, the team should be trained. The training should preferably be conducted by a Lean expert consultant. Having the team trained is a good first step in establishing a Lean culture. After the Team has been educated, its first task should be to determine perimeters of action by identifying the highest prioritised value stream. After the perimeters have been established, the team should develop a plan to implement Lean. The plan should include a schedule and a budget. The final step in the pre-implementation phase is to measure the current situation at the company using Lean indicators, KPIs. The team should define the performance indicators based on the objectives and goals set at the beginning. After the indicators have been defined, a first measurement of the indicators should be executed so that the current performance of the company can be assessed. [38]

Implementation phase: The implementation phase emphases on improvement in all levels of the company. The implementation phase starts with a warm-up step in which the appointed Lean team updates the workforce and workstations to enable the application of Lean. The Lean team should train other employees in Lean practices and tools. This so that the workforce becomes acquainted with Lean. Training the employees also prepares the employees for change. After the employee training, the team should begin to implement Lean tools. The first effective practice is a Five S's program. The Five S's is certified by several researchers as easy to implement and low in resources consumption. After the Five S's program has been implemented a cultural change at the company should start to make itself visible. The next step is to map and analyse current process statuses. This is done to identify where improvement can be made and where performance can be increased as most. Once the areas of improvement are identified it is time to implement Lean tools. The tools should be implemented in the form of pilot projects. Involvement of employees is recommended for a successful implementation of Lean. [38]

Post-implementation phase: The final phase aims to finalise the implementation project and to confirm that continuous improvement will follow. The company should measure the progress through follow-up on previously identified KPIs. After goals and objectives have been achieved, the optimal way to complete the tasks should be registered, standardised and shared. Capitalising and standardising previously achieved goals is very important as it locks gains made in the implementation phase. When this is done the team should repeat the process and start selecting perimeters for a new project. [38]

The framework presented by Amine et al. can be seen illustrated in Fig. 4.1. [38]

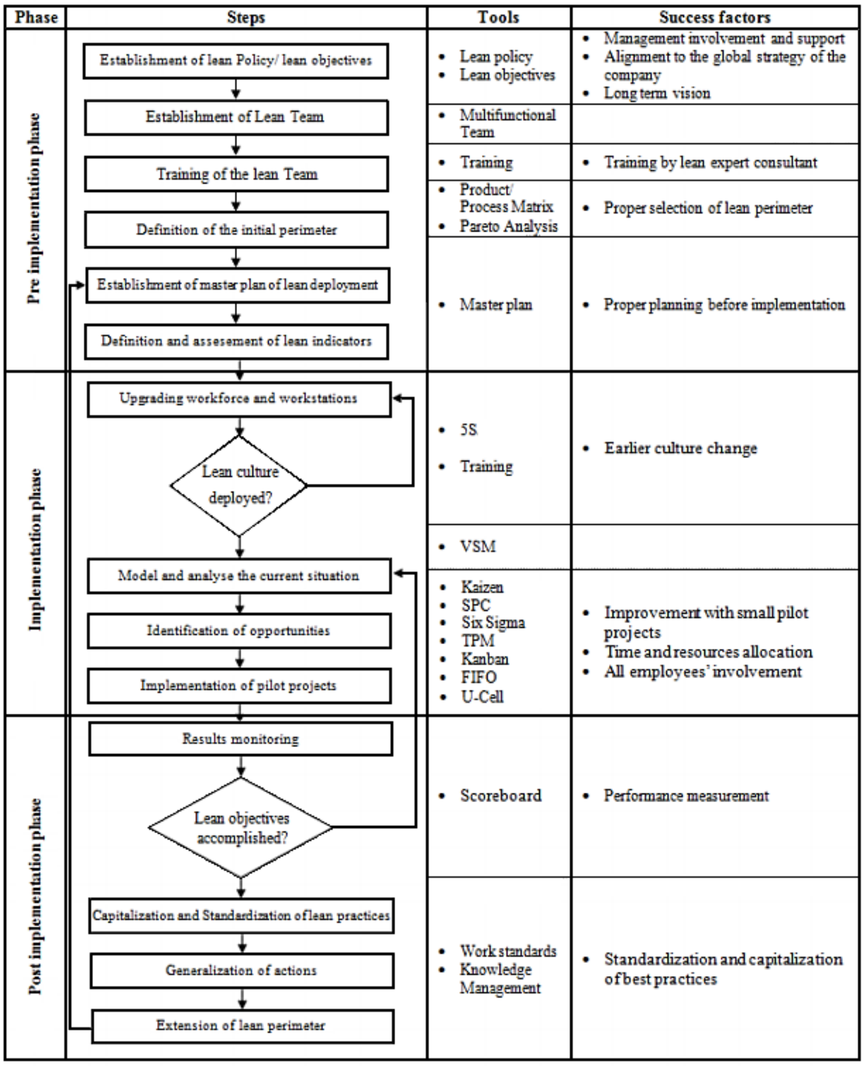

Figure 4.1. Framework for implementing Lean at SMEs, Amine et al. [38].

The second method for implementing Lean that will be presented was designed by Azharul & Kazi [39]. Azharul & Kazi underline the importance of having a performance measurement system. Such a system helps a company to collect the information necessary for proper decision-making and to follow-up on previously implemented changes.

Azharuls' & Kazi's Lean implementation methodology consists of six steps. The six steps are as follows: [39]

1. Process and production details; the company implementing Lean should first of all define and measure Lean related values. This so that they can assess the current situation and so that they

can see the effects of the applied changes later. Some of the values the company should measure are production type, order volume, demand quantity, product types, product quantity, variety and profit margin.

2. Lean team; the company should establish a Lean culture through the composition of a Lean team. The team should undergo training about Lean and its underlying tools, principles and methods. The team should preferably consist of experts and management personnel. The team should have the goal to organise personnel and resources so that Lean can be implemented.

3. Performance variables; the Lean team should further assess and measure performance variables. The variables can be both financial and non-financial but should in some way make it possible to evaluate company performance.

4. Mapping the current process; the company's processes should be investigated using VSM. This to identify all non-value adding, NVA, activities.

5. Measurement of performance; after the processes has been mapped they should be measured. This can be done through measurement of e.g. productivity, efficiency and defect rate. Measuring performance both before and after Lean implementation is an important part of this methodology.

6. New process design; the final step is to create a new and improved process via application of Lean tools and techniques. This should be done with the main objective to minimise waste. The selected Lean tools should not create new NVA activities. The tools should also be suited for the company and for the budget.

Lean Start-up

As the Company itself is a start-up company it might be of interest to discuss a concept called Lean Start-up. The concept is not directly derived from Lean but share a close resemblance to QFD. The Lean Start-up was developed by Eric Ries [40] and aims to reduce risks when starting a new company. The concept revolves around replacing the entrepreneur's intuition with customer feedback, and in doing so decrease the risk of failure when launching a new product. The term Lean Start-up is derived from Lean as the concept too aims to eliminate waste and NVA efforts. The waste within Lean Start-up refers to product features that are not wanted by the customers. Eliminating these features makes the product more likely to sell and the start-up less likely to fail. [41]

Girgenti et al., who have investigated Ries Lean Start-up, argue that the traditional way of starting a new company usually begins with the entrepreneur drafting a business plan. The business plan often contains long-term estimation for future demand, cash flow, incomes and profit. If the business plan attracts enough attention, an investor might agree to fund the idea. The funding is used to develop the product, paying both for the man hours and for the resources needed. Only after the product is fully developed is it presented to the customer. Not once during the development process are customers asked to provide feedback on the product. This makes the entire project very risky as most of the budget has been spent on developing a product with no certainty of selling. This risky and old way of starting a business might, according to Girgenti et al., be the reason that 75% of all new ventures in the US never return the investment. [42]

The Lean Start-up approach sees the business plan as a list of hypotheses rather than a long-term forecast. Girgenti et al. say that the Lean Start-up approach can be divided into three steps: [42]

1. Idea generation; create a business canvas with all the aspects of the business plan. The canvas should contain hypotheses about the product, customers, suppliers, key factors and general costs.

2. Proposed idea; build a minimum viable product, MVP, and introduce it to the customers. The MVP is used to validate the progress of the project.

3. Pivoting; correct the design and test new hypotheses based on the feedback from the customers.

Girgenti et al. lastly say that performing the Lean Start-up method enables a company to create a product that is more likely to sell and in doing so minimise the risk of failure. A company should strive to first make a perfected product and only after that expand their production. [42]

Soft Lean

Holmemo et al. [43] argue that in Scandinavia, Lean is often used in a soft way, where employee involvement is favoured over tools and methods. Softer aspects such as participation, learning and leadership has become the predominant part of the concept. They say that implementing these softer aspects is not as straight forward as implementing tools and techniques. A lot depends on the personnel and their willingness to change. For this reason, implementation of soft Lean requires that the implementation methodology is tailored to each company. Holmemo et al. say that there are some noticeable differences between soft Lean and more traditional so-called hard Lean. The differences can be seen in Fig. 4.2. [43]

Hard	Soft
- Technical, tool-based	- Value systems, philosophy
- Prescriptive: one best way	- Adaptive
- Focus on cost-efficiency	- Focus on customer value
- "Mean"	- Participative
- Concerning shop floow	- Concerning whole organisation

Figure 4.2. Differences between hard Lean and soft Lean, Holmemo [43].

The soft Lean approach implies that the principles and employee-oriented tools of Lean are of greater significance when implementing the philosophy at a Scandinavian company. An explanation to this might be that Scandinavian workers value independence highly and do not respond well to strict rules and commands. This is worth considering when implementing Lean at the Company.

Lean Lite

Lean Lite is a less extensive version of Lean which can be applied where financial or other resources are not in abundance. Establishment of Lean is both time and resource consuming. Lean Lite might therefore be a good alternative. The Lean Lite initiative, as suggested by Chaplin et al., can be divided into three core concepts: [44]

- Waste; aim to maximise all value adding activities and minimise all non-value adding activities. In doing so customer value is increased.

- Flow; internal material movement is a non-value adding activity. The company should strive to match flow with customer demand to avoid overproduction and match internal production flow to avoid in-process stock build-up.

- Workforce involvement; take advantage of the in-house knowledge. The employees at a company usually have both experience and expertise. Use that to identify improvement opportunities and to create solutions to problems.

Working with these three steps can create what Chaplin et al. refers to as “quick wins” which can be seen almost immediately. Lastly, they argue that the Lean Lite approach cannot achieve the same effects as a full Lean program can. [44]

4.3 Evaluation of Lean tools and methods

The tools, methods and principles described in the results chapter are not all appropriate to use at SMEs. This section evaluates the tools’ and the principles’ suitability at young and small companies in general, and at the Company in particular. Firstly, the Company’s own evaluation of the tools is presented. After that, previous researchers’ evaluations of the tools are brought up. Lastly, I evaluate each Lean tool, method and principle and determine their suitability at small and young companies.

The Company’s evaluation

In February of 2018 the tools, methods and principles described in the results chapter were presented to the heads of the Company. The Chief Executive Officer, CEO, the Chief Operating Officer, COO, and the Production Manager, PM, were all asked to evaluate the tools based on the likelihood of the tools being implemented at the Company. They all provided valuable comments on the tools, methods and principles and ranked them on a scale from one to five, where five being very high likelihood of the concept being implemented and one being very low. The form used to register the ratings can be seen in **appendix 1**. The CEO’s, COO’s and PM’s ratings are summarised in Tab. 4.2.

Table 4.2. The Company's evaluation of Lean tools, methods and principles.

	PM	COO	CEO	Average
Andon	5	3	5	4,3
Autonomation	5	2	5	4,0
Decoupler	5	2	5	4,0
DFMA	5	5	5	5,0
Five S´s	5	5	4	4,7
Five Whys	5	4	4	4,3
FMEA	5	5	5	5,0
Gemba Walk	3	5	4	4,0
Group tech.	3	3	3	3,0
Ishikawa diagram	4	4	4	4,0
Just-in-Time	3	5	3	3,7
Kaizen	5	5	5	5,0
Kanban	3	3	5	3,7
KPI	3	5	5	4,3
Lean Leadership	5	2	4	3,7
Make-to-Final Inv.	4	5	4	4,3
Model for Manu. Eco.	2	5	4	3,7
MO-CO-MOO	5	2	5	4,0
OPF	5	5	5	5,0
Pareto diagram	3	3	3	3,0
Poka-Yoke	5	5	5	5,0
Process sheet	5	5	5	5,0
PSM	3	4	2	3,0
QC-circles	4	3	4	3,7
QFD	3	3	3	3,0
RCA	3	5	3	3,7
Seven wastes	4	4	4	4,0
Six Sigma	2	1	2	1,7
Small stock	5	5	3	4,3
SMED	4	4	4	4,0
SPC	2	1	2	1,7
Stat. follow-up	5	3	4	4,0
Suggestion System	5	5	5	5,0
The Toyota Way	4	5	4	4,3
Toyota's 14 principles	4	4	3	3,7
TPM	5	4	5	4,7
TQC	5	4	4	4,3
VSM	3	5	4	4,0
Zero Defect	5	3	3	3,7
Zero Inventory	2	3	3	2,7

The table displays that some tools, methods and principles are very likely to be implemented at the Company and others are less likely to be implemented. The methods, tools and principles that got low scores were mainly an effect of overwhelming complexity, uncertain customer demand and company expansion. For example, Six Sigma might be too complex to use for a small and young company and the goal of Zero Inventory might be hard to achieve when the Company is expanding rapidly. The PM, COO and CEO know the Company well and their feedback was therefore heavily influential on the proposed plan for Lean implementation at the Company.

Previous evaluations of Lean tools

Matt & Rauch investigated several Lean tools to find out which were suitable at small companies and which were not. The results were as follows: [34]

- Very well suitable: The Five S's, FIFO, Benchmarking, Kaizen, Ideas Management, Just-in-Time, Visual Management, Zero Defects.
- Well suitable: Low cost automation, SMED, Cellular Manufacturing, Supply chain optimization, VSM, Work station design, Autonomous work groups, Job rotation, Standardisation, Kanban, Poka-Yoke.
- Suitable: Preventive Maintenance, optimal lot size, QC-circles.
- Less suitable: OEE, TPM, OPF, Line balancing and muda reduction, milkrun, SPC, Supplier development, TQM.
- Unsuitable: Simulation software, QFD, Six Sigma.

Matt & Rauch argue that some methods such as Six Sigma, simulation software, FMEA or QFD are not to recommend for small companies as they often require time, capital and qualified personnel. [34] Xu et al. saw during their survey in Singapore at eight MNCs that the tools with the highest success rate at the investigated MNCs were VSM, The Five S's, Visual Management and Standardisation. Some of the MNCs also used SMED, Kaizen Events and Kanban with success. [35] By looking at the results from Matt & Rauch and Xu et al. it becomes obvious that the tools that are less suited for SMEs are the ones with high complexity and the ones that only becomes useful when performing large scale production.

The Toyota Way

The first Lean principle I will evaluate is The Toyota Way. The Toyota Way is a mindset more than anything else. The five components; Challenge problems, Continuous improvement, Genshi Genbutsu, Respect and Teamwork can be utilised by all personnel within a company. The Toyota Way is suitable to implement at a small company as well as at a large company as the principle applies to each separate individual. The COO at the Company was very interested in introducing the concept companywide to establish both a long-term thinking and a go-and-see attitude. I personally believe that the Toyota Way would be a good fit at the Company and should be introduced early in the Lean implementation process.

Toyota's 14 principles

Toyota's 14 principles are, similar to The Toyota Way, a mind-set. The thoughts and rules of thumb can be utilised by any employee at a company to different extents. For this reason, Toyota's 14 principles are well suited to implement at a small and young company.

During the evaluation with the CEO, COO and PM the principles 2, 5, 8 and 13 where the most discussed ones. Improvements could without a doubt be made regarding principle 2, 5 and especially 13. Some of the other principles the Company felt they had come further with e.g. principle 8. I think that Toyota's 14 principles should be presented and imparted to all employees at the Company. The 14 principles should preferably be incorporated into the Company's policy.

Lean Leadership

Similar to The Toyota Way and Toyota's 14 principles, Lean Leadership can be used by many different employees within a company. However, the seven exhortations should mainly be used by managers. Avoiding departmental thinking is perhaps of greater importance at larger companies. The other points are just as applicable at a small company as at a large company. I would argue that Lean Leadership should be presented to all the managers at the Company.

Just-in-Time

JIT is a very important part of Lean and should therefore be, at least to some extent, included in a Lean implementation program. For a small company JIT might be applied as a mind-set rather than in concrete actions. Striving towards minimising stock and having a timing within all operations is achievable at all companies, no matter their size. The Company was at the time of this evaluation yet to start large scale production of their first product. Having a JIT mind-set when planning for production might be a good way to incorporate the concept. I believe that JIT is suitable at the Company as a goal to strive towards and as a way of thinking when designing new processes.

Autonomation

Autonomation is, like JIT, a large part of Lean and should therefore also be included in any Lean implementation. Having the mentality to always solve a problem as soon as it arises is usable for any company regardless of size. Autonomation is therefore suitable to introduce to a small and young company. At the Company, autonomation can be used in almost all processes. The concept should be taught to all employees at the Company in an early stage of the Lean implementation.

Kaizen

The Kaizen concept is applicable at any company. Continuous improvement can be made in all processes and by all employees. The CEO, COO and PM argued that the Kaizen way of thinking was already utilised by the three of them. They did however want the other employees to be informed so that they too could start thinking in the Kaizen way. I believe that Kaizen would be a great fit at the Company and should be implemented early in the implementation process.

DFMA

Depending on what industry a company resides in, the DFMA concept can be used to different extents. If a company designs products with many inbound components, then the concept is very applicable. Information is a key component to make DFMA work. The PM at the Company saw himself as the link between the manufacturing and the design department. The PM felt that improvements could be made but that the Company already tries to keep a continuous flow of information between the design department, the in-house manufacturing and the subcontractors. I think that the Company is doing well in terms of DFMA but could use a system and/or framework to keep the information flow accessible and structured.

QFD

QFD is an interesting concept that can be used by any company developing a product. Its close similarity to Lean Start-up makes it very relevant when discussing its suitability at a young and small company. The PM, CEO and COO was not over excited about the idea of using QFD as they had used a more traditional approach when developing their product. I would however recommend considering QFD when commencing development of the Company's next product or when further developing the existing product.

FMEA

FMEA is a concept that can become both time and resource consuming depending on the analysis' level of complexity. Detailed and complex FMEAs might be overwhelming for a small company. Smaller, less complex FMEAs might however be of good use to a small company, as knowing ones' weaknesses is never a bad thing. If the Company is going to use the concept, then it should be a specially designed FMEA tailored to small companies.

Kanban

The Kanban system has proven very effective at large companies. At small and young companies however, the concept might not be as suitable. The concept is based on a having a well determined customer demand and a multistep production line with many stations and employees. Customer demand is often difficult to estimate for a young company, especially if the company has not sold any products before. A multistep production line is also unusual to find in young and small companies. However, enabling for future Kanban capability is not a bad idea. I would therefore recommend keeping the concept in mind when developing the first production and assembly line.

TPM

TPM is, like Kanban, often more suitable at larger companies. There are however some aspects of TPM that can easily be adopted by small companies. Operator knowledge enhancement and information spreading can be utilised by any company. I think that operator knowledge is especially useful at small companies as this would increase both productivity and quality. I would therefore recommend the Company to teach the operators as much about the product as possible and to encourage increased responsibility.

Statistical follow-up on productivity and quality

To keep track of selected productivity and quality values is very useful as progress made through implemented changes is visualised. Statistical follow-up can be made to varying degrees. Some companies might want to collect a large amount of data, others less. The important thing is to collect at least some data. I would argue that a small company should put effort into selecting a set of values that describes the company's current state and that enables for visualisation of achieved progress. The Company is however yet to begin large scale production and to select values might therefore be difficult.

Suggestion system

Installing a suggestion system is useful at all companies. Having new ideas registered and addressed has few to no drawbacks. I would therefore recommend creating a suggestion system early in the Lean implementation process at the Company.

The Five S's

The Five S's can be applied in different ways. At a Scandinavian company where individual freedom is valued highly, the Five S's should be implemented as a mind-set rather than strict rules. The COO, CEO and PM argued that it is important for employees to be in control of their situation. They therefore welcome the idea of implementing the Five S's as early in the implementation process as possible.

The Five Whys

The Five Whys are very easy to introduce at a company, regardless of the company's size. The CEO, PM and COO at the Company find that employees, and sometimes themselves, at many times work on projects that are not essential nor time critical. The CEO, PM and COO therefore want the Five Whys to be used to identify whether a task is essential and urgent or not. I think that the Five Whys should be introduced to everyone at the Company and encouraged to be used in as many situations as possible.

Zero Defects and Zero Inventory

The goal of having zero defects is applicable at any company. Zero inventory is however not as suitable at every company. The CEO, COO and PM were all for having the goal of zero defects. The idea of having zero inventory however was not as well received. They argued that for them as a small start-up company it is too early to minimise inventory. This as the Company is growing rapidly. They did however agree that avoiding excessive stock build-up is a good idea. I think the Company should implement the goal of zero defects early in the Lean implantation process. The goal of zero inventory could perhaps be introduced at a later stage.

Poka-Yoke

Making sure that errors cannot occur is a concept that can be used in all parts of an organisation and at all types of companies. Creating Poka-Yoke processes can be done by anyone, anywhere. I believe that mistake-proofing a process should be done to largest possible extent. I would argue that the Poka-Yoke mind-set should be taught to all employees at the Company early in the Lean implementation process. This so that they can begin mistake-proofing process at an early stage. The Poka-Yoke mind-set should also be used when designing production and assembly lines.

Pareto diagram

Using a Pareto diagram is a good way to structure the causes to why a problem occurs. The diagram can be used as a tool for communication between employees as describing the problem and its causes becomes easy to do. Learning to use the tool is easy and can be done by any employee at a company. For this reason, I would argue, that it is important that all employees at the Company learn to use and present the diagram.

Ishikawa diagram

Like the pareto diagram, the ishikawa diagram is a good tool for both structuring and presenting a problem. Learning to use and understand the diagram can be done by any employee at any company. I would recommend that the Company teaches its employees how to use the diagram.

RCA

RCA can be done with various complexity. For small companies the best solution might be to use a less complicated version of RCA. The CEO, COO and PM reasons that a basic RCA methodology should be easy to implement at the Company. The tool can be used both as a mind-set and as a structured way of finding the true cause of a problem. I believe that the method should be introduced to all employees early in the implementation process.

SPC

Small and young companies do usually not have the time nor the resources to implement extensive SPC. Collecting data and selecting KPIs is however important so that the company see and measure progress. Enabling for future use of SPC when collecting data is a possibility that should be considered by any small company that is about to implement Lean. For the Company I would not recommend implementing

SPC any time soon. The Company should however enable for future use of SPC by setting up guideline for data collection.

QC-circles

Small companies do usually not have the manpower to create large scale QC-circle programs. There are however many features of the QC-circle concept that can be implemented at a small company. The different departments at the Company is already working in a way similar to QC-circles. Whenever a problem arises within a department, all members of that department usually contributes to the solution. Introducing the QC-circle concept would therefore be easy as the employees already work in a similar way. I would argue that QC-circles should be used at the Company to better structure the problem solution process. The concept should be introduced relatively early in the implementation process.

TQC

To truly achieve good quality, it is important that everyone at a company understand what good quality is and how it is accomplished. Any company should aspire to keep communication going between all employees so that the improvements can be made continuously, regardless of the company's size. It is also important to inform all employees that they in some way influence the product, directly or indirectly. I would recommend creating a companywide understanding for what quality is at the Company.

Group technology

The group technology concept has proven successful at many companies around the world. As long as a company is producing a couple of products using more than one station, the concept should be considered. When the Company is about to design its assembly and production lines it will be of great use to do it with a group technology mind-set so that both time and resources can be spared in the future.

SMED

Introducing a SMED methodology can indeed be useful in production, but also in other parts of an organisation. Aiming to optimise time usage can be and should be done by any employee. I would recommend implementing a SMED mind-set in all parts of the Company as a way of increasing efficiency and productivity. Later on, when production is up and running, the SMED concept can be used in a more practical manner within production.

Andon

Andon boards can be used in many ways. They can display limited to extensive information about a company's status and can be placed anywhere at a company. The PM, COO and CEO were all very enthusiastic about implementing andon boards or similar information screens. Together with the PM, COO and CEO we decided that the boards should be used to communicate the status of the different departments within the Company, both internally in each department and externally throughout the Company. I believe that the andon boards should be used to clearly visualise and convey information about different processes at the Company and that development of the boards should be done as soon as possible.

Small stock

Having low stock is of interest to any company. This leads to having a lower amount of tied up capital and can create the benefits promised by the JIT philosophy. As previously mentioned the Company cannot minimise their inventory at the moment. They can however lower it in and avoid building up extensive stock. Decreasing stock should therefore be a long-term goal and part of the Company's vision.

OPF

OPF can be hard to implement for a company that already has a functional production system up and running. This as converting to a OPF system demands a significant amount of work and planning. The OPF concept would however be a good fit at the Company. The Company was at the writing of this thesis yet to build its first production and assembly lines and introducing the concept ought therefore to be easy. Implementing OPF early is a good example of how a young company can make the right choice from the beginning and thereby avoid changing their system later. I believe that creating OPF production and assembly lines would be of great benefit to the Company.

VSM

VSM is often very resource consuming as it occupies both time and manpower. Using VSM in a very basic way might however be a good solution for a small company as it would indicate where waste is occurring. I would argue that teaching certain employees how to perform basic VSM is a good idea. Performing VSM before the Company has produced and sold any products might however be difficult. I would therefore recommend performing a VSM later in the implementation process, when production has commenced.

KPIs

Many of the researchers that have been investigating how Lean can be implemented at a small company argues that establishing KPIs was very important for a successful implementation. I would therefore recommend that selecting sensible KPIs at the Company. Doing this before production has started would however be difficult. Selecting KPIs should therefore be done in the later stages of the Lean implementation.

The Seven Wastes

Ohno's Seven Wastes can be found at any company, regardless of size. By knowing the Seven Wastes and by looking for them a company can continuously improve production. I would recommend teaching the Seven Wastes to everyone involved with production at the Company.

Gemba Walk

Using Gemba Walks is a good way to systematically seek out waste in company processes. Gemba Walks can easily be performed at SMEs as well as at MNCs. The CEO, PM and COO at the Company do, to some extent, already perform Gemba Walks. They do however not have a method or structured way of looking for waste within selected processes. I would suggest establishing a framework for how a Gemba Walk should be performed so that waste identification can be made thoroughly.

MO-CO-MOO

MO-CO-MOO is a great tool for ensuring quality and could be used at any company. For a small but not young company implementing MO-CO-MOO might, similar to OPF, be both time and resource consuming. At a young company however, MO-CO-MOO would most likely be easier to implement. I would argue that MO-CO-MOO capability should without a doubt be introduced to the Company's production and assembly lines. This as the Company has no previous production or assembly system. The MO-CO-MOO concept is not too difficult to implement and ought to be of great use at the Company as it guarantees quality and helps identify errors in the process.

Decouplers

Decouplers is a great concept for enabling the MO-CO-MOO capability. Decouplers in combination with Poka-Yoke, OPF and group technology should enable for smooth production and assembly lines that ensures good quality. I strongly recommend introducing decouplers to the production and the assembly system at the Company.

Make-to-Final Inventory

For any sized company is good so satisfy on-time delivery. The CEO, PM and COO all argued that implementing the make-to-final inventory concept was a good idea. I too believe that the concept should be implemented as part of the assembly line development.

Process sheet

Using process sheets is very suitable for production as well as for other part of a company. Using process sheet helps avoid errors and smoothens production as employees do not need to call upon attention if they need help. The PM, COO and CEO at the Company thought that some process sheets could be video recordings of something being done correctly. Leaving small comments on how something should be done correctly is also useful. I believe that process sheets should be made continuously and as often as possible.

Six Sigma

Six Sigma is often complex, time consuming and resource consuming. I believe that the method is more suited for larger companies. I do not recommend implementing Six Sigma at the Company.

PSM

The PSM is easy to use. It does however consume manpower as continuous time measurements are to be registered. If the PSM is designed so that it takes as little time as possible to collect data, I think that the PSM could easily be implemented at companies of all sizes. I would recommend developing a PSM system that can be used when production is up and running at the Company.

Production cost model

A system that calculates production cost based on Ståhl's model would needs some initial work to develop. After the system is developed however, I believe it would be very useful to any company. The model is easily scalable and could fit both large- and small-scale production. At the Company, a system that utilises the production cost model could and should be used in many ways. The model can be used to quickly estimate the cost of producing a component. The production cost model can also be used during the production line development to calculate future costs and to simulate the proposed production line. Lastly the model can be used to follow-up on produced components to see the true cost of production. I would recommend implementing the Production cost model at the Company.

4.4 Company implementation plan

In this section I propose a six-step plan for the Lean implementation at the Company. The plan is based on my and the Company's evaluations of the Lean tools, methods and principles and on the Lean implementation research. The steps are to be executed chronologically starting with step one.

Step one; goals and vision

The first step in my suggested implementation process is to establish goals and a long-term vision for the Lean implementation at the Company. This should be done together with the heads of the Company; the COO, CEO and PM. Assessing their wills and reaching a consensus is a given first step as lacking management commitment is one of the largest barriers for a successful Lean implementation.

Step two; company preparation

The second step is to introduce Lean to the employees and to prepare them for the changes that comes with a Lean implementation. Lectures about the different principles, methods and tools should be held, where the employees can ask question and get a first insight into the philosophy. A Lean handbook should be developed. The Lean Handbook should consist of brief descriptions of different Lean tools, methods and principles that are suitable to be used at the Company. Using the handbook, the employees can find inspiration for more efficient ways to work e.g. the Five S's, the Five Whys. The handbook can also be useful as a reminder for how different techniques work e.g. ishikawa diagram, RCA. Enlightening all employees about what Lean is and about the upcoming changes should facilitate the implementation. After the Lean tools has been presented to all employees they can hopefully begin using a Kaizen, Autonomation and Poka-Yoke mind-set when performing their daily tasks.

Step three; implementation of minor tools

The third step is to implement less extensive Lean tools such as a suggestions system, andon boards and a Gemba Walk framework. Introducing these tools should make achieved improvements visible which should further fuel the Lean implementation. A Lean culture should by this stage hopefully be established and the employees at the Company should have begun using the different Lean tools and methods on a regular basis.

Step four; surrounding systems

The fourth step in the implementation process is to establish surrounding systems. Systems such as the production cost model, DFMA systems and PSM. These systems should be developed so that they are easy to use, understand and update. These systems enable the Company to continuously improve for a long time ahead. The production cost model can also be used as a simulation tool to make informed decisions. This step could eventually be placed later in the implementation process after the production system has been developed. But as the Company is not ready to begin designing production and assembly lines until the very end of this thesis project I have placed this step as number four.

Step five; production design

The fifth step is to implement the production related tools and methods. Tools and methods such as OPF, MO-CO-MOO and Decouplers. Implementing these tools in an early stage of production should prove beneficial as the Company do not have to rebuild a previously constructed production system. Some of the tools should be used when designing the system such as Decouplers and Make-to-final inventory. Other tools, such as SMED and the Seven Wastes ought to be used as supporting systems once the production system is operational. The reason for this step being placed late in the implementation process is because the step must be timed with the Company's development.

Step Six; mapping and KPIs

The final step is to select and measure KPIs. Some of the researchers argued that KPI selection should be the first step in an implementation. The reason that the KPIs is not being selected earlier in this implementation process is because the Company is not commencing large scale production until the very end of this thesis project. Some non-production related KPIs can however be assessed earlier. The final step should also include a mapping of NVA activities at the Company. This should be done using a less advanced version of VSM.

4.5 Lean implementation at the Company

In this section I describe the execution of the plan presented in section 4.4. The Lean implementation began in early March 2018 and continued into late May the same year.

Goals and vision

Together with the CEO, COO and PM, the desired results from the Lean implementation were drafted. The main goals of the implementation were as follows:

- Reduce waste.
- Increase productivity.
- Create a companywide mind-set change.
- Increase standardisation.
- Create a Lean manufacturing system.
- Create a Lean culture.

These goals are not quantified nor well defined. For this reason, they are goals to strive towards rather than goals to can be fully completed.

All the heads of the Company were keen on applying Lean and approved the implementation plan. This was vital, as having managerial support is a key to a successful implementation. The heads and I decided that the implementation should take a Soft Lean approach as this fit well with the Scandinavian workforce at the Company. The CEO, COO and PM did however not want to take the Lean Lite approach as they are prepared to put both time and resources into the implementation project.

Company preparation

After discussions with the CEO, COO and PM, we agreed that I would hold a lecture for all employees at the Company. The lecture included the Lean principles, tools and methods that has a high chance of being implemented at the Company. The CEO, COO, PM and I also decided that a Lean handbook should be developed and distributed to all employees at the Company.

During the lecture the employees were introduced to the following principles, tools and methods: The Toyota Way, Toyota's 14 principles, Lean Leadership, JIT, Autonomation, Kaizen, DFMA, QFD, FMEA, TPM, Suggestion system, The Five S's, The Five Whys, Pareto diagram, Ishikawa diagram, RCA, QC-circles, TQC, Poka-Yoke, SMED, Andon, Small stock, OPF, VSM, KPI, The Seven Wastes, Gemba Walk, MO-CO-MOO, Decouplers, Make-to-final inventory, Process sheet, PSM and the Production cost model.

All employees responded well to the presented tools, especially to Kaizen, RCA, Poka-Yoke and the Five Whys. This is not surprising as these tools are more related to the Soft Lean approach. Toyota's 14 principles were also heavily discussed as the employees felt they could improve on many of the points, especially number 5, 6, 12 and 13. Many of the employees argued that decision-making could be improved, with more fact-based and informed decisions. After the lecture the employees expressed that they were all aboard with the implementation project and curious on the upcoming changes.

To follow-up on the lecture the Lean handbook was developed in the following weeks. The handbook contains the tools mentioned at the lecture, all briefly described. Using the handbook, the employees at the Company can adopt the Lean mind-set and hopefully begin refining their work methods. The COO wanted to incorporate the Lean handbook into the company policy. This was done in the middle of March. Incorporating the Lean handbook into the company policy was a clear indication that management was committed to the implementation project. The handbook can be seen in **appendix 2**.

The COO and PM also wanted some of the tools mentioned in the handbook to be printed and placed on the walls around the office. This was also done in the middle of March. The signs were meant to inspire and remind all employees of the Lean working methods. A picture of a Kaizen sign that was placed in the office can be seen in Fig. 4.3.

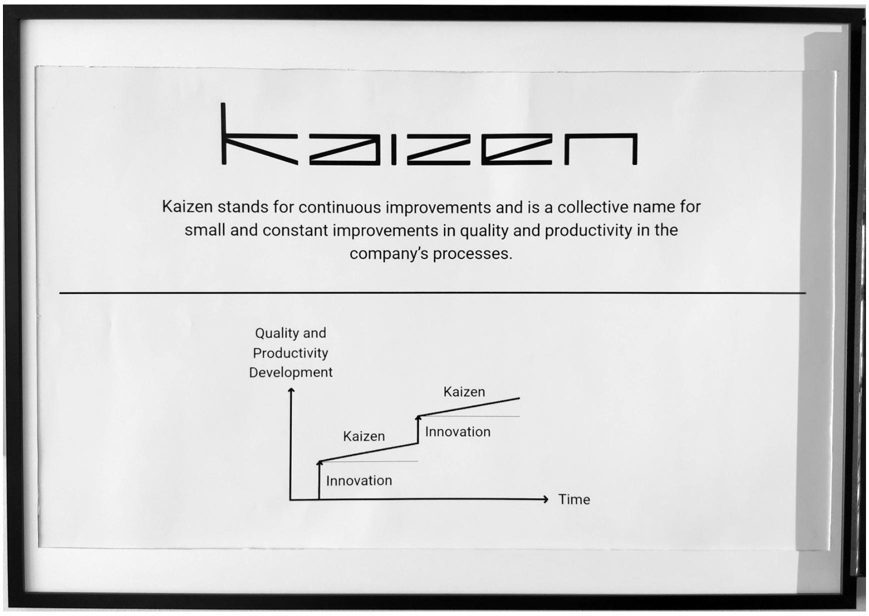

Figure 4.3. Poster of the Kaizen concept.

Implementation of minor tools

The first minor tool that was implemented was the suggestion system. The idea was that anyone should be able to submit a suggestion as soon as they think of an improvement. Being able to freely submit ideas should hopefully increase the sense of participation among the employees. It is also a good way for the Company to further utilise the competence of the employees. The simplest way to make a functioning suggestions system is by creating a form in which employees can leave their proposals. The submitted suggestions should be reviewed by the managers at the Company at least a couple of times a month. The suggestions should be anonymous and only if the improvement idea is implemented should the name of the employee be brought up, so that that employee can be awarded accordingly. Being anonymous ought to prevent employees from feeling scared of leaving critical suggestions.

The above-mentioned suggestion system was established at the Company in the middle of March 2018. The form was created online in Google Forms. The form enables the employees to submit as many suggestions as they want. The CEO, COO and PM can all see the submitted suggestions but cannot see the name of the suggestion creator. All employees at the Company were informed of the created suggestion box and were given access to it via a link. A screenshot of the suggestion box can be seen in Fig. 4.4.

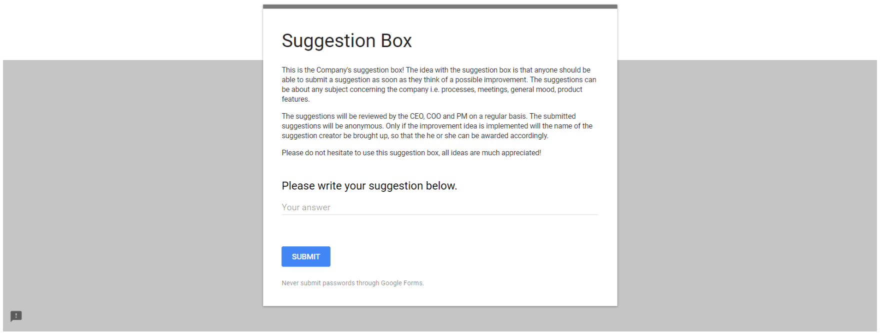

Figure 4.4. The suggestion box created for the Company.

In the following weeks after the suggestions box had been established the usage of the system was low. But as time went on the suggestion box began being used for several activities. The box was used mainly to bring up general issues at the Company but also to collect product feedback. As the product was being tested by the employees at the Company, the employees left their feedback on the product in the anonymous suggestion box. This was convenient as the employees that performed the tests did not have to hold back on any criticism of the product. Another practical benefit from using the suggestion box to collect feedback was that all the feedback was gathered in one place. This allowed for easy structuring which in its turn enabled unwanted and wanted product features to be clearly identified.

The second minor tool that was implemented was the andon boards. As the Company is small, only two andon boards were needed; one andon board at the production site and one at the office. The boards should present a concise but comprehensive amount of information. The information should be changeable from day to day or perhaps even in real-time. These specifications are easily achieved by a system presented on a screen. The andon screen should be able to display information about deadlines, statistics, important messages and KPIs. The screen should be mounted on the wall so that it is clearly visible to everyone. This enables information to be spread quickly to all employees at the Company. A program for the display should be designed so that it is easy to update the information on the andon screen. The program should be accessible from any computer so that changes can be made easily. The program should also use many different input sources, such as deadlines for each department. To solve this, I designed a system in Google Sheets. Using Google Sheets anyone at the Company can easily make changes and updates from any computer. By combining different sheets every department got their own sheet in which they can make updates. The changes made in the separate sheets becomes registered and immediately appear on the andon screen, which is also a sheet in the system. The COO and PM especially wanted deadlines to be on the andon screen. This as they felt that making the employees aware of what needs to be done was the most important thing. After a couple of days work the andon board system was finished. The final system displayed:

- The main long-term goals for each department
- Ongoing tasks in each department, how much progress has been made in each task and how many days there are left until the task deadline.
- The percentage of completed tasks in each department.
- Days until a mayor deadline within each department.
- Days until product launch.

- Upcoming events.
- The time and date.

The content of the andon screen may change with time. Using the system changes can be made easily. A blurred picture of the andon screen can be seen in Fig. 4.5. Due to confidentiality reasons, information seen in the real system is not displayed in the picture.

Figure 4.5. Picture of the andon screen implemented at the Company.

Each head of the departments was given the responsibility to continuously update the information concerning their department. The employees at the Company were enthusiastic about the andon board system as it helps clarify tasks, deadlines and goals.

The first weeks after the andon system had been implemented the system was not used as much as one could have hoped. The heads of each department did not find the time to fill in the information that was to be displayed on the board. After some encouragement however, the board eventually became used to full extent.

The third minor tool that was implemented was the Gemba Walk framework. The framework is not meant to be very advanced but can be helpful when trying to improve a process and when looking for waste. Following the proposed framework should achieve a standardised and more resolute improvement process.

The framework should investigate if Lean tools such as the Seven Wastes or the Five S's can be applied to the investigated process. The Gemba Walk framework should also contain questions that the person performing the Gemba Walk can ask himself or herself. Examples of such questions are:

- Can the process be completed faster?
- Can the process be done with less errors?
- Can the process be made easier?

Using the requirements mentioned above, the proposed Gemba Walk framework seen in Fig 4.6. was developed.

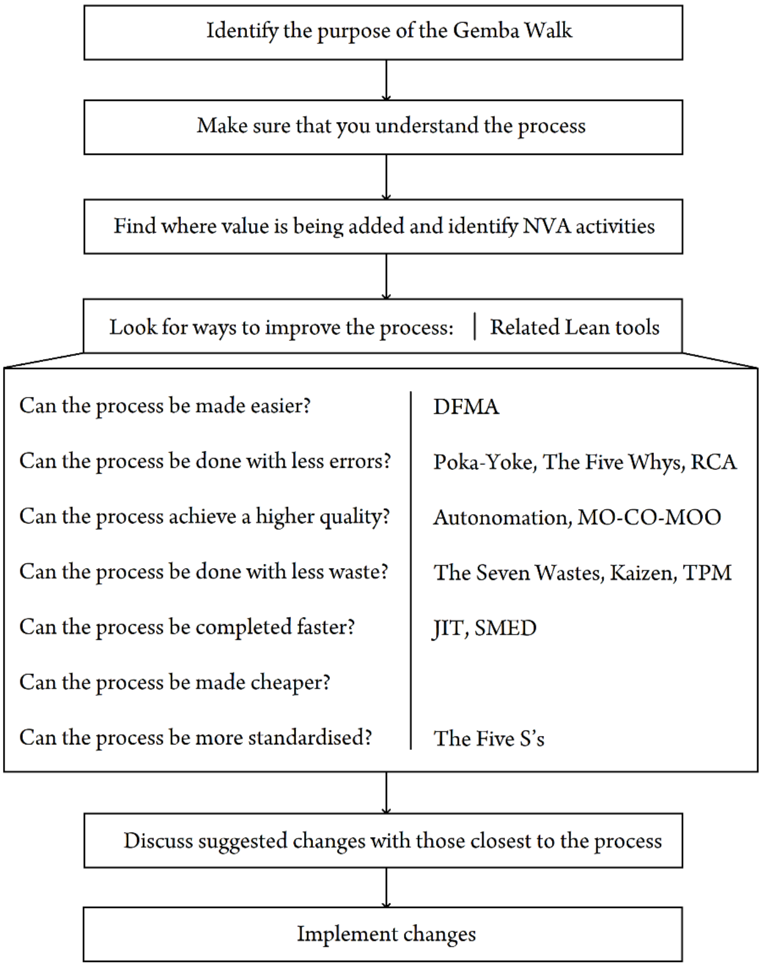

Figure 4.6. Proposed Gemba Walk Framework.

By the end of this implementation step a Lean culture should have begun developing at the Company. Changing people's mentality is however not so easy. Even though the employees have heard about autonomation and JIT it does not mean that they changed their working methods. The same goes for tools such as FMEA, Ishikawa diagrams and RCA. If there is no incentive to begin using the Lean tools, then the employees will not do it. Simply saying that the Company works with Lean methods will not spur any real change. To tackle this problem, incentives needs to come from the managers. The managers need to begin using the tools on a regular basis and only then will the others do the same.

Surrounding systems

The fourth step in the implementation plan was to establish systems that will help the Company continuously improve in the long run. The first system that was established is the production cost model. The model is used to quickly estimate the cost of producing a component. Using the model, the Company hopes to make more informed decisions that will benefit them in the long run. To create the system, I used Google Sheets as it is easy to access from any computer. The COO wanted the model to give a fact-based estimation on the cost of producing one component. In the beginning of April, the Company was still developing its first product and was therefore only producing test components. The model presented by Ståhl is designed to be applied at large scale production. For this reason, the model implemented at the Company was slightly modified to better fit the circumstances. As the Company begin to produce components in bigger quantities the model can be adjusted to fit that situation. A screenshot of the first model that was implemented at the Company can be seen in Fig. 4.7.

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Production parameters	
Nominal batch size, N0 [piece(s)]	3
Nominal cykel time per detail, t0 [min]	10
Setup time, TSU [min]	60
Percentage of production downtime, qS [0.00]	0.2
Percentage of rejects, qQ [0.00]	0.05
Relative pace loss, qP [0.00]	0
Manufacturing cost parameters	
Tool cost, kA [kr]	800.00 kr
Produced pieces untill tool change [piece(s)]	300
Machine cost during production, kCP [kr/h]	**413.17 kr**
Machine cost during standstill or conversion, kCS [kr/h]	**273.17 kr**
Operator Labour costs, kD [kr/h]	300.00 kr
CAM Labour salary [kr/h]	200.00 kr
CAM time [h]	8
CNC Programming cost [kr/h]	300.00 kr
CNC Programming time [h]	0.5
Other parameters	
Full batch production time, TP [min]	10000
Utilisation rate at reduced occupancy, URB [0.00]	1
Material parameter	
Material	Al 7075 Rundstav
Length of material [mm]	90
Price per meter [kr]	**3,333.33 kr**
Length needed per piece [mm]	40
Material cost per detail, kB [kr/piece]	**133.33 kr**

Output	
Detail cost attributed to tool cost [kr/piece]	**2.67 kr**
Detail cost attributed to cost of material [kr/piece]	**140.35 kr**
Detail cost attributed to machine cost during production [kr/piece]	**72.49 kr**
Detail cost attributed to machine cost at standstill [kr/piece]	**103.04 kr**
Detail cost attributed to labour cost [kr/piece]	**165.79 kr**
Detail cost attributed to CAM Labour cost [kr/piece]	**533.33 kr**
Detail cost attributed to CNC Programming Labour cost [kr/piece]	**50.00 kr**
Total cost per detail, k [kr/piece]	**1,067.66 kr**

$$
\begin{aligned}
k = {} & \frac{k_B}{N_0}\left[\frac{N_0}{(1-q_Q)\cdot(1-q_B)}\right]_b + \frac{k_{CP}}{60N_0}\left[\frac{t_0 N_0}{(1-q_Q)(1-q_P)}\right]_{c1} + \\
& \frac{k_{CS}}{60N_0}\left[\frac{t_0 N_0}{(1-q_Q)(1-q_P)}\cdot\frac{q_S}{(1-q_S)} + T_{su} + \frac{1-U_{RB}}{U_{RB}}T_{pb}\right]_{c2} + \\
& \frac{k_D}{60N_0}\left[\frac{t_0 N_0}{(1-q_Q)(1-q_S)(1-q_P)} + T_{su} + \frac{1-U_{RB}}{U_{RB}}T_{pb}\right]_d
\end{aligned}
$$

Figure 4.7. Screenshot of the cost model implemented at the Company.

The numbers seen in Fig. 4.7. are fabricated and were never used at the Company. Using the model, the COO, CEO and PM can make fast and relatively precise estimation of the cost of producing a part.

In the middle of April, the developed cost model was presented to the COO and PM. The COO thought that the cost model would become useful as a tool to quickly estimate what it would cost to produce a single part. The COO also thought the cost model would become useful at a later stage as well, when the Company has established functioning production lines.

The second surrounding system that was implemented was the Production Security Matrix. The PSM was developed to be used at the production site to identify improvement opportunities. I developed the PSM to be flexible and easy to alter so that it could be continuously used as production expands. A screenshot of the first PSM that I created can be seen in Fig. 4.8.

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Factor groups	Q1 Fine surface defects	Q2 Coarse surface defects	Q3 Geometry defects	S1 Planned stops	S2 Unplanned stops	P1 Production rate	Sum [min]
A Tools							**0:16**
A1 Dirt	0:12	-	-	-	0:04	-	0:16
A2 Scratches	-	-	-	-	-	-	0:00
B Working material							**0:00**
B1 Chips	-	-	-	-	-	-	**0:00**
C Process							**1:13**
C1 Feed error	-	-	-	-	-	-	**0:00**
C2 Output scrap	-	-	-	-	0:14	-	**0:14**
C3 Output chips	0:11	0:19	-	-	0:09	-	**0:39**
C4 Chucking	0:20	-	-	-	-	-	**0:20**
C5 Plunder	-	-	-	-	-	-	**0:00**
D Personnel and organisation							**1:02**
D1 Meeting	-	-	-	-	0:02	-	**0:02**
D2 Break	-	-	-	1:00	-	-	**1:00**
D3 Staff shortage	-	-	-	-	-	-	**0:00**
E Wear and maintenance							**0:00**
E1 Wear	-	-	-	-	-	-	**0:00**
E2 Tool failure	-	-	-	-	-	-	**0:00**
E3 Tool maintenance	-	-	-	-	-	-	**0:00**
E4 Machine maintenance	-	-	-	-	-	-	**0:00**
F Special factors							**1:11**
F1 Retooling	0:20	-	-	-	-	-	**0:20**
F2 Equipment change	-	-	-	0:21	0:30	-	**0:51**
G Surrounding equipment							**2:24**
G1 Die change	-	-	-	0:11	-	-	**0:11**
G2 Pallet change	-	-	-	0:42	1:30	-	**2:12**
G3 Carriage change	-	-	-	0:01	-	-	**0:01**
H Unknown factors							**0:44**
H1 Unknown	-	0:44	-	-	-	-	**0:44**
Sum [min]	**1:03**	**1:03**	**0:00**	**2:15**	**2:29**	**0:00**	**6:50**

Figure 4.8. The PSM developed for the Company.

The values seen in the PSM are fictional. To gather data for the PSM the Company uses a form which registers stop times, start times and comments on what caused the stop. The form also describes which factor group each stop is attributed to. A screenshot of the form can be seen in Fig 4.9.

Edit / **Don't Edit**

Stop time	Start time	Min/stop	Stop type	Stop factor	Comment
-	9:00				Start of the day
9:30	9:35	**0:05**	S1 Planned stops	G1 Die change	Replacement of full chipback
9:55	10:00	**0:05**	S2 Unplanned stops	C3 Output chips	The chips were stuck in the discharge, cleaning
10:20	10:25	**0:05**	Q1 Fine surface defects	A1 Dirt	Cleaning tools
11:00	11:03	**0:03**	Q1 Fine surface defects	A1 Dirt	Cleaning tools
11:15	11:19	**0:04**	Q1 Fine surface defects	A1 Dirt	Cleaning tools
11:30	12:00	**0:30**	S1 Planned stops	D2 Break	Lunch
12:50	12:54	**0:04**	S2 Unplanned stops	C3 Output chips	The chips were stuck in the discharge, cleaning
13:16	13:22	**0:06**	S1 Planned stops	G1 Die change	Replacement of full chipback
13:55	14:20	**0:25**	S1 Planned stops	G2 Pallet change	Pallet change, finished details
14:35	14:41	**0:06**	S2 Unplanned stops	G2 Pallet change	Run out of material, wait for delivery of new workpieces
15:05	15:25	**0:20**	Q1 Fine surface defects	F1 Retooling	Replace tool
16:10	16:14	**0:04**	S2 Unplanned stops	C2 Output scrap	Scrap stuck, cleansing
16:45	16:55	**0:10**	S2 Unplanned stops	C2 Output scrap	Scrap stuck, cleansing
17:00	-				End for the day
-	9:15				Start for the day
9:17	9:25	**0:08**	Q1 Fine surface defects	C4 Chucking	Problems with automatic workpiece input
9:31	9:36	**0:05**	Q1 Fine surface defects	C4 Chucking	Problems with automatic workpiece input
9:41	9:48	**0:07**	Q1 Fine surface defects	C4 Chucking	Problems with automatic workpiece input
9:48	9:50	**0:02**	S2 Unplanned stops	D1 Meeting	Discussion about workpiece replacement problems
9:50	9:54	**0:04**	Q2 Coarse surface defects	C3 Output chips	Scrap stuck in the tool due to poor chip discharge
9:55	10:00	**0:05**	Q2 Coarse surface defects	C3 Output chips	Scrap stuck in the tool due to poor chip discharge
10:04	10:23	**0:19**	S2 Unplanned stops	G2 Pallet change	Run out of material, wait for delivery of new workpieces
10:24	10:29	**0:05**	Q2 Coarse surface defects	C3 Output chips	Scrap stuck in the tool due to poor chip discharge
10:38	10:40	**0:02**	S1 Planned stops	G2 Pallet change	Replace full scrap pallet
10:43	10:46	**0:03**	Q2 Coarse surface defects	C3 Output chips	Scrap stuck in the tool due to poor chip discharge
10:50	10:52	**0:02**	Q2 Coarse surface defects	C3 Output chips	Scrap stuck in the tool due to poor chip discharge
11:16	11:37	**0:21**	S1 Planned stops	F2 Equipment change	Replace worn bracket for workpiece
11:37	12:07	**0:30**	S1 Planned stops	D2 Break	Lunch
12:07	12:37	**0:30**	S2 Unplanned stops	F2 Equipment change	Continued replacement of holder
12:42	13:26	**0:44**	Q2 Coarse surface defects	H1 Unknown	Quality problem, surface after finishing holes not good, discussion of action
14:29	14:48	**0:19**	S2 Unplanned stops	G2 Pallet change	Run out of material, wait for delivery of new workpieces
14:57	15:01	**0:04**	S1 Planned stops	G2 Pallet change	Pallet change, finished details
15:23	15:44	**0:21**	S2 Unplanned stops	G2 Pallet change	Run out of material, wait for delivery of new workpieces
15:46	15:46	**0:00**	Q3 Geometry defects	A1 Dirt	Pressure mark on detail during tension due to dirt
15:46	15:50	**0:04**	S2 Unplanned stops	A1 Dirt	Cleaning tools
15:53	15:59	**0:06**	Q1 Fine surface defects	C3 Output chips	Scrap stuck in the tool due to poor chip discharge
16:03	16:06	**0:03**	Q1 Fine surface defects	C3 Output chips	Scrap stuck in the tool due to poor chip discharge
16:09	16:20	**0:11**	S1 Planned stops	G2 Pallet change	Pallet change, finished details
16:41	16:59	**0:18**	S2 Unplanned stops	G2 Pallet change	Run out of material, wait for delivery of new workpieces
16:59	17:00	**0:01**	S1 Planned stops	G3 Carriage change	Scrap Wagon Replacement
17:04	17:06	**0:02**	Q1 Fine surface defects	C3 Output chips	Scrap stuck in the tool due to poor chip discharge
17:08	17:15	**0:07**	S2 Unplanned stops	G2 Pallet change	End of material, wait for delivery of new workpieces
17:15	-				End the day

Stop factor groups
A Tools
A1 Dirt
A2 Scratches
B Working material
B1 Chips
C Process
C1 Feed error
C2 Output scrap
C3 Output chips
C4 Chucking
C5 Plunder
D Personnel and organisation
D1 Meeting
D2 Break
D3 Staff shortage
E Wear and maintenance
E1 Wear
E2 Tool failure
E3 Tool maintenance
E4 Machine maintenance
F Special factors
F1 Retooling
F2 Equipment change
G Surrounding equipment
G1 Die change
G2 Pallet change
G3 Carriage change
H Unknown factors
H1 Unknown

Stop types
Q1 Fine surface defects
Q2 Coarse surface defects
Q3 Geometry defects
S1 Planned stops
S2 Unplanned stops
P1 Production rate

Figure 4.9. Form that gathers data for the PSM.

Using IF()- and SUMIF()-functions the data gathered in the form is easily structured and transferred to the PSM. The goal was to make the form easy to fill in so that the employee that operates the machine has time to fill in the form parallel with operating the machine. The only thing that the employee that fills in the form need to do is to fill in the stop time, start time and write a small comment on what caused the stop. The rest is taken care of by the program.

In the middle of April, the developed PSM was presented to the COO and PM. They both agreed that the PSM would eventually become useful. They did however not think they would use the PSM at the current state as there was no ongoing continuous production.

The third surrounding system that was implemented was a DFMA system. The Company did, even before the Lean implementation, work hard to keep ongoing communication between the design department and the production department. The PM was the link that continuously kept the communication going between the two departments. The PM did however think that mistakes were still being made because of lacking communication. To tackle this problem, I designed a framework to follow when designing a new component. The framework ensures that no step in the communication process is skipped. Together with the design department the framework seen in Fig. 4.10. was developed.

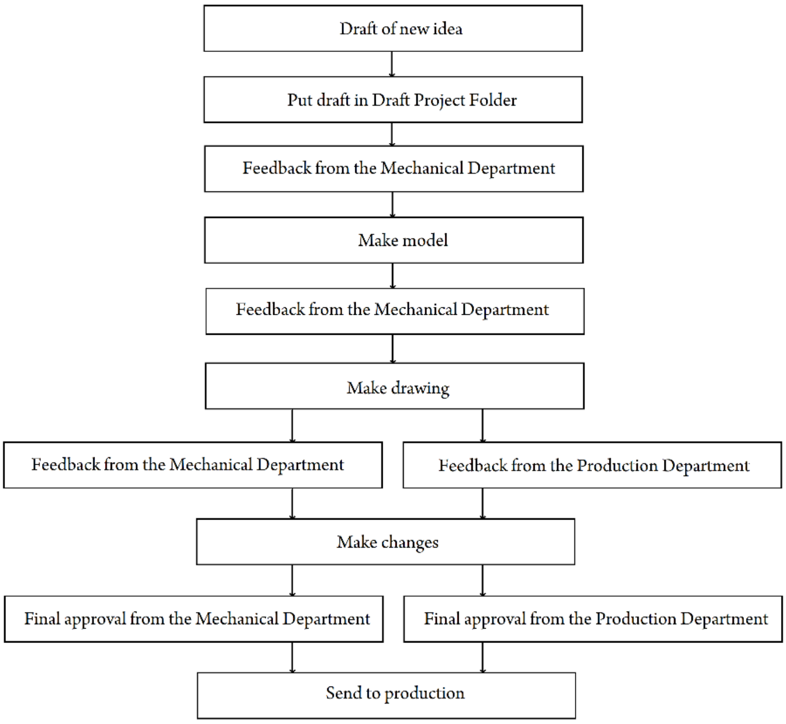

Figure 4.10. DFMA Framework developed for the Company.

Using the framework, the employees at the design department has a clear structure of which steps should be included during the development of a new part or feature. The framework also makes sure that the production department gets involved in the design of the new part or feature on several occasions. Having a clear framework should make sure that no step in the development process is skipped and thus preventing unnecessary mistakes from being made.

During the discussions with the design department another DFMA problem was brought up. The employees wanted generated know-how about design, producibility and undesired features to be in some way stored and preserved. At the time, knowledge about DFMA was passed verbally between the different employees at the design department. Ideally, the generated know-how would be converted into easily accessible design guidelines. The easiest way to approach this problem was to simply set up a document in which the different employees at the design department could fill in things they had learned. In doing so, different rules of thumb could be established.

In late April both the DFMA Framework and the know-how document was presented to the PM. The PM approved of the framework and thought it would decrease the amount mistakes made because of poor communication.

Production design

The fifth step in the Lean implementation process was to begin designing the production system. The prospective production system should ideally contain Lean tools and methods such as; OPF, MO-CO-MOO, JIT, Decouplers, Make-to-final inventory, SMED, the Seven Wastes, Poka-Yoke and process sheets.

The PM had at the time of this implementation step already began production planning. The PM was however interested in how Lean could be further incorporated into the production and assembly system.

The PMs plan was to create three separated subassembly lines which leads up to a final main assembly line. A concept picture of the PMs assembly line system can be seen in Fig. 4.11.

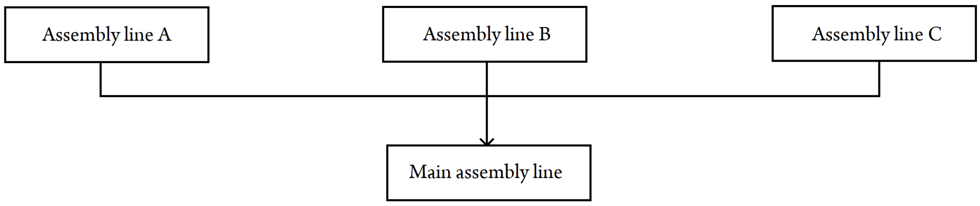

Figure 4.11. The PM's planned assembly line layout.

The PM had a preliminary idea of how each assembly line would look but wanted to further develop the lines as the first products are assembled. Quality control was an area in which the PM was very interested in applying Lean. The PM asked me to investigate how e.g. decouplers and MO-COO-MOO could be applied in the different assembly lines.

Parallel to developing the assembly lines an assembly handbook would be developed. The handbook should in detail describe every part of the assembly process from start to finish. Parts of the handbook would be distributed to the different assembly stations to serve as instructions. The handbook was meant to be developed continuously as products were being assembled. The PM wanted me to investigate how the handbook could be developed and improved with a basis in Lean.

The two above-mentioned tasks were commenced in the beginning of May 2018. I began with looking into how Lean and quality control could be applied at the assembly lines. MO-CO-MOO, decouplers and Poka-Yoke are three Lean concepts that I wanted to incorporate into the assembly lines. Together with the PM we decided to include three types of quality control stations; small decoupler stations after each assembly station, larger quality control stations after each sub assembly line and a final test station after the main assembly line. The decoupler stations enables for MO-CO-MOO capability. At the stations a checklist should be filled in to make sure that each step in the assembly process has been completed. The checklist should preferably be digital to allow for easy registration and to minimise the amount of paper and administration needed. The idea is to have a screen close by the employee that assembles the part. On the screen the employee logs into the system by using his or her personal code. After each assembly step has been performed the employee ticks off tasks in a checklist. This is beneficial as the employee will not forget any steps in the process. The screen automatically collects data and stores it in a sheet. The sheet should collect the following data:

- Who performed the assembly
- When the assembly was performed.
- If all the assembly steps were completed and controlled.
- The serial numbers of the assembled components.

Using the sheet makes it easy to track where a problem arose and what caused the problem as the system enables for traceability.

One of the employees at the Company had previously worked within aircraft maintenance. I consulted the employee on how his previous employer had handled quality control. The employee stressed the importance of dual inspections of critical areas to avoid costly mistakes. The employee agreed that a digital solution would be a good solution to implement as paperwork quickly becomes overwhelming. The employee did however say that a paper-based back-up system should be available in case the digital system breaks down. To handle traceability in an easy way the employee suggested to use assembly kits. An assembly kit contains all components necessary to assembly a whole part. Using assembly kits, the person putting together the part only need to register the kit-number in the screen system. Information about the components that are stored in each assembly kit is registered separately. A system like this should ensure efficient traceability as only the kit-number is needed to find the sought component.

After establishing how quality control at the assembly lines should be performed, I began developing the layout of the screens meant to be used at the small decoupler stations. The system should register the employee name using logins. The logins will automatically log-out when the systems have not been used for a while. This will prevent other employees from using someone else's log-in. The system should also display the following things:

- A task checklist.
- A button that, if pushed, displays assembly instructions.
- A button that, if pushed, enables the person that assembles the product to leave suggestions for improvement.

A concept picture of the screen can be seen in Fig. 4.12.

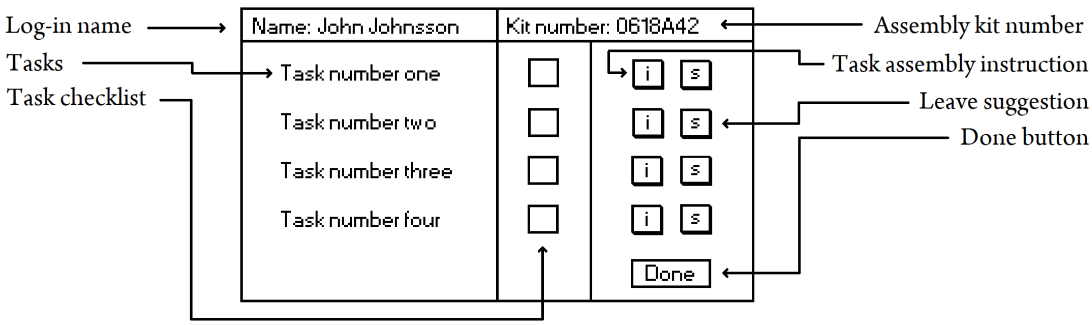

Figure 4.12. Concept picture of assembly screen.

The paper-based back-up system should look similar but without the instruction and suggestion alternatives. Instead, the employees would use a printed version of the assembly handbook for instructions.

The time it takes to perform one task should be measured. This can be done by starting a clock each time a new task is commenced and stopping it once the task is finished. Starting and stopping the clock can be done manually be adding an extra button to the system or automatically e.g. when a task is finished the clock starts for the next task. Measuring the time of each assembly task will help improve the assembly as bottlenecks are easily discovered.

To understand the entire quality control process at the assembly lines I developed an overview. The overview displays the steps needed to ensure good quality and reliable traceability. The overview can be seen in Fig. 4.13.

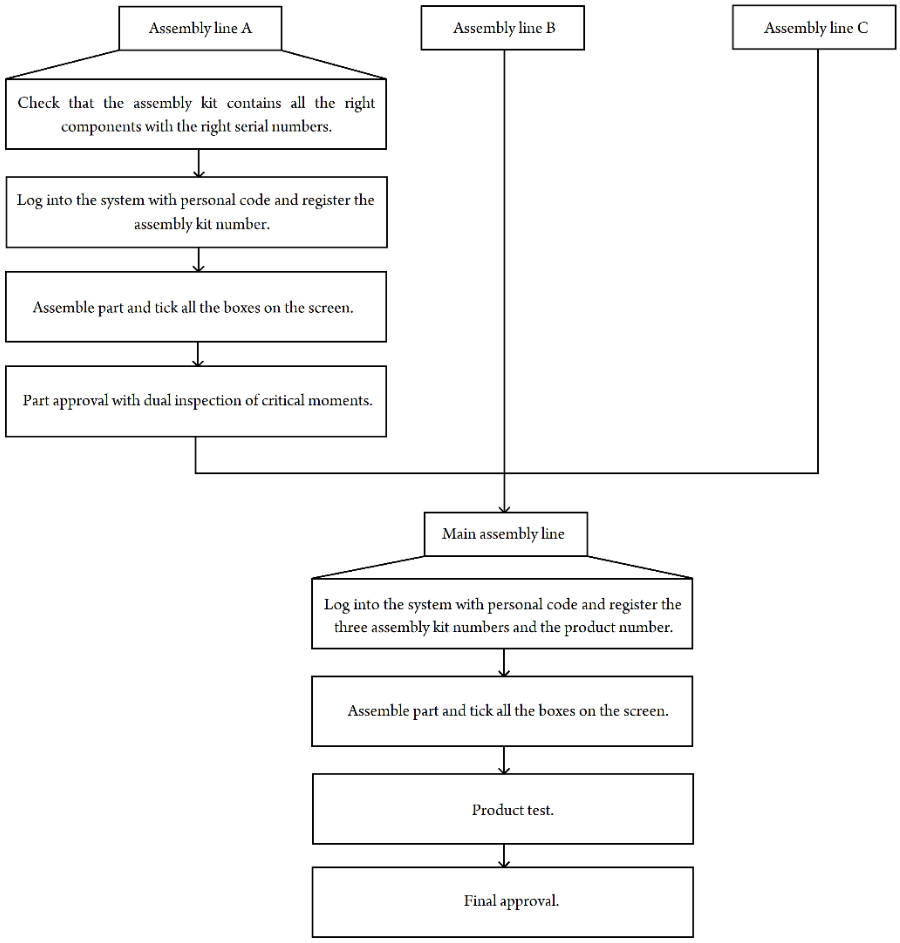

Figure 4.13. Overview of the proposed assembly line layout.

Assembly lines B and C follows the same quality control structure as assembly line A. By using this proposed quality control system, it should be easy to trace components. By simply knowing the product number one knows which assembly kits were used and hence which components that were used.

The second thing I investigated as part of the production and assembly line development was the assembly handbook. I wanted to determine how the handbook should be constructed and how it should be continuously improved as production starts. As the handbook is meant to be continuously altered and improved a digital version would probably be the simplest solution. I believe that the assembly handbook should contain the following things.

- Step by step assembly instructions and comments on things to consider when assembling the part.
- A bill of material for the components used in the assembly.
- Detailed pictures of the where each component go and of the finished assembly.

After discussion with the design department it became clear that fully developing an assembly handbook would not be reasonable before the product has been fully locked for mass production. This, as developing step by step assembly instructions for every component is very time consuming. When a lot of the assemblies build upon previous steps it is often complicated to make changes, even if the system is both digital and well designed. Instead of using the assembly handbook from the start the design department suggested that CAD-generated assembly drawings should be used. After some time, a complete and extensive assembly handbook should be developed. I developed a concept picture of how a page in the assembly book could look when the assembly handbook is fully developed, see Fig. 4.14. The concept picture seen in Fig. 4.14. is completely fictive.

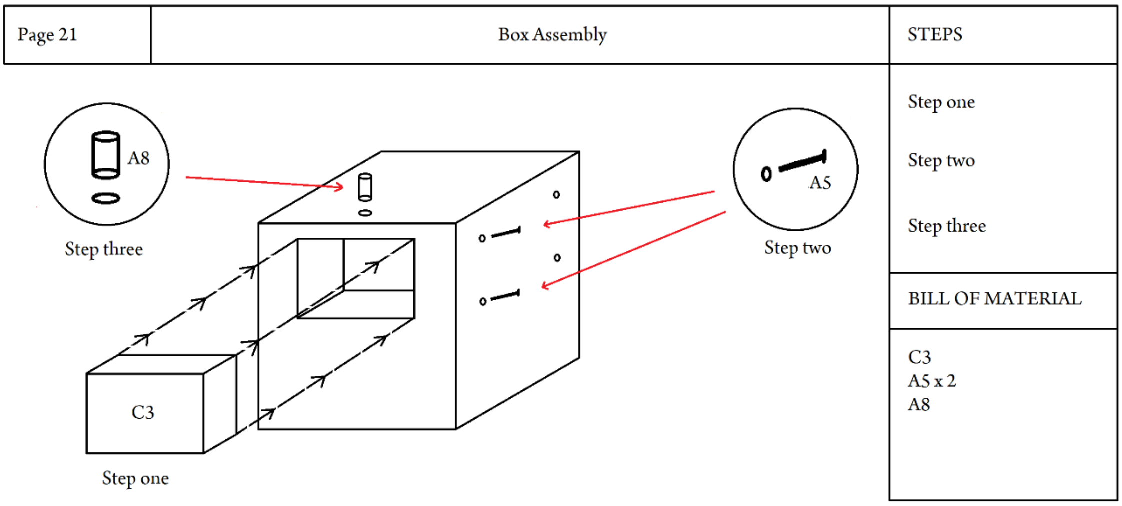

Figure 4.14. Concept picture of a page in the assembly handbook.

To improve the different assembly processes, the employee working at a station should from time to time contemplate if and how a process can be improved. This can be done by asking a set of questions. I would recommend the questions found in the Gemba Walk Framework, see Fig. 4.6. The questions should be visible to the employee that assembles the product to make sure that he or she constantly keeps thinking of ways to improve the process. By routinely applying the questions on the process, improvements should continuously be made.

Mapping and KPIs

The final step in the implementation process is VSM and selection of KPIs. As the Company is small, the KPIs should be few and easy to monitor. This so that the workload of registering is as low as possible. To decrease the amount of work even further I decided to divide the responsibility of KPI registration. The heads of each department should each be responsible to monitor KPIs related to their own operations. The KPIs monitored should be stored in a way so that it is easy to see progress made during a period e.g. monthly. This could easily be done by designing a system in Google Sheets. Using the system, the heads of the Company can easily follow-up on progress made over the last few months. This allows them to make fact-based decisions about the development of the Company.

Together with the heads of each department I decided on which KPIs to use at the Company. The electronics department and the mechanics department could not think of values that would be relevant to compare from period to period. It could be possible to measure the number of tasks completed on time within the departments. However, those values would not say much about the overall progress of the Company as the tasks may vary a lot in complexity and scope. As the electronics and mechanics department did not need to monitor KPIs, the selected KPIs was instead centred around production and operations. The selected KPIs were as follows:

Production:

- ➢ Availability, defined as Run Time divided by Total Time.

- ➢ Performance, defined as Produced Products/Production Target.
- ➢ Quality, defined as Good Parts/Total Parts
- ➢ Cycle ratio, defined as Normal Cycle Time/Real Cycle Time.

Operations:

- ➢ Units sold.
- ➢ Revenue.
- ➢ Costs.
- ➢ Profit

What KPIs that are used may vary over time as the Company evolves. New KPI may be added and old ones removed. Using the above-mentioned KPIs a system was designed in Google Sheets. A screenshot of the system can be seen in Fig. 4.15.

Edit / **Don't Edit**

	KPI	March 2018	February 2018	January 2018	December 2017	November 2017
Operations	Units Sold	20	5	1	0	0
	Revenue	3,000,000.00 kr	600,000.00 kr	120,000.00 kr	0.00 kr	0.00 kr
	Costs	2,000,000.00 kr	1,000,000.00 kr	800,000.00 kr	500,000.00 kr	400,000.00 kr
	Profit	1,000,000.00 kr	-400,000.00 kr	-680,000.00 kr	-500,000.00 kr	-400,000.00 kr
Production	Run time [h]	100	50	20	10	10
	Total time [h]	160	160	160	160	160
	Availability	**0.63**	**0.31**	**0.13**	**0.06**	**0.06**
	Produced products [Pieces]	50	20	10	5	1
	Production target [Pieces]	55	30	12	5	1
	Performance	**0.91**	**0.67**	**0.83**	**1.00**	**1.00**
	Rejects/reworks [Pieces]	20	20	30	20	10
	Good parts [Pieces]	480	220	100	40	30
	Quaility	**0.96**	**0.92**	**0.77**	**0.67**	**0.75**
	Real cycle time [min]	15	20	30	40	45
	Standards cycle time [min]	13	13	13	20	20
	Cycle time ratio	**0.87**	**0.65**	**0.43**	**0.50**	**0.44**

Figure 4.15. Screenshot of the developed KPI monitoring system.

The values seen in Fig. 4.15. are fabricated. Using the proposed KPI follow-up system it is easy to assess company progress.

In the beginning of May, the KPI system was presented to the COO. The COO liked the concept of following-up on values that describes the development of the Company. The COO did however find it important to make the information accessible to everyone at the Company. The COO also wanted to minimise the amount of manual labour and the number of sheets used at the Company. The COO therefore suggested to incorporate the KPI follow-up system in the Andon screen system. By doing so, fewer sheets are used and the information becomes clearly visible to everyone at the Company.

After the discussions with the COO, the KPI follow-up system was integrated into the Andon screen system. All the KPIs was stored in the Andon system but only some of the KPIs was displayed on the public screen. The KPIs that were displayed were “Produced products”, “Production target” and “Quality”. The KPIs showed on the screen may however alter with time depending on what the managers want to display.

The final thing that was supposed to be done as part of the Lean implementation at the Company was a VSM. However, after some discussions with the PM we concluded that a VSM would not be of much use at the Company at that moment. The Company was still in the stage of developing the product and as of this none of the material and data flows had been fully locked for continuous use. For this reason, the VSM would not create any lasting value and the PM therefore advised me not to conduct the mapping.

4.6 Conclusion

This chapter has evaluated the Lean tools, methods and principles mentioned in the results chapter based on their suitability at young and small companies. The evaluation has been performed both by me and by the heads of the Company. The evaluations showed that the majority of the mentioned Lean tools, methods and principles are well suited to be implemented at young and small companies. Only a few of the tools and methods are less suited. The reason that some of the tools and methods should not be implemented is that they are either overwhelming in complexity or that they are not compatible with the uncertain customer demand that often exists at young and small companies. The rates of change and expansion at young companies are also contributing factors to why some Lean tools are less suitable to implement. The Lean tools, methods and principles that are well suited and those that are less suited to be implemented at small and young companies can be seen summarised below.

- Well suited: The Toyota Way, Toyota's 14 principles, Lean Leadership, JIT, Autonomation, Kaizen, DFMA, QFD, FMEA, TPM, Suggestion system, The Five S's, The Five Whys, Pareto diagram, Ishikawa diagram, RCA, QC-circles, TQC, Poka-Yoke, SMED, Andon, OPF, VSM, KPIs, The Seven Wastes, Gemba Walk, MO-CO-MOO, Decouplers, Make-to-final inventory, Process sheet, PSM and the Production Cost Model.

- Less suited: Six Sigma, Small stock, Zero Inventory, Statistical follow-up on productivity and or quality and SPC.

This chapter also investigated what aspects to consider when implementing Lean at small and or young companies. After looking at previous Lean implementations it became clear that the following are the most significant aspects to consider when implementing Lean at small companies:

- Management need to be fully committed to the implementation project.

- The Lean implementation project needs to get proper funding.

- The employees at the company needs to be involved in the implementation process.

- KPIs should be established so that progress can be registered.

At young companies there are some additional aspects to consider. Young companies tend to have a habit of changing its operations as the company grows. For this reason, it might not be a good idea to invest too heavily in a single Lean project as the process that the tools are being applied to might alter or disappear within a near future. Lean should instead be applied in a broader fashion at younger companies so that lasting results can be achieved. At young companies it is also important to plan the Lean implementation project so that it is synchronised with the company's expansion. This became evident during the practical Lean implementation performed at the Company.

The implementation project carried out at the Company displayed similar results as the previous research had pointed towards. Most of the Lean tools, methods and principles were applicable at the Company. Some of the tools were however not suited to be used at certain moments e.g. VSM. This as the timing of the implementation project and the Company's status did not always align. This is something that strengthens the argument that timing is an important aspect to consider when implementing Lean at young companies.

At the end of the implementation project it appeared that only a few of the implemented Lean tools and systems were being used on a regular basis. The majority of the employees at the Company were only using a few of the tools and the rest were not using any of them. It became obvious that just because the tools had been taught to the employees it did not mean that the tools would be used. Even though the previous research had stated that lacking commitment from management and employees is the biggest barrier for a successful implementation I did not stress it enough. To truly succeed with a Lean implementation, it is of the highest significance to involve and engage the people concerned. I do however not consider the implementation project a failure. The Lean tools, methods and principles have been taught to those at the company and Lean related systems have been created and are ready to be used whenever management deem appropriate.

To summarise my conclusion, it is clear that Lean tools and methods are very applicable at small and young companies. However, to implement Lean tools and methods is one thing, to make people use them is another.

Consumption is the sole end and purpose of all production; and the interest of the producer ought to be attended to only so far as it may be necessary for promoting that of the consumer.

Adam Smith

5

Discussion

THIS THESIS HAD TWO OBJECTIVES. The first objective was to find and describe methods, tools and principles that are central to the Lean production philosophy. The second objective was to investigate how the described tools, methods and principles can be implemented at young and small companies. In this chapter I discuss whether the objectives have been fulfilled. I also discuss the process of writing the thesis and challenges faced on the way.

5.1 Fulfilling the objectives

Regarding the first objective the outcome of my research is presented in chapter three, results. To fulfil the objective, I knew that I would have to complete a significant amount of research. Lean is a term that has been used in a broad variety of ways and the term has become somewhat watered down. Therefore, I decided to only include the tools, methods and principles that are mentioned frequently within different publications. Using literatures that are Peer Reviewed enabled me to find the scientific version of Lean. This was important to do as the term Lean has often been altered by companies and consultancies to fit certain market players. I would argue that the first objective of this thesis has been fulfilled. Reading about the tools, methods and principles mentioned in this thesis should provide the reader with a basic understanding of what Lean is. This thesis can however only serve as an introduction to the subject of defining Lean. To fully describe Lean would need a separate thesis that is completely devoted to defining the term. I would like to make a reservation and say that this thesis may have excluded parts of Lean that others would argue are essential to the concept.

Regarding the second objective the outcome of my research can be found in chapter 4, analysis. I decided to put the Lean implementation research in the analysis chapter to allow myself to make speculative and subjective inputs. I also decided to place the research in the analysis so that the entire implementation part of the thesis can be found in one chapter. This even though some of the information presented about Lean implementation is strictly scientific.

When I was researching barriers for implementation at small companies I wanted to use many sources of information so that the conclusions made in the separate publications could be verified. I believe that this approach clearly highlighted the most important factors to consider when implementing Lean at a small company.

Finding information about Lean implementation at young companies was difficult. There has been little to no research on the subject. I find this to be both good and bad. Not finding any previous research made the thesis more difficult to write as my conclusions could not be verified. Exploring a new subject is however exciting as it enables this thesis to make a scientific contribution.

To answer whether the second objective has been fulfilled is not as easy in comparison to the first objective. The second objective was to display how the different Lean tools could be implemented at a young and small company and from that implementation make conclusions about important factors to consider when implementing Lean. The different tools and methods have been implemented at the Company. However, the conclusions made cannot be verified as the implementation was only done at one company. With regard to the limited time and resources dedicated to this thesis, I would argue that the objective has been achieved. I would however like to argue that a larger research project on the subject would be needed to verify and strengthen the conclusions made in this thesis.

5.2 Writing the thesis

Before I started my thesis project I roughly knew what I wanted to write about. As time went on the thesis changed, both in structure and in content. I did however never feel that I needed to make any drastic changes. In the end I believe the thesis achieved what was stated in the target document and fulfilled its purpose.

The process of writing this thesis was both rewarding and challenging. The largest challenge I faced during my thesis project was to keep the managers and employees at the Company interested and engaged in the Lean implementation. As the Company was in an expansive state during my time with them, I often felt that my work was put on the back burner. This is of course natural as a growing company needs to prioritise. It did however make it harder for me as I continuously needed to motivate every step in the implementation process. In the end I do however consider this challenge beneficial as it helped me grow as a future professional.

The most rewarding part of the thesis was seeing the Lean tools being practically applied. When one reads about the tools it is never fully clear exactly how they are supposed to be implemented. To implement the tools was therefore rewarding as I could follow the entire process. I hope that this thesis to some extend reflect my experience so that the reader too can see how Lean can be practically implemented at a young and small company.

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Appendices

Appendix 1. Form used at Company Evaluation

Faculty of Engineering LTH

Lean Tools - Company Evaluation
Student: Fredrik Hasselgren
Examiner: Professor Jan-Eric Ståhl
Advisor: Doctor of Technology Fredrik Schultheiss
Date: 14/02/18

Lean Tools – Company Evaluation

Thesis: Practical implementation of Lean at small and young companies

◯ PM, Production Manager ◯ COO, Chief Operating Officer ◯ CEO, Chief Executive Officer

This evaluation is carried out to assess different Lean tools, methods and principles based on the likelihood of the them being implemented at the Company. The methods, tools and principles are to be ranked on a scale from one to five, five being very high likelihood of the concept being implemented and one being very low. The participants are also encouraged to leave comments below each method, tool or principle.

The Toyota Way ◯1 ◯2 ◯3 ◯4 ◯5

Toyota's 14 principles ◯1 ◯2 ◯3 ◯4 ◯5

Lean Leadership ◯1 ◯2 ◯3 ◯4 ◯5

Appendix 2. Lean Handbook

Lean handbook

Project: Lean Handbook
Date: 13.03.18
Latest update: 13.03.18
Authors: Fredrik Hasselgren, master thesis student.

Intro

This handbook was developed at the Company to be a guide to Lean principles, methods and tools for all employees at the company. The handbook contains a selected number of Lean tools which can be used to find inspiration for more efficient ways to work. The handbook can also be useful as a reminder of how to use different techniques e.g. ishikawa/pareto diagrams.

The Toyota Way [1]

Continuous improvements:

- Challenge – create a long-term vision and face challenges with courage and creativity.
- Kaizen – Improve the operations continuously to create innovation and development.
- Genshi Genbutsu – Go and see. Go to the source and find the facts to make informed and correct decisions. Develop after that consensus and realise the goal at fastest possible speed.

Respect your surroundings:

- Respect – Respect others. Do everything you can to understand each other, take responsibility and strive to create a mutual understanding.
- Teamwork – Stimulate personal and professional development, share possibilities for development and maximise the individuals and the group's performance.

Toyota's 14 principles [1]

1. Base decisions on long-term thinking, even if it has a negative impact on short-term goals.
2. Create process flows that brings problems to the surface.
3. Let the demand govern, avoid overproduction.
4. Smoothen the workload.
5. Stop processes to solve problems, so that the quality is right from the beginning.
6. Standardised operations are the basis for continuous improvements and for personal involvement.
7. Make operations transparent so that no issues remain hidden.
8. Only use reliable, well proven techniques that fits the employees and the processes.
9. Develop leaders that knows the organisation.
10. Develop outstanding persons and work teams that follows the company philosophy.
11. Respect partners and subcontractors by challenging them and helping them become better.
12. Go and see with your own eyes to fully understand the situation.
13. Make decisions slow and with unity – execute them quickly.
14. Become a learning organisation through tireless and constant improvement.

Just-in-Time [2, 3, 4, 5, 6]

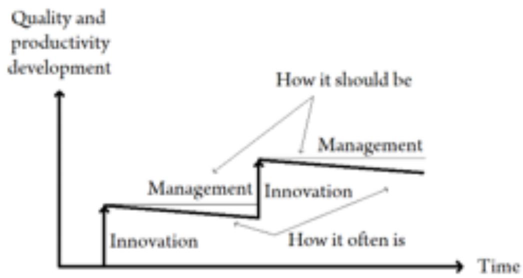
- Having the right thing, in the right amount, at the right location, at the right time.
- Avoid building up stock.
- Stock often hides disturbances in the process e.g. faulty parts do not get noticed.
  Any problem should be dealt with immediately.
- Having low stock highlights problems in the process. This gradually increases quality and productivity.
- JIT decreases the storage cost and decreases the lead times.
- JIT reduces disturbances and variations in process.

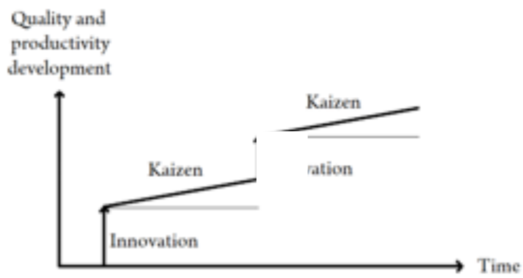
Jidoka [7]

- Create systems that detect production abnormalities and stops the process when they arise.
- Stop a process and immediately fix a problem when is occur rather than waiting to solve the problem later.
- JIT and Autonomation are the pillars which Lean is built on.

Kaizen [2, 8, 9, 10]

- Continuous improvements.
- Small ongoing improvements in quality and productivity in all processes.
- Relationship between innovation and Kaizen improvements.





Design for Manufacturing and Assembly [2]

- Apply a cost minimising mind-set when developing the product.
- Encourage communication and questioning between the production department and the design department.
- Minimise the number of inbound components.
- Improve the assembly properties of the remaining components.

Quality Function Deployment [2]

- Translate the customers' requirements into technical specifications.
- Ingoing restrictions lowers the need to make changes later in the processes.
- Saving the company both money and time.
- Lowers the lead time, hence serving the customer quicker.

Failure Mode and Effects Analysis [2, 9]

Method to ensure that potential flaws have been considered.

1. Form divided into construction and process analysis.
2. Evaluate risk of error, effects of the error, possibilities for error detection.
3. Quantify on a numbered scale.
4. Multiply the three values, high numbers indicate risk factors.
5. Develop measures of improvement.
6. Implement the measure and perform a new FMEA.

The Five S's [2, 9, 11]

- Seiri, sorting out what is necessary and what is not. Keep the things that isn't being used away.
- Seiton, straightening and setting in order. Mark where different things are to be stored so that they can be found easily.
- Seison, sweeping and shining. Clean your own workplace.
- Seiketsu, standardise. Standardise the developed work process.
- Shitsuke, sustaining. Follow the rules at the company and maintain achieved progress.

The Five Whys [12]

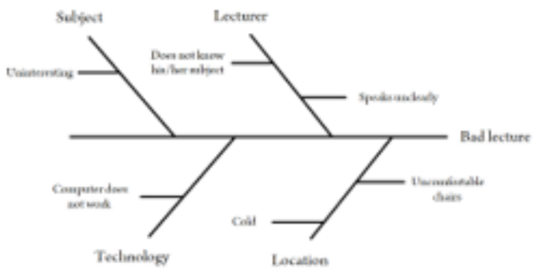
- Avoid treating symptoms. Treat the source.
- Ask why five times to ensure that the problem has been dealt with correctly.

Root Cause Analysis [9]

- Eliminate recurring problems.
- Looks for the underlying cause of the problem.
- Identify root cause, develop and implement curative action.

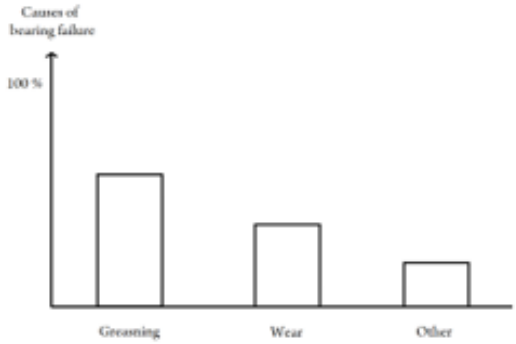
Ishikawa diagram [1, 2]

- Visualise how events result in a problem occurring.
- Uses different lines to derive the different events.



Pareto diagram [1, 2]

- List causes to a problem in a bar graph
- Appoint the percentage of failures that can be attributed to each cause.



Quality Control Circles [2]

- A selected group meet and solve different problems.
- The group solves problems related to their own work.
- The members may use other Lean tools to solve the different problems.

Poka-yoke [9]

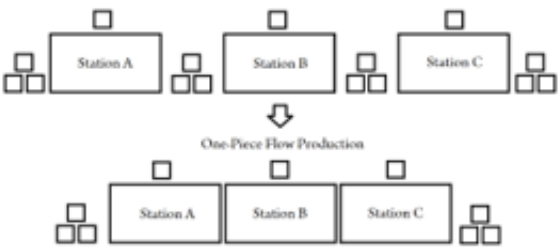
- Japanese term meaning mistake-proofing or defect prevention.
- Design a process in a way so that mistakes physically or procedurally cannot occur.

Single Minute Exchange of Die [2]

- Convert internal changeover time to external changeover time. This lowers the overall time of a changeover.
- Internal changeover time occurs when the process is at a standstill.
- External changeover time occurs when the process is running.
- Prepare for the next step instead of waiting.

One-Piece Flow [1, 9]

Transfer one part at a time without stopping in storages in between.



Value Stream Mapping [1, 9]

- Map the flow of material and data.
- VSM can be performed on any process within the company.
- Find non-value adding activities between processes.
- Eases planning in the long-run.

Key Performance Indicator [1]

- Value that reflect the current status of the company.
- An important tool for analysing progress.

The Seven Wastes [1, 9, 12]

1. Overproduction.
2. Idle time.
3. Transports.
4. Excess processing.
5. Excess inventory.
6. Wasted motion.
7. Poor quality.

Gemba Walk [9]

- Investigate a process to find waste.
- Being busy is not the same as being productive.

MO-CO-MOO [9]

- Make One – Check One – Move One On.
- Inspect a product after each step of the process.
- After an inspection the part is moved forward to the next step in the process.
- A way of controlling quality of produced parts.

Process sheet [9]

- A set of instructions.
- Describes how something should be performed so that mistakes can be avoided.

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