CHALMERS
UNIVERSITY OF TECHNOLOGY

Evaluating the relationship between the implementation of Lean Production and Resource Utilization

A study of manufacturing firms in the western region of Sweden

Master of Science Thesis in the Management and Economics of Innovation Programme

ANTON BRINGSVED
SEBASTIAN DJERF

Department of Technology Management and Economics
Division of Supply and Operations Management
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2016
Master's Thesis E 2016:024

MASTER'S THESIS E 2016:024

Evaluating the relationship between the implementation of Lean Production and Resource Utilization

A study of manufacturing firms in the western region of Sweden

ANTON BRINGSVED
SEBASTIAN DJERF

Tutor, Chalmers: Mats Winroth

Department of Technology Management and Economics
Division of Supply and Operations Management
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2016

Evaluating the relationship between the implementation of Lean Production and Resource Utilization

A study of manufacturing firms in the western region of Sweden

Master's Thesis E 2016:024

Department of Technology Management and Economics
Division of Supply and Operations Management
CHALMERS UNIVERSITY OF TECHNOLOGY
SE-412 96 Göteborg,
Sweden
Telephone: + 46 (0)31-772 1000

Chalmers Reproservice
Gothenburg, Sweden 2016

ABSTRACT

The concept of Lean production has been described and studied by many researchers and has become a standard in many production settings. There is a trade-off between being flow oriented, i.e. focusing on flow and throughput time, and being resource oriented, i.e. focusing on maximizing the use of resources. This relationship is investigated in this study by a combination of qualitative and quantitative evaluation methods. The study was conducted through a day's visit at 13 manufacturing companies from different industries in the western region of Sweden. The data was acquired through observations and interviews at each company. Lean production is also evaluated from a sustainable competitive advantage point of view, comparing empirical findings with theory.

The findings show of a relationship between the implementation of Lean production and the amount of waste in terms of non-value adding activities for operators. The percentage of Lean implementation also correlates with the overall equipment efficiency measures at the participating firms. The findings show that a higher degree of Lean production implementation corresponds to a lower degree of wasteful, non-value adding activities in the production. Moreover, there are some indications that a high degree of Lean production implementation corresponds to a higher degree of OEE as well. However, the relationship is more evident in the comparison between Lean implementation and operators non-value adding activities than when comparing Lean implementation and the OEE measure.

Lean production is also argued to provide a sustainable competitive advantage for companies that successfully manage to permeate Lean production throughout their organization. Lean production is evaluated from the perspective of the VRIO model and it is concluded that the *organizational fit* is the most crucial criterion in order to capitalize on the value and the savings enabled by implementing Lean production. Further, the findings indicate that companies with a high degree of Lean production implementation is rather rare. The researchers argue that the rarity is due to the difficulty to imitate the full concept of Lean production. If these criteria are met and if Lean production is permeated through the organization, the researchers argue that Lean production can be a sustainable competitive advantage.

Overall, this study provides an indication of how well large companies within the western region of Sweden have implemented Lean production in their production process. Further, this study provides an indication to practitioners that implementing Lean production could provide means to lower non-value adding activities for the operators and to increase the OEE measure of the machinery. The theoretical contribution of this study is an assessment tool for evaluating the percentage of Lean production implementation. This assessment tool is argued to be suitable for future studies with similar time constraints and similar geographical settings. This research also contributes to the discussion whether Lean production can be regarded as a sustainable competitive advantage.

Keywords: Implementation of Lean production, Resource efficiency, Flow efficiency, Resource utilization, Lean a sustainable competitive advantage,

ACKNOWLEDGMENTS

This Master's thesis was conducted during the spring semester of 2016 at the Master's Program Management and Economics of Innovation at Chalmers University of Technology in Gothenburg, Sweden. This research was initiated and conducted in collaboration with Triathlon Group, based in Gothenburg.

We would like to thank Kristina Ljunggren and Linnea van Lokhorst at Triathlon Group for the opportunity to write this Master thesis and for their guidance throughout this research. In addition, we would also like to thank all employees at Triathlon Group for their support and enthusiasm regarding this research. Several meetings have been conducted at Triathlon Group where their employees have helped us with valuable insights regarding plant visits, interview techniques and worked as a sounding board for the analysis.

We would also like to thank our supervisor at Chalmers University of Technology, Mats Winroth at the Supply Chain and Operations Management division. Mats has been of great guidance for the completion of this research thanks to his wide experience regarding Lean production. Mats has also been of great support for the structure of this research.

During this research, we have visited 13 manufacturing firms throughout the spring 2016. We would like to thank all participating companies for letting us observe their production processes. Our contacts at each company have designated a lot of time and effort during our visit, especially with regards to the extensive interview. Since all participating firms asked to be anonymous, we cannot thank all contacts by name in this report.

We would also like to thank Peter Almström at Chalmers University of Technology. Peter together with Anders Kinnander established the Productivity Potential Assessment model used in this research and has provided valuable guidance regarding how to conduct this assessment model in a suitable way. Peter has helped us to avoid pitfalls with the assessment model and also been of guidance regarding how to conduct a frequency study.

This Master's thesis has also helped us to gain valuable insight for the manufacturing process in general. To visit 13 manufacturing firms, many within different industries, has been a great experience for us. Different from the otherwise theoretical education at Chalmers University of Technology.

Gothenburg, June 2016

Anton Bringsved Sebastian Djerf

CONTENTS

FIGURES

TABLES

FORMULAS

GLOSSARY

APS = Autoliv Production System

Lean questionnaire = The model used in this research to assess the degree of Lean implementation

Lean implementation = The word used for the implementation for Lean production

MSDD = Manufacturing System Design Decomposition. A method for productivity assessment

OEE = Overall Equipment Efficiency

PPA = Productivity Potential Assessment. A method for productivity assessment

Resource utilization = The word used for the utilization of staff and machinery

RPA = Rapid Plant Assessment. A method for Lean assessment

SCB = Statistiska Centralbyrån, Statistics of Sweden

SPS = Scania Production System

TPS = Toyota Production System

TUTKA = tuotantojärjestelmän kehittäminen ja arviointi. A method for productivity assessment

VPS = Volvo Production System

VRIO = A model used to assess whether a product/service is regarded as a sustainable competitive advantage

CHAPTER 1 - INTRODUCTION

After 45 laps at the Nürburgring race track in Germany, the driver of a Formula 1 car has to refill gas and change tires. Ten mechanics await the pit stop and within less than 3 seconds the car is back on track. The exchange time is continuously improved with the aim to minimize the waiting time for the car to almost nothing. Imagine an opposite scenario where instead of ten mechanics maintaining one car, one mechanic maintains ten cars. The pit stop will take minutes. In the highly competitive environment of a Formula 1 Grand Prix, the first scenario is a must to have a chance of winning the world champion title. The cost however is a tenfold increase of mechanical salaries. These two scenarios exemplify the tradeoff between flow - and resource efficiency. This tradeoff and how it relates to Lean production will be described in the following chapter.

This section will describe the theoretical background, a short description of Triathlon Group as well as the identified problem and purpose with the study. The research questions and limitations of the study will also be presented.

1.1 Theoretical background

The globalization has resulted in hostile markets and competitive market atmospheres. The competition extends from local competitors to competitors on the other side of the globe. The manufacturing industry has been especially exposed due to competition from low labor cost countries. This has resulted in price pressure and a cut of margins for many companies. In addition, the demand for customized products with short lead times has increased. Not only is the cost of the product an important competitive advantage, but speed has become an important order winning criterion (Bellgran & Säfsten, 2010). Efficient manufacturing has become more important than ever in order to remain competitive.

When efficient manufacturing became increasingly important for companies in order to stay competitive, different philosophies emerged. These philosophies aim to improve the overall productivity of manufacturing firms in various ways. One of the most prominent and widely spread philosophies is Lean production. The Lean philosophy emerged from the Toyota Production System (TPS) developed by Toyota Motor Company in the second part of the 20th century (Ohno, 1988). TPS was later brought to the western manufacturing companies under its new name *Lean Production* during the 1990's (Krafcik, 1988), (Holweg. 2007). Shah and Ward (2007) however argue that there are cultural differences between western countries and Japan and that the original structure of TPS often needs to be altered to fit the western culture.

In their book *This Is Lean*, Modig and Åhlström (2012) explain the different dimensions of Lean production. On a high level of abstraction, Modig and Åhlström (2012) argue the necessity to constantly have access to information within an organization. They illustrate this through an example of a game of football. The first thing that comes to mind when discussing how to score goals and winning games is tactics, strength of the players, the opposition etc. This is however not the essential information you need to play the game of football. The most basic level of information, directly critical for the game to be played, is; that all players always see the ball and the goal, that they see all the other players on the pitch and hear the referee. These things are essential for the game and likewise is the importance of information in an organization.

Flow efficiency is, next to the necessity of information, the other cornerstone of Lean Production. With a flow efficient strategy, the flow unit is at focus where a firm tries to maximize the value receiving time on that unit (Modig & Åhlström, 2012). Moreover, Rahani and Al-Ashraf (2012) argue that Lean tools help identify non-value adding activities and therefore be able to reduce unnecessary steps (waste). As a result, managers could reduce work-in-process inventory, lower the throughput time and most importantly increase the flow of products (Rahani & Al-Ashraf, 2012). Karlsson and Åhlström (1996) further explain that a better flow of products is one major benefit of the implementation of Lean Production. Modig and Åhlström (2012) conclude that the access of information in combination with the constant focus of a high level of flow efficiency are the two main principles of Lean production.

Lean production is as described flow oriented and focuses on the throughput time. However, Modig and Åhlström (2012) argue that many Swedish manufacturing firms instead emphasize on a high degree of resource utilization and have done so for the last two hundred years. The degree of resource utilization can be measured on different organizational levels including both operators and equipment. Hence, the definition of resource utilization in this study is both utilization of labor and utilization of machinery. Resource utilization indicates how well the resources are used for a specific period of time. The reason for companies to strive for a high resource efficiency is the opportunity cost. Opportunity cost symbolizes the cost of not using the resource. The excessive capacity is in a sense wasted since the invested capital could have been used to generate value through other means. Modig and Åhlström (2012) further elaborate that the basic principles of a high level of utilization are specialization and that work is divided into smaller tasks performed by different functions. Hence, to find economies of scale has been a key objective of resource utilization. By increasing the utilization of resources, so that staff and machinery can be used more cost efficient, product cost will decrease.

In the illustration of the Formula 1 example, the obvious winning strategy is to maximize flow efficiency at the cost of a low degree of utilization i.e. high cost for mechanical salaries. However, the strategic decision to focus on throughput time over a high level of utilization is not always favorable. In many cases the tradeoff between flow efficiency and resource efficiency is troublesome for managers. Resource efficiency focuses on maximum utilization of current capacity and is common when resources are either scarce or associated with high cost (Modig & Åhlström, 2012). Modig and Åhlström (2012) further describe that flow efficiency on the other hand, focuses on minimizing the throughput time which is the winning strategy for Formula 1 Grand Prix. Thus, the trade-off between a low throughput time and a high degree of utilization of resources is again troublesome for production managers.

1.2 Problem identification

The relationship or trade-off between Lean production and a high level of utilization is not established among manufacturing firms in the western region. There is a general view that there is a constant trade-off between either a high level of flow efficiency and a high level of resource utilization. Where throughput time is of the essence, flow efficiency is often preferred over resource efficiency. However, where resources are scarce or costly, a high level of resource utilization is the most favorable strategy. This view almost implies that the implementation of Lean production reduces the level of resource utilization among Swedish manufacturing firms. Moreover, since all manufacturing firms contacted for this research actively strive to be more "Lean" might imply that these firms do not see unutilized staff and/or machinery as a waste, based on previous argument. Hence, the relationship for how the implementation of Lean production affects the degree of resource utilization calls for further investigation.

The level of utilization is, in theory, well established among Swedish manufacturing firms. Statistics of Sweden (SCB) gather these data each year with the help of surveys. Almström and Kinnander (2011) however, describe that there is a mismatch between statistical self-assessment surveys regarding resource utilization and the actual level of utilization found in Swedish manufacturing companies. Moreover, there is also little information of how far Swedish manufacturing firms have come in their implementation of Lean production principles. Although many firms actively strive to follow Lean production, few or no assessments have been conducted in the western region of Sweden to assess the level of Lean implementation[1]. The lack of information for these two parameters naturally affects the research of the relationship between Lean production implementation and resource utilization why these two parameters need to be assessed in this research as well.

Manufacturing firms implement Lean production in order to make their production more efficient and stable. However, Lean production is complex and there are many challenges related to the implementation. Some companies are very successful in their implementation of Lean production and gain a competitive edge against their competitors while other companies fail to gain this advantage. How resources and capabilities form the basis of long term competitive advantage is studied by many researchers. The same applies to Lean production. However, studies investigating how Lean production affects the competitiveness among Swedish manufacturing firms is not established. This information gap is important to fill why this research will explore the relationship between Lean production and sustainable competitive advantage at manufacturing companies in the western region of Sweden.

1.3 Corporate Background

Triathlon Group, is a management consulting group based in Gothenburg, Sweden. They collaborate with large organizations and multinational companies with base in the Scandinavian region in order to strengthen these companies' competitiveness. They focus their consulting efforts towards five main practices. One of these areas of practice, and the one that the researchers have cooperated with throughout this research, is Production Management.

Triathlon Group have a strive to improve and develop their abilities in order to help customers improve their business in the best possible way. The Production Management practice are in

[1] Lean implementation will henceforth be used as short for Lean production implementation

this case the one that focus on improving productivity within manufacturing. Lean production is one of the Production Management practice's most commonly used strategy for productivity improvement and is also an area where they want to gain more knowledge. In order to get a deeper understanding of the customers' needs, Triathlon Group wants the following study to discover the degree to which Swedish manufacturing companies have implemented Lean production as well to how Lean production and resource utilization relates to each other.

1.4 Purpose

The purpose of this research is to analyze the relationship between the implementation of Lean production and the resource utilization in a Swedish manufacturing setting. In order to execute this, a suitable assessment tool needs to be formulated at an initial stage, both to assess the degree to which firms have implemented Lean production as well as to assess their resource utilization. Therefore, this report aims to both investigate a proper tool that is suitable for an assessment of Swedish manufacturing firms as well as to do the actual analysis of the relationship between Lean production implementation and the resource utilization. In addition, the researchers will also investigate if Lean production can be regarded as a sustainable competitive advantage. The analysis regarding Lean as a competitive advantage will be based on the found relationship between Lean production implementation and resource utilization as well as related theory.

1.5 Research Questions

With regards to the background, problem identification and purpose; the research questions of this research is as follows:

RQ1. What is the relationship between Lean production implementation and resource utilization among manufacturing firms in the western region of Sweden?

RQ2. Based on the empirical findings and related theory, can Lean production be regarded as a sustainable competitive advantage?

1.6 Limitations and delimitations

One of the most evident delimitation of this report is the selection process related to the size of the participating companies. The researchers actively decided to remove small manufacturing firms from the list of potential participating companies. This since smaller manufacturing firms were considered to lack a sufficient budget and the right competence to be able to implement Lean production in a structured way. Thus, manufacturing firms with less than 500 million SEK in sales or less than 150 employees, both at corporate level, were excluded from this research. This selection was discussed and finalized in consultation with employees at Triathlon Group as well as with our supervisor Mats Winroth at Chalmers.

Another delimitation was made regarding what type of industries that were suitable for this study. Since the researchers could not exclude any industries based on fact, all industries were initially considered potential for this research. However, after discussion with professors at

Chalmers, process industries such as refineries etc. were excluded from this research since frequency studies were considered hard to conduct at these companies. However, these firms are not that labor intense, often less than 150 employees, why several of the process based companies in the western region already had been excluded.

This research also has limitations. These are mainly related to time constraints. Due to these constraints the number of firms analyzed have been limited to 13 manufacturing firms ranging from medium to large sized. This research would benefit from a greater number of participating companies but since each company visit requires a large amount of time and effort from the researchers, including transportation, there was not enough time to conduct a broader study with regards of the deadline at the end of the semester. Moreover, in regards to these constraints, the geographical focus area for this study consisted of manufacturing firms based in western region of Sweden.

CHAPTER 2 - LITERATURE REVIEW

In order to assess and compare resource utilization with the principles of Lean production it is essential to understand the two parts and how they relate. There are different views and definitions of both resource utilization and Lean production and this literature review aims to presents these different views. The first part of this review addresses earlier studies made of this relationship. This is followed by a section describing resource utilization and methods for how to assess the utilization at manufacturing firms. This chapter will also give a description of Lean production principles and a set of tools for how to conduct Lean assessment for manufacturing firms. Theory stating if Lean production can be regarded as a sustainable competitive advantage concludes the chapter.

2.1 Lean production

The increased competition over the last two decades have prompted manufacturing firms globally to search for new manufacturing philosophies (Shah & Ward, 2003). Ward and Shah (2003) state that Lean production has emerged as one of the most commonly used philosophies to respond to the threat of increased global competition. Lean production has its origin from the Toyota Motor Company and received global recognition when Taiichi Ohno published the book *Toyota Production System (TPS)* in 1978 (Shah & Ward, 2007). Lean production is widely used in the automotive industry as a means to compete regarding price (Katayama & Bennett, 1996).

The term *Lean* was first coined in the late 1980’s by Krafcik to describe the manufacturing system used by Toyota. After a few years, Womack, Jones and Roos first used the term Lean production in their publication *The Machine That Changed the World* as a way to characterize Toyota’s production system (Shah & Ward, 2007). Over the years, Lean production has found acceptance in various manufacturing operations and gained a strong position compared to the more traditional manufacturing philosophies (Doolen & Hacker, 2005). Rinehart, Huxley and Robertson (1997) further states that the early literature within the area of Lean production claims that Lean will be the undisputed manufacturing standard of this century. However, since TPS is both multifaceted and complicated it was not easy for western managers to comprehend the true nature of the production process (Shah & Ward, 2007).

Further, Shah and Ward (2007) argue that western managers often focused on a single, visible aspect of the process while missing the highly inter-dependent links of the system as a whole. Hines, Holweg and Rich (2004) further argue that when implementing Lean production, it is important to understand the different levels of abstraction. Lean production can be viewed from both an operational level and a strategic level with different aspects to consider at each level. They argue that it is crucial to understand these abstraction levels to be able to implement Lean production in a successful way. In line with this, western firms have adjusted the original view of the Toyota Production System to more fit their own culture. Scania Production System, Volvo Production System and Autoliv Production System are some of the Swedish examples and modifications of TPS (Autoliv, 2016), (Scania, 2016), (Volvo, 2016). The following quote from Autoliv illustrated the relationship between Lean production and in this case Autoliv Production System (APS) (Autoliv, 2016).

The fundamental goal of any business is to produce the highest value products and services with the least amount of time, effort and cost. This may sound simple in theory, but it's difficult in real life. To achieve this goal Autoliv has implemented the principles of Lean Manufacturing throughout its plants under the name Autoliv Production System (APS).

In their book *This is Lean* Modig and Åhlström (2012) describe the essence of Lean production. In order to understand the core of Lean production they argue that one must understand the two different types of efficiency within production, namely resource efficiency and flow efficiency. Being resource efficient is described as a production method where the degree of utilization of resources (costly equipment or costly experts etc.) is planned and used to their maximum capacity. Modig and Åhlström (2012) illustrate this with a story about a patient that has to wait weeks in order to get a proper diagnosis from various doctors (costly experts). The focus is to utilize the doctors rather than to minimize the waiting time for the patient. Flow efficiency focuses on the opposite. The goal is to minimize the throughput time for a product throughout the system rather than maximizing the utilization of resources. Modig and Åhlström (2012) illustrate this with another example from healthcare. In this example the doctor, the one that can give a complete diagnosis, awaits the patient. By doing so the patients waiting time between different steps in the process is reduced to a fraction of the former time. Modig and Åhlström (2012) therefore conclude that the main concept about Lean production is the emphasis on flow efficiency over a high degree of utilization of resources.

Lean production is a multi-dimensional approach that consists of a wide variety of manufacturing practices such as just-in-time and supplier management etc. (Shah & Ward, 2003). Shah and Ward (2007) propose a definition to capture the many facets of Lean production:

Lean production is an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability.

Lean production focus on takt-time, the amount of production that the customer demand at a specific time unit (Shah & Ward, 2007). However, since many manufacturing firms face changing demand, Lean production is also related to smoothing techniques such as “heijunka” to adapt to these changes. Lean production also consist of numerous tools and practices. Marin-Garcia and Carneiro (2010) conclude that Lean production relates to 13 different practices. This is based on an extensive literature review where they have studied Cronbach’s alpha to assess the correlation between the manufacturing system and the practices. This is further elaborated in section 2.2.2 *Assessment method 2* (Marin-Garcia & Carneiro, 2010) below.

Moreover, Karlsson and Ahlström (1996) have developed a model which summarize the important principles within Lean production. They argue that the ultimate goal of implementing Lean production in an operation is to enhance quality, reduce lead times, lower cost, increase productivity and to establish a flow in the production process. According to Karlsson and Ahlström (1996) Lean production consists of practices such as *Continuous improvement, Multifunctional teams, zero defects/JIT, Vertical information systems, Decentralized responsibilities/integrated functions, Pull instead of push* and most importantly the *Elimination of waste.* In addition, Hines, Holweg and Rich (2004) stress that companies should use widespread measures such as overall equipment efficiency (OEE) to support the strive to eliminate waste. OEE is not part of the traditional Lean production methodology. However, Hines, Holweg and Rich (2004) still argue that it is a good mean to supplement the Lean techniques and measure the success rate of the Lean implementation.

2.2 Resource Utilization

Manufacturing firms in Sweden and other high-cost countries face an ever present threat of aggressive competition in the global market (Sundkvist, Hedman & Almström, 2012). Regions, especially in east Asia have gained rapid economic growth the last four decades due to the improvement within manufacturing and cheap labor (Hallward-Driemeier, Iarossi & Sokoloff, 2002). Moreover, according to Statistics Sweden (Statistiska Centralbyrån, 2016), the utilization rate of Swedish firms varies between 85-90 percent (except for 2009) see Figure 1 (Statistics Sweden, 2016). Based on these changes in the competitive landscape, outsourcing to low-cost countries is the only natural step to increase profitability. However, firms in Sweden and other western countries can increase their competitiveness in more ways than merely to lower employee salaries e.g. increasing the resource utilization (Sundkvist, Hedman & Almström, 2012). Almström and Kinnander (2006) argue that since the capacity utilization data presented by Statistics Sweden is gathered by questionnaires and surveys, there are reasons to believe that some of these data points are based on wishful thinking i.e. that firms still have potential to increase their level of utilization.

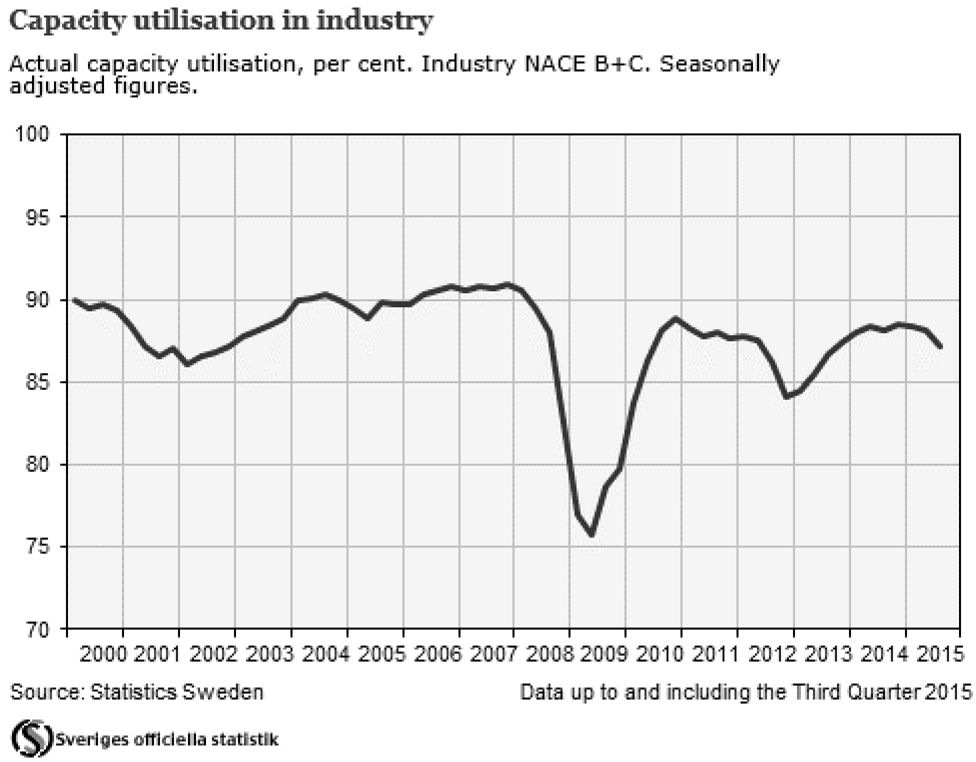

Figure 1. Average capacity utilization in Swedish industry. Source: Statistics of Sweden

Utilization is often defined as the relationship between the actual output from a person or machine, and the potential output that can be produced (Corrado & Mattey, 1997). However, there are debates on what the potential or maximum output really is. Firms have the potential to utilize their staff and machinery 24 hours a day 365 days a year. This definition however is not very realistic (Corrado & Mattey, 1997). Corrado and Mattey (1997) argue that the greatest level of output is within a realistic work schedule, taking account of normal downtime and assuming sufficient availability of inputs to operate machinery and equipment. Statistics Sweden define maximal capacity as the maximal capacity with the current production method i.e. if a firm produce for 8 hours a day, the maximum capacity is 8 hours and not 24 hours (Statistics Sweden, 2015). Moreover, Statistics Sweden presents utilization as the average ratio of the maximal capacity measured during a quarter of a year, expressed in percentage (Statistics Sweden, 2015). The most common definition of potential or maximal is therefore based on the scheduled or planned production time. The definition used for this research is found in Formula 1.

$$Utilization = \frac{Actual\ Output\ During\ Planned\ Time}{Potential\ or\ Maximal\ Output\ During\ Planned\ Time}$$

Formula 1. The definition of Utilization used in this report

2.3 Relationship between Lean Production and Resource Utilization

Resource efficiency emphasize on the resource and aims to maximize the degree of utilization and value adding time for that resource. The cornerstone of Lean production; flow efficiency instead focusses on the flow unit and try to maximize the value receiving time on that unit

(Modig & Åhlström, 2012). In order to provide a clear view of this relationship, Modig and Åhlström (2012) designed the efficiency matrix. In this matrix, organizations are classified based on their level of recourse - and flow efficiency. They argue that the perfect state would be when both resource - and flow efficiency are high. See Figure 2.

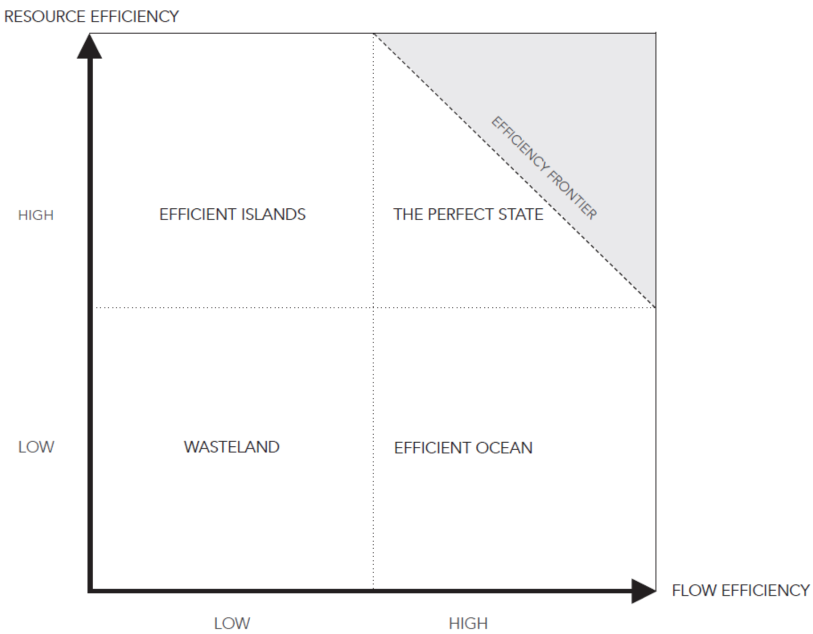

Figure 2. The efficiency matrix (after Modig & Åhlström, 2012, p. 103).

However, Modig and Åhlström (2012) argue that the *Perfect State* is hard to reach due to variations in product type, time and volume. Moreover, the gray area within the *Perfect state* quadrant is impossible to reach based on the same argument. Hence, the maximum level an organization can achieve is the efficiency frontier, the dotted line found at Figure 2. The journey to achieve the *Perfect State* is argued and presented by Modig and Åhlström (2012). Modig and Åhlström (2012) state that the perceived starting position for manufacturing firms is the *Efficient Island* quadrant. If this were true, manufacturing firms only need to improve their flow efficiency to reach the *Perfect State.* The resource utilization is however much lower compared to the firms perceived understanding of their utilization where many activities were superfluous. The actual starting position is instead often in the bottom left quadrant, the *Wasteland.* In the *Wasteland* quadrant, firms need to increase their Lean activities to establish a better flow as well as to increase their resource utilization for their staff and machinery. Modig and Åhlström (2012) argue that companies often fail to achieve both simultaneously. They further argue that manufacturing firms should establish a flow in their production process prior to their attention towards increasing resource utilization. The main driving forces to establish a better flow is teamwork, specialized equipment and standardization (Modig & Åhlström, 2012). This initiative leads the firms into the *Efficient Ocean*, were a Lean focus is established but firms still have a low level of resource utilization. Although specialized equipment and standardization help to establish a better flow efficiency, the creation of a common standard with the help of new equipment made capacity planning easier and helped remove superfluous work (Modig & Åhlström, 2012). This increases the level of utilization at the shop floor. When resource efficiency is established in a flow efficient production process, manufacturing firms reach the *Perfect State*. Since the top most corner is impossible to reach, firm now strive to perfect both resource efficiency and flow efficiency to reach the efficiency frontier.

Moreover, Howell, Ballard and Hall (2001) describe the same relationship in terms of resource utilization and waiting time. They illustrate the dilemma with a queue on an urban road, where the limitations in capacity constrain the ability for cars to flow through the system. If you reach utilization levels close to 100 percent, the waiting time will increase rapidly. This is relationship is also presented in the queueing theory described by Agner Krarup Erlang (Adan & Resing, 2002). Cobham (1954) further adds complexity to the relationship between waiting time and resource utilization. Cobham (1954) states that units that have higher prioritization affects the balance and therefore increases the average waiting time for the whole process. Variations and prioritization all affect resource - and flow efficiency. The relationship of how variation affects throughput time is illustrated in Figure 3.

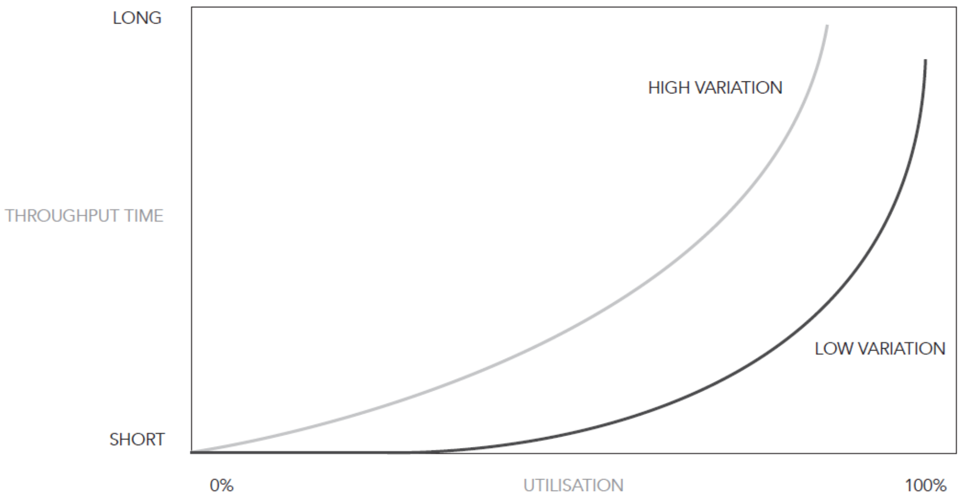

Figure 3. Illustration of how variation effects throughput time

When having explained the two different efficiency aspects, the journey to reach the perfect state and how variation affects throughput time, Modig and Åhlström (2012) elaborate on the definition of Lean production in terms of efficiency. They conclude that Lean is the "new form of efficiency" and they argue that this philosophy emphasizes on flow efficiency not resource efficiency. Lean production focuses on the amount of time spent from the point where a need is identified to the same need is satisfied, often with the sacrifice of a lower level of resource utilization.

2.4 Methods for Production Assessment

To be able to do an assessment of the actual utilization of a manufacturing firm i.e. the resource utilization, the shop-floor level needs to be evaluated (Almström & Kinnander, 2011). Three methods for assessment will therefore be presented below.

2.4.1 Productivity Potential Assessment (PPA)

The PPA model was developed around the mid 2000's by Peter Almström and Anders Kinnander at Chalmers University of Technology. The method was developed on behalf of Nutek (Verket för näringslivsutveckling) to be able to quickly assess the productivity status and also the productivity potential of Swedish manufacturing firms (Almström & Kinnander, 2006). According to Almström and Kinnander (2011), productivity consist of three basic factors: the Method, the Performance and the Utilization, see Formula 2. *Method* refer to the production method, i.e. manual labor vs. a production line etc. *Performance* refer to the performance of either the operators or the machines. *Utilization* refer to the extent that operators and/or machines are utilized. The PPA method focuses on the utilization factor and is therefore the only factor that is measured with this assessment tool (Almström & Kinnander, 2011)

$$Productivity = Method * Performance * Utilization$$

Formula 2. Productivity and its three basic factors

The PPA method has gained great support over the years, from politicians to industry associations to unions etc. The method has been used to assess the productivity potential at around 100 manufacturing firms, often focusing on firms connected to the automotive industry. The strength of the PPA method is its ability to rapidly gather an objective view of the productivity potential in a firm's production unit (Almström & Kinnander, 2006). Almström and Kinnander (2006) further argues that the PPA method can assess the strengths and weaknesses of the production unit and present potential improvements to the management and therefore help Swedish firms strengthen their competitiveness on the global market.

The PPA method is usually performed during one day by two inspectors (Almström & Kinnander, 2011). The work procedure is standardized but Almström and Kinnander (2011) highlight the need to make individual adjustments for each and every company. The two inspectors perform their assigned task individually followed up by a summit at the end of the assessment where both inspectors share their gathered inputs. See Figure 4 for a broad overview of the work procedure.

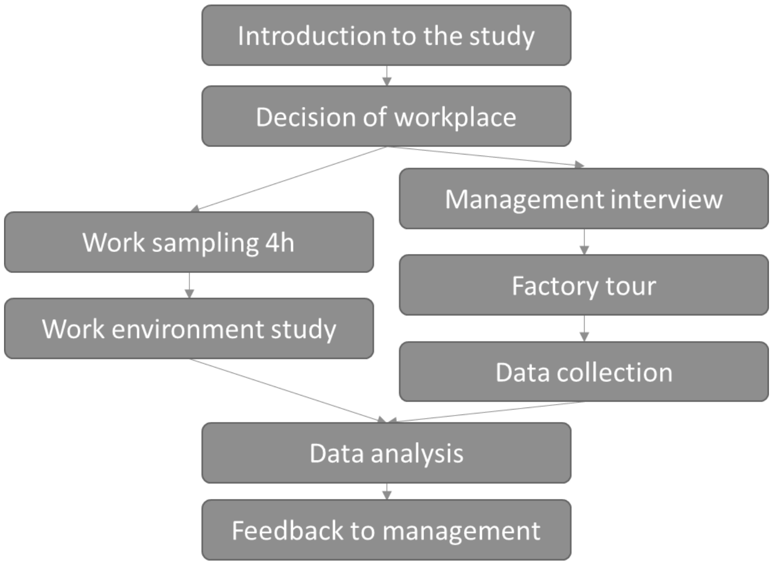

Figure 4. The work procedure of the PPA method (Almström & Kinnander, 2011, p. 9).

The method itself consist of four main levels and an additional level that consider company facts. The four main levels and the additional level of company facts is merely a form of categorization of the complete PPA assessment. See Figure 5 for a general overview of the PPA method. The levels will be described further in the sections below.

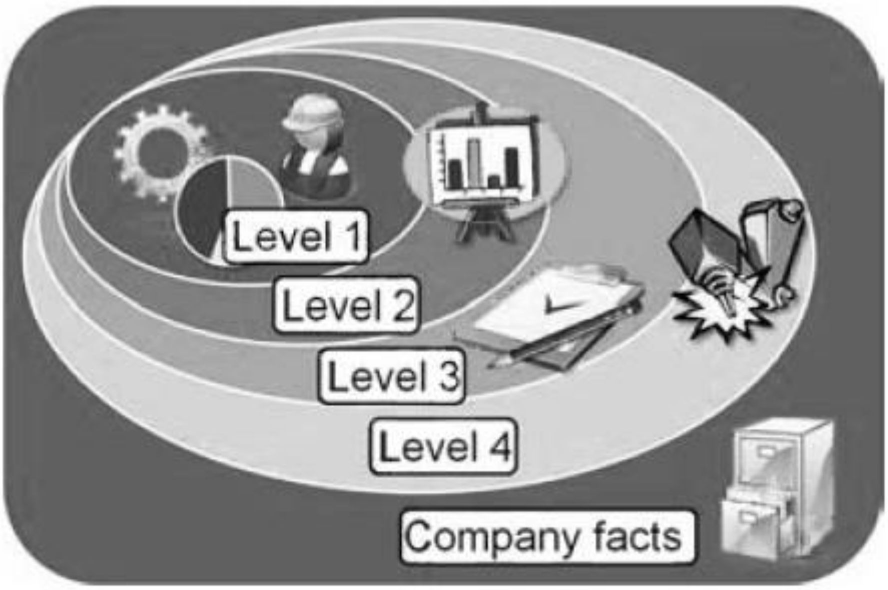

Figure 5. The levels of the PPA model (Almström & Kinnander, 2011, p. 4).

Level 1 is the core level of the Productivity Potential Assessment method. In this level, the inspectors measure both manual labor as well as the OEE (Almström & Kinnander, 2011). A small and well limited production unit needs to be chosen for the assessment. Almström and Kinnander (2011) argue that the unit selected for the measurement should be of great importance for the firm, be scheduled at 100 percent during the measurement period and preferably be a bottleneck. The method used to measure the manual labor is *Work Sampling* where 480 data points are collected in four hours. The activities that the operators perform during the four hours are categorized into three categories, where supporting activities and especially the non-value adding activities highlight potential areas of improvement. The definition of these parameters are often standardized but they may need to be modified at each company (Almström & Kinnander, 2008) The three categories are:

1. Value adding (Load and un-load, finish operations, all activities of a normal cycle)
2. Supporting (Set-up, planning, cleaning and maintenance)
3. Not value adding (Disturbance, waiting, personal time)

The productivity potential for the machines are measured using OEE. Almström and Kinnander (2011) argue that the OEE measure is widely spread and is therefore a preferable tool to use in the PPA method. The OEE data isn't something that the inspectors gather themselves during the plant visit, but instead something that manufacturing firms should be able to provide for the assessment (Almström & Kinnander, 2011). The OEE number is based on three factors; *Availability, Performance efficiency and Quality rate.* Availability is measured as the ratio between the unit's available operating time in regard to the scheduled time. Performance efficiency is the ratio between the measured performance (speed) of the work unit in regard of to its designed performance (speed). Quality rate is the ratio between units approved and the total number of units produced (Hansen, 2001). Thus, these three parameters give the overall equipment efficiency. The formula is as follows:

$$Overall\ Equipment\ Effectiveness\ (OEE) = Availability * Performance * Quality$$

Formula 3. Definition of Overall Equipment Efficiency (OEE)

Level 2 of the Productivity Potential Assessment consist of various parameters used to control and analyze the operations of manufacturing firms (Almström & Kinnander, 2011). The result parameters are:

- Inventory turnover
- Delivery accuracy
- Scrap rate
- Customer reject rate

Inventory turnover is defined as the total revenue of the plant divided by the sum of raw material, work in progress and finished goods (Almström & Kinnander, 2011). *Delivery accuracy* is the measure of how able a manufacturing firms is to deliver on-time. Almström and Kinnander (2011) argues that this parameter is highly important, especially in the automotive industry due to just-in-time etc. *Scrap rate* is a direct area of great potential for improvement since every part that is default lowers the overall productivity for the plant. Similar to the *Scrap rate* is the *Customer rejection rate*. However, this parameter is of greater importance compared to the *Scrap rate* since a high *Customer rejection rate* not only affects the overall productivity of the plant but also risks to affect the customer relationship (Almström & Kinnander, 2011)

Level 3 measure firms and its managements' ability to run and develop its production (Almström & Kinnander, 2011). The assessment at this level consist of 40 *Yes* or *No* questions, see Appendix 1 for the complete set of questions. Further, Almström and Kinnander (2011) have divided these questions into 11 categories. The categories are:

1. Strategy – goals
2. Work methods
3. Maintenance
4. Competence
5. Cleanliness and order
6. Material handling
7. Change over
8. Continuous improvement
9. Calculations
10. Planning
11. Quality

The 40 questions present the ideal state of production engineering where 40 yes indicate world class. Almström and Kinnander (2011) argues that the 40 questions are not based on a particular production philosophy but rather their own expertise within production management. Level 3 also consists of an evaluation of the work environment. Both the physical and the psychosocial work environment as well as the workload ergonomics are assessed (Almström & Kinnander 2011). These areas are listed on a scale of 1-5, where 5 is consider to be the ultimate level. Almström and Kinnander (2011) argue that there is no claim that a good work environment helps to boost the manufacturing productivity. However, Almström and Kinnander (2011) claim that a low score affects the manufacturing productivity negatively due to personnel turnover, illnesses, lacking motivation and discontent.

In *Level 4,* inspectors increase the productivity through method improvements (Almström & Kinnander, 2011). However, since PPA emphasize on quickness where the plant assessment should be completed in less than a day, there is too little information at hand to give a valid recommendation for a method improvement. *Level 4* is therefore not considered as a formal part of the PPA method (Almström & Kinnander, 2011).

Company Facts is the last layer of the PPA method. These facts are not used to assess the utilization of the various firms but instead used to compare different firms based on these facts. These parameters can often be gathered from the firm's annual report. Examples of the parameters that are measured are:

- Level of automation in the production (automated production, semi-automated production or manual production)
- Revenue
- Operating profit
- Investments
- Number of employees
- Operating profit as a percentage of revenue. etc.

Results from previous use of PPA

The Potential Productivity Assessment tool has been used at over 100 manufacturing companies and the result of the first 45 visits is currently available (Almström & Kinnander, 2008*).*

Kinnander and Almström (2008) describes that the construction of the assessment tool has been an iterative process and the result from the first 25 studies comes from an older version of the PPA-tool. However, once the pilot studies had been completed and the assessment tool updated, the finalized PPA-tool were used to assess the level of utilization of the last 20 out of the 45 companies. The result from these studies will be presented below.

From the frequency studies, Kinnander and Almström (2008) chose to divide the value adding activities, the supporting activities and the non-value adding activities based of the level of automation for the first 45 companies. See Table 1 for the utilization of manual work.

Table 1. Efficiency of manual work (Almström & Kinnander, 2008, p3)

	Auto	Semi	Man	Total
Value adding	40,6%	40,9%	64,0%	45,1%
Supporting	28,1%	24,3%	19,7%	24,3%
Not value adding	31,4%	34,8%	16,3%	30,6%

The result from the OEE is based on 29 studies. The remaining 16 companies were either labor-intensive and did not use machines at their shop floor or that the researcher were unable to collect and analyze the needed data (Almström & Kinnander, 2008). The average OEE at these 29 sites was 63 percent.

The level of production engineering that is based out of the 40 questions is available for the last 20 assessed manufacturing firms (Almström & Kinnander, 2008). The result measured of the number of yes is presented for all 40 questions below, see Table 2. The highest number of yes received by a manufacturing firm was 29 (72,5 %). The lowest score received by a manufacturing firms was 6 yeses (15 %). The average score for the 20 assessed manufacturing firms was 17 yeses (42,5 %) (Almström & Kinnander, 2008).

Table 2. Results of the PPA questionnaire (Almström & Kinnander, 2008, p6)

1. Can management present a clear production strategy, based on qualifying and order winning criteria?	50%
2. Is the strategy been converted into measurable goals for the production?	45%
3. Are the goals measured regularly and are these measures available to the shop-floor personnel?	45%
4. Is the fulfilment of the goals connected to any kind of reward?	15%
5. Is a standardized work method used and is it documented?	15%
6. Is the standardized work method changed if the workers find a better method?	10%
7. Do operators serve several machines?	65%
8. Is down time measured and are causes for stoppages documented?	35%
9. Is down time measured by an automatic system?	15%
10. Are small stoppages monitored and actions taken to eliminate them?	10%
11. Is preventive maintenance used?	65%
12. Is condition based maintenance used?	20%
13. Is there anyone responsible for and competent to measure manual work?	25%
14. Has the foreman knowledge to do all work tasks on the shop-floor?	55%
15. Is there a competence development plan?	65%
16. Have all material, tools etc. fixed positions and is everything in place when not used?	10%
17. Is there enough space around the workplace to be able to move all material as planned?	60%
18. Is the floor and other surfaces free from waste material, scrap products etc.?	35%
19. Are the load carriers (pallets etc.) adapted to the components?	35%
20. Does the batch size correspond to the delivery pace?	25%
20. Does the batch size correspond to the delivery pace?	25%
21. Is the same load carrier used for a component as far as possible?	50%
22. Is material stored close to the point of use?	60%
23. Is the shop independent of trucks, cranes etc. to move the material?	15%
24. Are changeover times measured?	30%
25. Is there a continuous effort to reduce changeover time in the bottleneck?	25%
26. Are tools, fixture etc. stored close to where they used?	75%
27. Is the continuous improvement work carried out systematically, and is it documented and visualized?	30%
28. Are the workers engaged in the improvement work?	35%
29. Has the management a realistic idea about the productivity potential?	55%
30. Is knowledge from previous development projects used systematically?	5%
31. Are investment calculations revised?	45%
32. Are product calculations revised?	35%
33. Is ideal cycle time known and is it based on facts?	55%
34. Are real operation times reported to the planning system?	50%
35. Are the operation times in the planning system updated based on the real operation times?	15%
36. Is the production planned according to pull principle when possible?	20%
37. Are lead times measured in order to reduce them?	15%
38. Is there a standardized quality system in use (e.g. ISO 9001)?	85%
39. Is the single operator responsible for the quality of his own work?	80%
40. Are there systematic methods used to eliminate the occurrence of errors?	55%

2.4.2 TUTKA

TUTKA derives from the Finnish words "tuotantojärjestelmän kehittäminen ja arviointi" meaning production system improvement and assessment (Koho, 2010). Koho (2010) further claim that the word "tutka" also refer to the English word for radar and is appropriate since TUTKA uses a method similar to radar technology i.e. to provide information of the current location and situation. The method was developed late 2000's by Mikko Koho with the aim to assess the current state of the production facility and to identify means for potential and process improvements (Fasth, 2011). According to Koho (2010), the time required for a quick assessment of a production system is not measured in detail but the fastest pilot has been carried out in two days. Moreover, the TUTKA tool was mainly developed to assess the situation for Finnish manufacturing companies (Koho, 2010).

The TUTKA tool is divided into three main parts:

- Key characteristics of a well-performing production system
- Assessment scale
- Assessment method

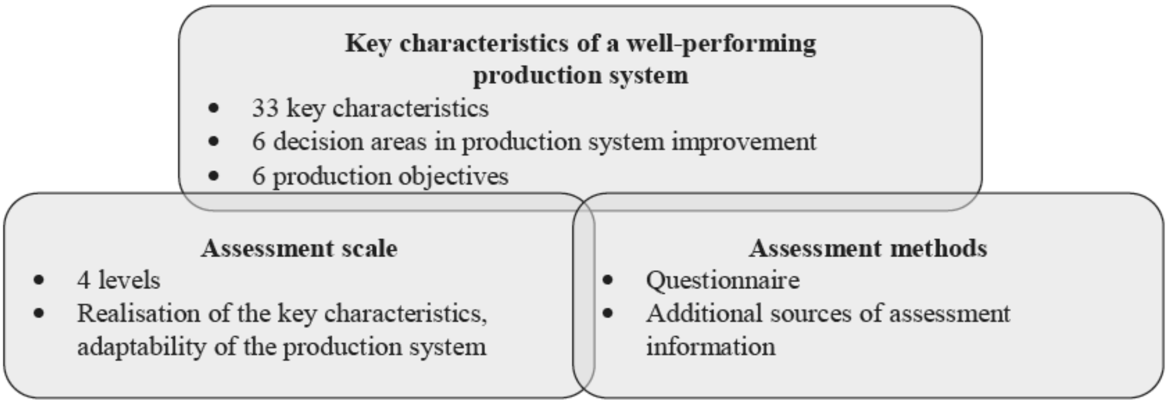

Figure 6. The TUTKA Tool divided into three main parts (Koho, 2010, p. 92).

The key characteristics of a well-performing production system is the basis for the TUTKA method (Koho, 2010). The key characteristics present the ideal state of a production system and is what the targeted company should strive for. The key characteristics also forms as a basis for the assessment process to which the analyzed company can be compared against. The key characteristics consist of 33 areas that focus on the production system and on the arrangement and organization of production resources (Koho, 2010). See Appendix 2 for a complete list of the key characteristics. These key characteristics are grouped into six decision areas regarding production decisions, changes and improvements. The decision areas are intended to make sure that all important areas of the production system are being considered. The six decision areas in production system are:

- Product architecture
- Production system structure
- Production process and management
- Production equipment
- Information and communication
- Human resources

Another aspect of the characteristic of a well performing production system is the six production objectives. These objectives are linked with each of the 33 key characteristics and the positive effects of a key characteristic on the production objectives is indicated with checkmarks (Koho, 2010). See Appendix 2 for a complete table of the relationship between key characteristics, the decision areas and the production objectives. The six production objectives are:

- Quality (Q)
- Time (T)

- Reliability of lead or delivery time (R)
- Volume flexibility (VF)
- Product flexibility (PF)
- Cost (C)

The second main part of the TUTKA tool is the assessment scale. This is used to assess the production system and to present the result of the assessment. The assessment scale focuses on the differences and similarities with the assessed production system and the key characteristics of a well-performing production system (Koho, 2010). The comparison is measured on a scale of 1-4. The first three levels of the assessment scale target the assessed production system at the present moment, where level three is the one manufacturing firms should strive towards. Level four consider the adaptability of the production system (Koho, 2010). This level is not assessed for all key characteristics, but instead the ones that targets production flexibility and adaptability. The four levels are as follows:

- **Level 1: No correspondence.** The characteristics of the assessed production system do not correspond with the key characteristics of a well-performing production system. High potential of improvement
- **Level 2: Partial correspondence.** Parts of the assessed production system correspond with the key characteristics of a well-performing production system. Potential of improvement
- **Level 3: Full correspondence.** The assessed production system corresponds to the key characteristics of a well-performing production system. Potential to improve the adaptability of the production system.
- **Level 4: Adaptability.** The assessed production system corresponds with the key characteristics of a well-perfuming production system even if the product variety and/or the production volume change.

The third and final main component of the TUTKA tool is the assessment methods (Koho, 2010). This section is divided into two parts; the assessment questionnaire and performance measures and additional sources of information. The assessment questionnaire corresponds to the 33 key characteristics of a well-performing production system and are grouped into three sets (Koho, 2010). Set 1 regards questions or claims related to the key characteristics on a more general level. Set 2 consist of more detailed set of questions to get a deeper understanding for each key characteristic. The last set consist of questions that relate to the adaptability of the production system. Therefore, the first two sets of questions relate to level 1-3 of the assessment scale whereas the third set only relates to level four. The second part of the assessment method is the additional sources of information (Koho, 2010). This part consists of various additional information that can be of importance for the TUTKA tool in general. The additional information focus mainly on areas regarding production equipment and human resources. Examples of additional useful information is:

- Potential process capability index (C_p)
- Mean time to repair (MTTR)

- Number of days missed due to occupational accidents
- Number of initiatives or suggestions from employees in a given time period
- Layout picture of the production system etc.

2.4.3 Manufacturing system design decomposition (MSDD) model

The Manufacturing System Design Decomposition (MSDD) model was developed with the intention to assist in analyzing an existing production system or assist in the design or re-design of a production system. The model is developed by Cochran et al (2002) at the production system design laboratory at Massachusetts Institute of Technology. This framework integrates several different concepts described in literature. Some of them are; plant layout design and operation, human work organization, use of IT and performance measurement. The target industry of the framework is mainly medium to high volume repetitive manufacturing companies.

Cochran et al (2002) declare that there are several strategic objectives that a manufacturing system should satisfy. These objectives require the design of the production system to correspond to certain principles. These principles are the core in the MSDD model and consist of:

1. Clearly separate objectives from the means of achievement
2. Relate low-level activities and decisions to high-level goals and requirements
3. Understand the interrelationships among the different elements of a system design
4. Effectively communicate this information across a manufacturing organization

The model's general focus is manufacturing system design Cochran et al (2002). In more detail, to cover all aspects of creating and operating a manufacturing system. When creating a new system, the model includes equipment selection, arranging equipment, work design and so on. Regarding current operations, the model includes aspects necessary to run the factory. Further, the model is divided into six main branches; quality, identifying and resolving problems, predict output, delay reduction, operational costs, and investments.

The MSDD model is an axiomatic design based decomposition model. The base of the model is a set of functional requirements (FRs), and the design parameters (DPs) indicating the solutions and means of achieving the functional requirements (Cochran et al, 2002). Through the thorough use of these FRs and DPs, the model provides a logical foundation to evaluate if the FRs are achieved. This foundation also enables the model to guide users in the development of new manufacturing system designs. The main steps of the model are the following:

1. Determine the applicable FRs in the MSDD based on the project objectives
2. Determine dependent FRs based on the interrelationships defined by the design matrices of the MSDD
3. Analysis of the existing system with respect to its achievement of the initial and dependent FRs

4. Analysis of existing system capabilities against FRs determined in steps 2 and 3

2.5 Methods for Lean Production Assessment

There are numerous methods to evaluate and assess Lean production. Doolen and Hacker (2005) argue that a literature review of existing assessment methods need to be conducted to be able to study the use and ultimately the impact of Lean production practices. According to Shah and Ward (2007), Lean production can be described from two points of view, either from a philosophical perspective related to guiding principles and overarching goals or from a practical perspective with management principles, tools or techniques. This study will emphasize on the latter point of view and a number of assessment methods relevant for this type of study will therefore be presented below.

2.5.1 Rapid Plant Assessment

Rapid plant assessment is a tool or method for evaluating the leanness of manufacturing plants and was developed in the 1990's by R. Eugene Goodson. The assessment method emphasizes on visual information and time where less than an hour is needed to make a complete assessment of the plant (Goodson, 2002). The teams often consist of four or five people with one person as the assigned leader. Goodson (2002) argues that inspectors with equipment knowledge and manufacturing experience are preferred. However, teams with less experience give remarkably consistent ratings. The inspectors will gather the needed information for the assessment tool both from visual insight as well as from questions during a plant tour. The tool consists of two parts, the RPA rating sheet and the RPA questionnaire (Goodson, 2002). Goodson (2002) highlight the importance not to take notes during the plant tour since this will distract inspectors from gathering visual insights. Instead, the components of the rating sheet and the questionnaire is distributed among the inspectors and summarized jointly immediately after the tour. The RPA Rating Sheet consist of 11 categories:

1. Customer satisfaction
2. Safety, environment, cleanliness, and order
3. Visual management systems
4. Scheduling system
5. Use of space, movement of materials, and product line flow
6. Levels of inventory and work in process
7. Teamwork and motivation
8. Condition and maintenance of equipment and tools
9. Management of complexity and variability
10. Supply Chain integration
11. Commitment to quality

These categories are rated on a scale from *Poor (1 p)* to *Excellence (9 p)* to *Best in class (11 p)* with the maximum score of 121 points. The average score is 55 points (Goodson, 2002). The categories in the rating sheet relates to specific questions in the RPA questionnaire. For example, question 1, 2 and 20 helps assess the scale for the *Customer Satisfaction* category, where many yeses often indicate a higher result on the rating sheet. Generally, the RPA rating sheet categories 4 (*Scheduling system*), 5 (*Use of space, movement of material, and product line flow*) and 6 (*Levels of inventory and work in process*) often have the lowest ratings and the associated RPA questions often are marked as noes in average.

The RPA Questionnaire gives an indicator of the plants leanness (Goodson, 2002). The questionnaire consists of 20 yes or no questions and the more yes, the leaner the plant. The average number of yes for the more than 400 tours is seven. As an example, question 1 is: *Are visitors welcomed and given information about plant layout, workforce, customers, and products?* Again, this question corresponds to the *Customer Satisfaction* category. The complete RPA Questionnaire can be found in Appendix 3.

2.5.2 Assessment method II (Marin-Garcia & Carneiro, 2010)

Juan A. Marin-Garcia and Paula Carneiro made a thorough study to which degree Spanish companies use different principles in their manufacturing. They describe different types of manufacturing philosophies where Lean is the most prominent one. Marin-Garcia and Carneiro (2010) were able to construct a survey to assess the use of manufacturing principles based on a comparison of assessment models gathered from an extensive literature review. They argue that these previously made studies often lack the proper information needed to be able to validate if these assessments were properly conducted. Therefore, the aim of their research was to verify their analysis method and contribute with an assessment method qualified by statistics. They conducted a survey containing questions in the following areas of manufacturing principles;

- Visual management
- Continuous improvement
- TQM (Total quality management)
- JIT (just in time)/Kanban
- Standardized operations
- SMED (single minute exchange of die)
- Line balancing
- Continuous flow and Cell manufacturing
- TPM (Total preventive maintenance)
- Supplier relationship
- Customer relationship
- Automatization and propriety equipment
- Design integrated with manufacturing
- Knowledge management

The are several survey questions related to each manufacturing principle described above and the questions are rated on a scale from zero to five. The questionnaire was distributed to production managers (or similar positions) at companies in Spain. The survey, which can be found in its full in Appendix 4, was self-assessed by the contacted managers and the result was analyzed and compiled by Marin-Garcia and Carneiro (2010). They found that seven of the principles were commonly used. These were standardized operations, single minute exchange of die (SMED), continuous flow and cell manufacturing, TPM, supplier relationship, customer relationship, and knowledge management. Three of the principles were on an acceptable level; continuous improvement, automatization and proprietary equipment and design integrated with manufacturing. Further, three of the principles were used to a very little extent; visual management, JIT/Kanban and line balancing. They further conclude that, independent of principle, the statistical measures can be argued to be significant for these thirteen areas whereas the fourteenth area, TQM, is not valid.

2.5.3 Assessment method III (Susilawati et al, 2013)

Susilawati et al (2013) developed a framework of performance measurement and improvement system for Lean production activity. They observed that performance measurement systems described in literature lacked a thorough connection to Lean principles. Examples of these analyzed systems are; *balanced score card*, *the strategic measurement analysis and reporting technique system* and *performance measurement questionnaire*. Instead they built a new framework consisting of eight indicators with several sub-indicators in each area. These indicators are based on different definitions of the level of Lean in literature. The indicators consist of the following areas:

- Customer Issue
- Supplier Issue
- Manufacturing management*
- Internal business management*
- Manufacturing efficiency*
- Research and development
- Learning prospective
- Investment priority

These eight areas have several sub-indicators. Due to the manufacturing focus in this research, only the sub-indicators from manufacturing management will be further described. The sub-indicators consist of the following areas:

- Mistake or error proofing
- Lot size reduction
- Production scheduling
- Pull control
- Eliminate finished goods inventory
- Cellular manufacturing
- Eliminate manufacturing cycle time
- Total productive maintenance
- Work standardization
- Setup time reduction
- Equipment utilization

With these identified areas of indicators as a base, Susilawati et al (2013) constructed a framework of detailed measurable performance indicators in line with the dynamic multidimensional performance model to be able to assess the improvement of Lean activities. This model is divided into the following five main areas; financial, customer/market measures, process, people and future. In their research, the authors conclude that the framework could be applicable in the implementation phase of Lean production principles and by doing so support improvement of their performance (Susilawati et al, 2013). This assessment method is however a theoretical framework and this research does not evaluate the framework quantitatively.

In further research of Lean assessment tools conducted by the same authors, the method is more thoroughly tested in various manufacturing industries in Indonesia. The original model with eight indicator areas have been slightly modified and now contain six indicator areas. *Internal business management* and *manufacturing efficiency* is merged with the *manufacturing management area*. The three areas are indicated with an asterisk at the list above.

When studying similar investigations made by other researchers, Susilawati et al (2014) found and described four main areas of potential improvements. First they want to use a wider range of parameters to define and assess the degree of leanness. Second, they describe the issue of complexity and bias. Third, the issue concerning vagueness due to human judgment. Fourth, they describe a lack of databases able to benchmark the scores. These issue are addressed in different ways. The first issue is addressed by making the tool for assessment large and detailed. The second issue is addressed by using more than one evaluator reducing the risk of a biased view. The third issue regarding subjectivity and vagueness in judgment is addressed by using fuzzy number scoring. The fourth described issue have not been addressed in the study but the authors hope that the study will contribute partly by providing results possible to benchmark.

The method is based on a self-assessment survey where two evaluators within each subject is targeted. The survey was design by Susilawati et al (2014) following a set of seven steps suggested by Burges, Openheim and Pickard.

1. Define aims of survey
2. Identify population and sample
3. Choose survey methods
4. Design questionnaire
5. Run a pilot survey
6. Carry out main survey
7. Analyze the data

Susilawati et al (2014) chose a self-assessment questionnaire to gather the needed information. This due to limitations in geography, time and cost. Although some value might be lost due to the fact that the researcher cannot make sure that the questions are correctly understood, this method is a simple and cost efficient method to study a large number of companies. The survey, which is not added in their article, was carried out through web- and mail-based questionnaire. However, in similarity with other web based surveys the answer rate was below 20 percent resulting in a large information gap. The survey targeted middle to top level managers, knowledgeable within the area of Lean practices in their respective company. Each indicator area was rated by two evaluators on a scale of 1-5, the two scores was measured and an additional score of between 0,2-1 was added depending on for how long the Lean principle had been in use. 0,2 extra points were added for every year. The addition of these extra points made the scale range between 1-6, and were argued to make the results fairer and more valid than similar studies. The two scores are then recalculated with fuzzy logic to a 10-point scale in order to counteract the vagueness of human judgement.

The result show that small and medium-sized firms (between 10-250 employees) used Lean production principles to a lesser extent than large companies, in all the indicator areas. Within the large company base, the most adopted Lean principle was *manufacturing and internal management*. In the medium-sized and small companies, the area with most adopted principles was within *customer issues*. Further, the authors states that the majority of the medium and small sized companies lack information about Lean and productivity improvement methods.

2.5.4 Assessment method IV (Shah & Ward, 2007)

Shah and Ward developed their assessment method in 2007 with the hope to both explain the commonly agreed definition of Lean production as well as their method to assess and measure Lean production and its main components (Shah & Ward, 2007). According to Shah and Ward (2007), only a few assessment methods had been found related to measuring Lean production why they felt the necessity to define and develop such a tool. Shah and Ward (2007) started with an extensive literature review to investigate the general view of Lean production and its Lean practices among various researchers. A comprehensive set, consisting of 48 Lean practices, was established and later tested in a pilot study with the aim to validate each principle. Thus, Shah and Ward (2007) performed an exploratory data analysis consisted of three parts; (1) *Corrected Item to Total Correlation (CITC)* score (2) convergent validity and (3) to assess divergent validity. Based on the analysis, seven principles were excluded from the assessment method (six due to a low CITC score and one from the divergent validity test) (Shah & Ward, 2007). Once the method was tested, Shah and Ward (2007) sent out a survey to 2185 identified manufacturing firms. Shah and Ward (2007) used two criteria to select firms: (1) The firms need to belong to a manufacturing SIC code; (2) The firm's minimum number of employees had to exceed 100. Out of the 2185 firms, 280 responses were used is the study which constitutes to an effective response rate of 12,8 percent. The survey, made of the 41 Lean practices, were self-assessed on a scale of 1-5. Ranging from (1) no implementation to (3) some implementation to (5) complete implementation (Shah & Ward, 2007). See Appendix 5 for a complete overview of the survey.

Shah and Ward (2007) concluded that Lean production is most associated with the elimination of waste such as excessed inventory or excessed capacity. This overarching philosophical understanding for waste reduction is accomplished through a variety of mutually reinforcing practices and tools. Shah and Ward (2007) divided Lean production into three underlying constructs; *Supplier related*, *Customer related* and *Internally related.* Each of the three underlying construct consist of various operational constructs as well, such as *JIT delivery* and *Low setup* and eight others (Shah & Ward, 2007). Together, the 10 operational constructs contain the 41 Lean practices established from the exploratory data analysis described above. See Figure 7 for an overview of the proposed breakdown. Shah and Ward (2007) further argue that these 10 operational constructs are positively and significantly correlated with each other ($p < 0.001$) (Shah & Ward, 2007). The correlation between factors range from 0.77 (JIT Delivery and Developing suppliers) to 0.12 (Productive maintenance and Involved customers).

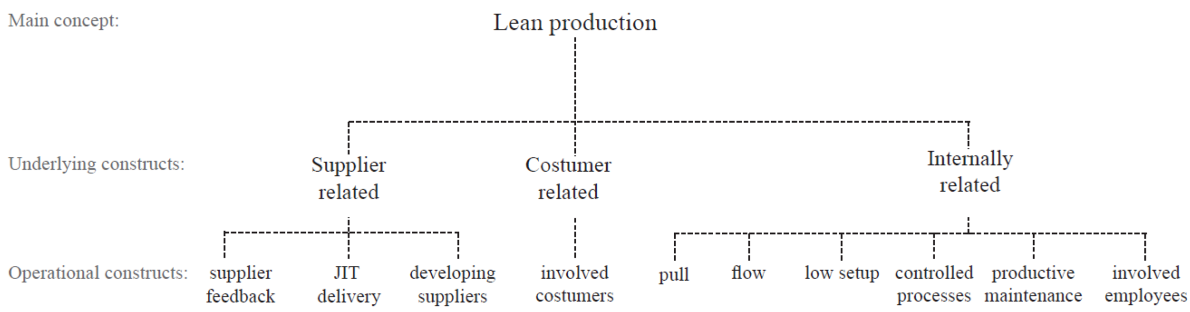

Figure 7. Illustration of the ten operational constructs (Shah & Ward, 2007, p15)

2.6 Strategic Implications of Lean production

In the following part, different strategic aspects of Lean production will be described. Firstly, Lean is described in terms of strategy, this is followed by literature describing a competitive advantage and what makes a competitive advantage sustainable. The chapter is concluded with literature describing the relationship between Lean production and sustainable competitive advantage.

2.6.1 Lean as a strategy

Since competitive manufacturing has become increasingly important, manufacturing strategies have got an apparent matter in the strategy of the company. The ability to make and deliver the right products, on time, with the right quality and to the right price is a requirement in order to stay competitive (Bellgran & Säfsten, 2009). In the strive to accomplish this, the manufacturing strategy provide support and guidance (Säfsten, Winroth & Löfving, 2014). Säfsten, Winroth and Löfving (2014) state that the general understanding regarding the importance of a functional production to stay competitive is relatively good. They further argue that there are different areas within production that are related to competitiveness. These competitive targets are quality, deliverability, flexibility and cost. Beside these competitive targets, there are a set of categories influencing these targets. These are described as decision categories and comprise; production process, facilities, capacity, vertical integration, quality management and control human resource, organization, production planning and control. These are areas in which companies need to make strategic decisions regarding their production (Säfsten, Winroth & Löfving, 2014).

2.6.2 Sustainable competitive advantage

A company can be competitive in different ways using different resources and capabilities to establish key success factors in the industry (Grant, 2010). However, in order to remain competitive, it is important to establish a competitive advantage that lasts. Such a sustainable competitive advantage is defined by several different characteristics and different researchers have different models. One of the most commonly used models is the VRIO model created by Jay Barney (1991). The VRIO model evaluates a competitive advantage and defines whether it is sustainable or not by evaluating a resource or capability from as set of questions. These are: Is it valuable? i.e. does it provide an advantage over other resources or capabilities. Is it rare?

i.e. is it an of the shelf solution that anyone can obtain or is it unique to the organization. Is it hard to imitate? If it is unique how costly is it to imitate it. Is the firm organized around it? Evaluating whether the resource fits the organization in term of strategy and goals. For example, a gold mine is valuable, rare and hard to imitate however it does not fit the organization of a furniture manufacturer. See Figure 8 for an illustration of the VRIO framework.

Figure 8. Illustration of the VRIO model (after Barney, 1991)

The VRIO model is a commonly used method to evaluate the value of resources and capabilities from competition perspective. In order to understand how resources and capabilities can generate a sustainable competitive advantages through methods of Lean production, Lewis (2000) illustrates a company as a set of resources, process and outcomes as shown in Figure 9. Resources can both be of a tangible and intangible nature and creates value for the firm if they are firm specific. In order to enable a competitive advantage, the resource and capabilities should be scarce and relevant (Grant. 2010). Some resources are directly valuable such as owning a gold mine, however many of the resources are useful and valuable only when they are used in suitable processes within the company. The ability to combine resources with a suitable process enable the company to improve its outcomes either by having a more efficient organization (lowered costs) or by being able to differentiate their product offer. In order to sustain this advantage, there has to be some barriers for competitors to imitate the resource or capability.

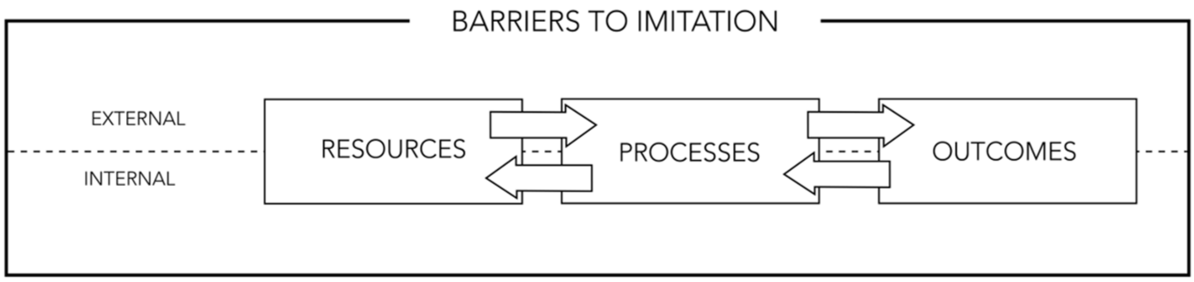

Figure 9. Illustration of the context of an organization in terms resources (After Lewis, 2000, p. 4)

2.6.3 Lean, a sustainable competitive advantage

The opinions whether Lean is to be viewed upon as a mean to establish sustainable competitive advantage or not vary among experts and organizations. There are some earlier studies conducted within this area of research and Lewis (2000) is one of the most prominent researcher. In his research, Lewis (2000) aims to evaluate the impact of Lean production in companies that have adopted the philosophy in several different areas. He states four hypotheses that will be accounted for below.

The first hypothesis evaluates whether Lean production increase the overall business performance through increased overall efficiency within the organization. More clearly, whether Lean production has increased the ability to convert resources of input to output. This is evaluated by measuring a set of key performance indicators. He argues that if a company manages to lower their costs this should improve the profitability or increase the sales (if the savings are re-invested). The results show that in two out of the three cases, the profitability decreased and the sales increased slightly. The last case increased both sales and profit. The results were discussed with company managers during interviews and Lewis (2000) conclude that becoming Lean does not automatically result in improved financial performance. He further elaborates that the main issue seems to be the ability for a company to capitalize the savings made to generate further value. A further impact on the financial performance is the distribution of power within a value chain. Being a strong player increase the abilities to convert savings into new value and vice-versa.

The second hypothesis focus on the specific starting position for the Lean implementation and evaluate if Lean production has a unique implementation path for every company. Lewis (2000) defines Lean according to Womack, Jones and Roos (1990) model containing three key principles. Improving flow, emphasis on customer pull and commitment to continuous improvement. This is one definition and the opinions vary among experts and Lewis (2000) highlights the findings of Bartezzaghi (1999) that the definition of Lean is rather vague. With basis in that Lean is difficult to define, Lewis (2000) further states that it is of importance to consider not only the outcomes from implementation of certain tools/techniques but also the Lean implementation path and the organizations starting position. The conclusion of his research is that every organization implement a unique mix of methods and techniques. He further concludes that the starting position affected the outcome significantly.

The following two hypothesis focus more on the sustainability of the competitive advantage of Lean production. The third hypothesis focus on the dynamics between the internal and external environment and consequently the specific context of each organization. The contextual factors are factors such as market type, supply chain structure or specific technology required. Lewis (2000) conclude that unique resources such as specific locations can provide a sustainable competitive advantage in combination with a Lean production based strategy. However, he argues that it could also be viewed as a risk due to the fact that changing markets and/or new markets have different requirements of suitable locations. Another aspect also discussed is the power of knowledge. Knowledge can be viewed as a scarce resource and difficult to imitate, possible a sustainable competitive advantage. However, educating operators and managers in order to achieve a Lean production will increase their value on the market and also increases the risk of losing them to competing firms. Lewis (2000) further argue that focusing more on the internal structure such as technology, infrastructure and knowledge acquisition, minimize the transfer of value from the organization to individuals and hence reduce the risk of knowledge drain.

The final research hypothesis explores the relationship between learning in organizations and Lean production. Lewis (2000) describes the reason for examining this relationship to be one of the key attributes of Lean production, namely continuous improvements. In line with Huber (1991), Lewis (2000) argues that learning in organizations can occur in many different ways and that it is questionable whether all learning can achieve a sustainable competitive advantage. Sitkin's (1992) research show that learning can either be to improve efficiency and reliability in processes or it could be to increase resilience in new situations. Lewis (2000) argues that continuous improvement focus on the former type of learning and somewhat limit the latter. Therefore, the last hypothesis state that implementing Lean production in a higher degree limits the general innovative capabilities. Lewis (2000) further discuss that limited innovative capabilities might be a source of disadvantage when markets shift in a rapid pace. From the three cases studies, Lewis (2000) concludes that some evidence support the hypothesis while other findings show that this is not always the case and that further investigations need to be made regarding the relationship between Lean production and innovative capability.

CHAPTER 3 - RESULT FROM THE LITERATURE REVIEW

In this chapter the researchers will describe the results from the literature review and state what methods that will be used to assess the resource utilization and level of Lean implementation of the participating companies.

3.1 Method used to assess the resource utilization

In the literature review three methods were described for production assessment, *Productivity Potential Assessment*, *TUTKA* and the *Manufacturing System Design Decomposition model (MSDD).* The assessment method used for this research is the *Productivity Potential Assessment* method for numerous reasons. The first aspect is time. The Productivity Potential Assessment method is the only assessment method that required less than a day to complete compared to TUTKA, were the shortest production assessment were completed in two days, and MSDD, were no data regarding time frame was presented. Time constraints is one of the major limitations for this research why an assessment method that requires less amount of time is preferable. Moreover, the researchers argue that the interest for manufacturing companies to participate in this study increases if the production assessment requires less than one day to complete. This since plant and production managers often have a busy schedule were an assessment of more than one day may be considered a too high of an investment.

Another advantages with PPA compared to TUTKA and MSDD is the access to the result from earlier assessment studies. In the article *Results and conclusions from the productivity potential assessment studies* by Almström and Kinnander (2008), there is a complete set of a minimum of 20 assessed manufacturing firms for every parameter studied during the factory visit. This data has enabled the researchers to compare the result both between the participating firms in this research as well as how they relate to manufacturing firms assessed in earlier PPA studies. This data could not be found for the other assessment methods.

Moreover, The *Productivity Potential Assessment* method was developed by the two professors at Chalmers University of Technology, Anders Kinnander and Peter Almström. Peter Almström is still a member of the Technology Management and Economics department at Chalmers University of Technology and has been highly valuable for guidance for this research. Discussion with Peter Almström has been conducted at numerous occasions during this research, both related to the tool itself and the outline for how it should be conducted as well as a training regarding frequency studies. This enables the researchers to conduct a more accurate production assessment. The researchers argue that this type of guidance is unlikely or much harder with TUTKA and MSDD.

In addition, although the PPA model measures various key performance indicators, most of these parameters have been excluded from this research. This since the researchers argue that these excluded parameters do not have a link to the Lean to utilization relationship nor have a link to whether Lean production is a sustainable competitive advantage.

3.2 Method used to assess the level of Lean implementation

The process to find a proper tool for the Lean assessment was somewhat different compared to the process regarding the assessment method for resource utilization. Although the researchers found four different methods with related interview questions to assess the level of Lean implementation, they all stressed different aspects or areas within Lean production. The researchers could therefore not make a decision to which assessment method that were the most favorable. Thus, the researchers first analyzed what areas or aspects that the general academia considered being related to Lean production. After an extensive literature review, these general areas could be established. These established areas derive both from Lean articles in general as well as from the described assessment methods. Examples of these established Lean areas are: *Just-in-time, Standardized Operations, Continuous Improvement* etc. The researchers thereafter cross-referenced the established "Lean" areas to the areas stressed in the four different assessment methods presented in the literature review. All questions related to these established areas of Lean production, from all four assessment methods, were later transferred to a raw-list with a total of 44 questions.

The raw-list of 44 question were later sent to the researchers' supervisor Mats Winroth and an expert at Triathlon Group to get an experts point of view. After some discussions with Mats Winroth and the expert from Triathlon Group, some questions were added to the questionnaire but even more questions were removed for the raw-list, mainly since these question were either too complex or considered irrelevant for this research. This was supported by the fact that 44 questions were considered too many to be answered during one interview session, partly since the PPA-tool itself consist of 40 questions. Fortunately, this problem solved itself since some of the questions from the PPA-questionnaire had enough similarity with some of the Lean questions why the researchers chose to bundled them together. The total number of questions were therefore at a manageable level. The finalized Lean questionnaire consists of a total of 39 questions divided into 12 Lean areas, see Table 3.

Moreover, of these 39 question, 12 were similar to related questions from the PPA-questionnaire and are therefore asked as one question and not as two separate questions. These 12 question are marked with an asterisk by the question number. All Lean questions are estimated on a scale of 0-5 and with 39 questions the maximum score is 195. Each point is weighted the same where the total sum, for all question, establish the total level of Lean implementation. Moreover, this research argues that a maximum score of 195 is ideal for all companies. However, this is not always the case since a full level of Lean implementation is not ideal for all companies and industries. How Lean production relates to individual firms and industries is not considered in this research. Likewise, this research does not stipulate if a specific degree of Lean implementation is good or bad. This research emphasize how Lean implementation relates to resource utilization.

In addition, to get a more accurate comparison, the 12 questions that showed enough similarity are answered and scored both as yes/no (the PPA grading system) as well as graded on a scale of 0-5 (The Lean grading system). The ideal situation is that these two scores should correlate i.e. a yes on a certain question should never be followed by a low Lean score (0-3) or vice versa.

To get a good flow throughout the interview with plant or production manager, the researchers arranged the Lean questions according to the PPA-structure so that all questions related to a specific area (*Material Flow* etc.) were asked together.

Moreover, the 39 Lean questions is divided into 12 Lean areas. Although the average number of question for these 12 areas is three, some areas deviate from this average. The reason for this variation is that areas with more than three questions were regarded as more important since these areas often were highlighted as key areas in the four investigated assessment methods. In comparison, areas that consist of less than three questions are indeed important to be able assess Lean implementation however, not equally as important compared to other Lean areas. This is based out of the four investigated Lean assessment methods. Hence, the Lean questionnaire is slightly weighed based on the number of questions found in each category.

Table 3. The Lean questionnaire used in the study

	Strategy – goals
1	Why did your organization choose to implement Lean Production? (The interviewee should understand that Lean Production isn't a goal itself but a mean to achieve a company goal)
	Work methods
2*	Is a standardized work method used and is it documented? Please give examples
3	To what extent is there a standardized job description at each work station? Please give examples
4*	Is the standardized work method changed if the workers find a better method? Please give examples
5	To what extent are product grouped into product families where they all have similar production process? Please give examples
6	To what extent are machinery grouped to form a continuous flow for each product family? Please give examples
7	To what extent is a Value Stream Mapping used to illustrated a current state as well as a future state for the shop-floor? How often is it updated? Please give examples
	Continuous improvements
8*	Is the continuous improvement work carried out systematically, and is it documented and visualised? Please give examples
9*	Are the workers engaged in the improvement work? Please give examples
	Competence
10	To what extent is the operators trained cross-functional? Please give examples
11	To what extent are information distributed throughout the organization? (Trough data bases, workshops meetings etc.) Please give examples
12	To what extent are the competence of each operator visualized at the shop-floor? Please give examples
	Maintenance
13	To what extent do your organization use OEE? Is the data visualized at the shop-floor or ideal at every machine? Please give examples
14*	Is preventive maintenance used? (Examples: based on number of strokes or calendar) Please give examples?
	Cleanliness and order

15*	Has all material, tools etc. fixed positions and is everything in place when not used? Please give examples
16	How well are these assigned spots labeled? Please give examples
17	To what extent is the working environment safe, clean and well lit? Is it noisy or have a distinct smell? Please give examples
Material handling	
18*	Is material stored close to the point of use? Please give examples
19	To what extent do your suppliers deliver at Just-In-Time basis? Please give examples
20	To what extent is Kanban used at the shop-floor? Please give examples
Changeover	
21*	Are changeover times measured? Please give examples
22*	Is there a continuous effort to reduce changeover time in the bottleneck? Please give examples
23	To what extent is the change over time visualized at the shop-floor? (ideal at every machine). Please give examples
Planning	
24*	Is the production planned according to pull principle when possible? Please give examples
25	To what extent is there a production plan for the days/weeks work available at the start of each day/week? Please give examples
26	To what extent is the takt-time calculated based on customer demand? Please give examples
27	To what extent is each work station balanced to have a similar workload? Is the balancing visualized at the shop-floor? Please give examples
28*	Are lead times measured in order to reduce them? Please give examples
29	To what extent is a capacity assessment conducted prior to a new product launch? Please give examples
Quality	
30*	Is the single operator responsible for the quality of his own work? Please give examples
31	To what extent is the production stopped when a quality concern is identified with the aim to find and solve the root cause of the problem? Please give examples
32	To what extent is the production managers or similar position actively involved in improving product quality? Please give examples
33	To what extent is the scrap rate visualized at the shop-floor? Please give examples
Supplier relationship	
34	To what extent do you strive to establish long-term relationship with your suppliers? Please give examples
35	To what extent is your suppliers evaluated based on total cost compared to cost per item? Please give examples
36	To what extent do your organization evaluate and give feedback to your suppliers based on quality and service level? Please give examples
Customer relationship	
37	To what extent is your processes interlinked with your customers? Examples EDI systems or VMI systems. Please give examples
38	To what extent do your organization receive current and future customer needs? Please give examples
39	To what extent is your customer satisfaction visualized at the shop floor? Please give examples

CHAPTER 4 - METHODOLOGY

The aim of this research is to investigate the relationship between resource utilization and the implementation of Lean production. This research will also study if Lean production can be regarded as a sustainable competitive advantage. This chapter will clarify how this study has been conducted and designed as well as to present the procedure for the methodological approaches and data collection.

4.1 Research approach

The methodology used for this research is a qualitative research method with an abductive approach. The abductive approach encourages the use of knowledge from literature and knowledge gained from empirical data to be used more iteratively (Dubois & Gadde, 2002). Although a sizeable part of our research consists of observations at various manufacturing firms, the analysis and conclusion are not based solely on the observations itself, which is the case for an inductive approach (Wallén, 1993), but instead from a comparison with the literature review. Moreover, since this research also investigates different forms of quantitative data gathered from each manufacturing site, there has also been a need for a quantitative research strategy. The researchers argue that the use of both a qualitative and a quantitative research strategy has strengthened the report.

4.2 Data Collection

The data collection was essential in order to achieve good results for this study. In this chapter the researchers will present the procedure for how the data was collected for this research. This chapter consist of both secondary data, mainly the literature review, and primary data received from observations and interviews at each company visits.

4.2.1 Literature Study

It is of importance to state that the secondary data collected for this study have other purposes than this particular research. The hypothesize or research questions for the secondary data may be similar to this research, however the data can both be biased and not fully comprehensive for this study (Björklund & Paulsson, 2003).

The literature review was an essential step in the early stages of this research. This was crucial, both to investigate interesting conclusions from earlier work related to this research as well as to be able to established various methods to gain the needed empirical data from both the level of resource utilization and the level of Lean implementation. The literature review has also been used as the bases for the researchers' analysis regarding if Lean production can be a sustainable competitive advantage. Therefore, the literature review consists of previously conducted studies in this area of research, various methods to assess both resource utilization and Lean production as well as the strategic implications related to Lean production implementation. Moreover, since the methodology used for this research is abductive, the literature review has been an iterative process where the researchers continuously filled information gaps with an extended literature review.

The material presented in the literature review have been collected through books, interviews, articles and various data bases. The researchers have mostly gained the information from data bases such as Google Scholar and Summon. These are secondary data and needs to be critically evaluated prior to application (Alexanderson, 2012). Moreover, primary data have also been used to gather the needed information related to the literature review since Triathlon Group as well as professors at Chalmers both have extensive experience of various tools and information that was of interest for this report.

4.2.2 Collect the empirical data

The following section will describe the procedure for how a company list was gathered as well as a presentation of the procedure for the company visits. This data is mainly primary data.

Contact companies

The researchers used websites such as allabolag.se and largestcompanies.se to compile a raw list of manufacturing companies in the western region of Sweden. The advanced search function at these websites enabled the researchers to compile a list of manufacturing firms in Västra Götalands Län. In addition, the researchers compiled the raw list with manufacturing firms from various industries all related to manufacturing. Process manufacturing industries however were excluded from this research, as already been described. This enabled the researchers to compare firms both within the same industry as well as between the studied industries.

The researchers structured the list based on both sales and number of employees and excluded the firms that were considered too small for these two parameters. Again, this resulted that all firms with less than 500 million SEK in sales or less than 150 employees, both at corporate level, were removed from the raw list. The finalized list consisted of 40 manufacturing companies within the western region of Sweden. The researchers where then able to initiate the procedure of contacting the plant manager or production managers at each potential manufacturing site. This were done by telephone since email were considered to have a much lower response rate. The contact was often mediated by a telephone operator at each company. Of the 40 contacted companies, 10 firms never replied or answered any calls. Of the remaining 30 companies 13 wanted to participate while 17 choose not to participate. The reason for why companies did not participate were often due to time constraints or some type of change initiative already in progress. Once the first initial contact was established an information sheet was sent out to each company by email that summarized the intent of the research and the outline for each factory visit. All participating companies were given the option to be confidential in both the report as well as towards other participating companies and all companies chose this option.

Pilot study

Prior to the first company visit, a pilot study was conducted to validate the two tools used in this research as well as a way for the researchers to practice both the usage of these tools as well as how to conduct interviews. Pilot studies are considered crucial for a good research design and often fulfil valuable details and insights for the researchers (van Teijlingen & Hundley, 2002). Van Teijlingen and Hundley (2002) further argue that pilot studies does not guarantee success of the research but does increase the likelihood. The pilot company used for this research is a small sized manufacturing enterprise in the Gothenburg region and was not a company that was on the list of potential participating companies. The participating pilot company was known by one of the researchers prior to this research and could therefore be schedule with short time notice.

Although the size of the company for the pilot study was considerable smaller compared to the companies ideal for this research, the pilot study gave the researchers valuable insights. This was mainly evident regarding the interview questions, both with the operators as well as with the production managers. Based on these found insights from the pilot interviews, some questions needed to be reformulated and illustrated with examples. In addition, the pilot study also enabled the researchers to practice the procedure of the frequency studies and to define what type of activities that were either value adding, supporting or non-value adding. Lastly, Triathlon Group also offered the researchers guidance regarding interview techniques prior to the pilot company visit.

Company visits

The assessment tools used to gather the needed empirical information from every participating company takes approximately six hours to conduct. The ideal procedure is to measure and observe the level of resource utilization (frequency studies) before lunch and to conduct an interview with plant or production managers with the aim the establish the companies level of Lean implementation after lunch. This outline enables the researchers to observe the shop floor and to conduct interviews with operators prior to the extensive interview with the plant/production manager why the interview itself converts to be more enriching. The following few sections will describe the methodology regarding both the observation and the type of interview.

The shop floor observations can according to Björklund and Paulsson (2003) either be *participating* or *non-participating, structured* or *non-structured.* The participating way of observing is where the observer is active or part of the studied operation whereas the non-participating method naturally is the opposite were the observer observe the operation without any participation. Since the researchers aim to study the shop-floor with related machines and operators at their “normal” pace, the non-participating observation method have been used for this research. However, there were occasions where the researchers asked the operators questions regarding the flow of product or related to a specific type of operation etc. This question however was considered to have a little to no impact on the overall observation why the researchers argue that this research has used a non-participating type of observation.

Moreover, the researchers have used a structured form of observation. A structured form of observation is where the observers have a pre-defined set of activities to study, often with some form of structured observation template (Björklund & Paulsson, 2003). Björklund and Paulsson (2003) further states that the opposite method, a non-structured observation, is where you observe a process without a set of pre-defined activates. A non-structured observation method is preferable if the hypothesis is yet to be defined. This research aims to investigate the relationship between resource utilization and Lean production implementation at 13 firms in the western region of Sweden. To be able to compare the results from each manufacturing site, the researchers need to have a structured form of observation. Hence, the observation used for this research was both non-participating and structured.

Interviews are often categorized into three types; structured, semi-structured and un-structured (Björklund & Paulsson, 2003). Björklund and Paulsson (2003) further argue that the general difference between the three interview methods is related to the set of interview questions. A structured type of interview, such as surveys, stresses the importance that all interview objects are presented with exactly the same set of question whereas in an un-structured type of interviews the questions are not at all prearranged. The researchers have used a structured type of interview method for this research. The reason is similar to the once already stated regarding the observation technique and are based on the need to be able to compare the data between all investigated companies.

During the interviews with either plant manager, production manager or similar role, the researchers have assumed different roles. One of the researchers have had the main responsibility of conducting the interview with regard to both time and that all questions were asked and answered. The other researchers have had the main responsibility to take notes during the interview. However, since all interview questions are answered in either Yes/No or graded on a level of 0-5, both researchers marked an individual score for each question. Both researchers were also responsible to ask follow-up question to receive the information needed to set a proper score for each question. After the interview, the researchers compared the interview data both with regards to the researchers individual score and takeaways as well as with regards to earlier observations of the shop floor. The researchers argue that this approach increases the validity of the gathered data and are also supported by Bryman and Bell (2007). Thus, the researchers were then able to set a finalized score for every question at each factory visit.

4.2.3 Data analysis process

This section will describe the process for how the data analysis process were conducted. The research approach for this research have been an abductive approach. Dubois and Gadde (2002) argue that this encourage the researchers to use the empirical findings and the literature review more iterative, as previously been stated. This iteration has concluded in the finalized literature review and empirical findings that have formed the basis for the analysis section. In the analysis section, findings from both the literature review and the empirical findings have been evaluated and compared. The outcome from this comparison have been finalized and discussed in *Chapter 6 - Analysis.*

Moreover, since this study’s two research questions gather data and information both from the literature review as well as from the empirical findings, the approach for the two research questions have been similar. The only difference between this study’s research questions is that research question one, were the researchers evaluated the relationship between resource utilization and Lean production implementation, were answered and analyzed prior to research question two. This were preferred since the researchers argue that a better understanding of research question one helps facilitate a better understanding and analysis of research question two.

4.3 Reliability and Validity

Reliability and validity is two important aspects of performing a research (Wallén, 1993) (Larsson, 2005). The following two section will describe this research's reliability and validity.

4.3.1 Reliability

Reliability is related to if the tool used to gather data is reliable i.e. if another researcher would use this research methodology and receive the same result (Wallén, 1993). This research has used both the Productivity Potential Assessment tool as well as newly composed method for Lean assessment. These two tools have a very structured way to assess manufacturing firms where the different stages for both tools are well defined. The assessment result however leaves room for variation and bias. Although the frequency studies always gather 480 observation related to three categories; value adding, supporting, and non-value adding, there is some room for the researcher to define if a specific activity should be either value adding, supporting or non-value adding. The researchers argue however that this risk of a subjective choice of activity is rather low since the PPA-tool have established a well-defined list of activities related to each of the three categories.

Moreover, the interview method used for this research is of a structured type. This often indicates a higher level of reliability (Wallén, 1993). However, the aim for the interview is to get the most truthfully answer from the interviewees. This sometimes calls for follow-up questions so that the researchers establish a better understanding for a specific area and therefore be able to grade each question in a more suitable way. Although the questionnaire is structured and related to a specific type of grading, there is a risk that another researcher asks other type of follow-up questions and grade a specific question in another way. However, almost all questions in the questionnaire encourage the interviewee to illustrate the answer with examples. This should increase the chance for the interviewer to get the right type (same type) of information to be able to grade each question in a suitable way and therefore increases the level of reliability.

In addition, since this research have had constraints regarding time and that each company visits have been conducted in less than a day, all aspects regarding a specific company have been impossible to gather. The researchers have only investigated and observed the OEE measure and the frequency study at a specific production area. The ideal scenario is that the studied production area should be of high importance for the company and preferably a bottle neck. There is a risk however, that another researcher investigates other part of the production where both the OEE for the machinery as well as the activates performed by the operators differs from the production area used for this study. However, the researchers argue that this risk is relatively low since the researchers have requested to observe the bottle neck, and if the bottle neck haven't shifted to other parts of the production, the results should be the same.

Moreover, an extensive part of the empirical findings has been gathered from interviews conducted at each firm visit. The number of participants for each interview range from one till two persons where one interview subject is the most common scenario. The researcher has asked to interview the production manager or plant managers at each company visit, but CI coordinators or similar positions have been interviewed at some firms instead. There is an evident risk that another researcher interviews a person different from the interview subject for this research. Since the majority of the interview questions are based on a subjectivity, there is a risk that another interview subject gives a different view of the current production for the manufacturing firm. The researchers argue that different interview subjects are the most apparent risk to the reliability of this report.

4.3.2 Validity

Validity can be divided into either external or internal validity. External validity relates to which extent this research can be generalized (Bryman & Bell, 2007). The internal definition of validity is that the model does not have any systematical errors and that the researchers only study what is the intent to study i.e. related to the purpose of the research (Wallén, 1993).

Although this research investigates manufacturing firms in the western region of Sweden, the researchers argue that this study is rather generalizable to other regions of Sweden or to other similar countries. Throughout this research, no information or data have been gathered by the researchers that indicates that the results and conclusions from this research have something to do with the geographical environment in Västra Götalands Län. Therefore, the external validity is argued to be rather high.

The researchers argue that the internal validity is high as well. As previously been mentioned, both researchers have graded each company individually based on the content from the two applied assessment tools. This individual grading has therefore been the base for a discussion where inputs from both researchers resulted in the finalized grading. There is a risk however that each interview subject embellishes the current situation of the production i.e. that the interview subject describes the situation more in regards to wishful thinking than the actual state. This risk is argued to be rather low since the researchers stress that all answers should be illustrated with examples. In addition, the information gathered from the interviews are also compared with the observations made at the shop floor to acquire a more truthful state for the production.

Moreover, general pitfalls and factors of success during the interview have also been discussed prior to the company visits with professors at Chalmers as well as with professionals at the Triathlon Group. In addition, the Triathlon Group have also been of great support for the researchers regarding guidance related to both the empirical data as well as the analysis section.

4.4 Method Reflection

This section aims to discuss what the researchers would have done differently if an identical study were to be conducted. The procedure to contact potential participating companies were more time consuming than first expected. The original time schedule for this research anticipated that all onsite visits were to be conducted in Mars or early April. However, since the procedure of contacting the potential firms was longer than expected, the majority of companies were visited in mid to late April. This naturally had an effect on the progress with the report since the necessary data needed to finalize the report were not gathered. Therefore, if a similar study were to be conducted again, the procedure of establishing contact with potential participating companies should be conducted earlier in the process.

Moreover, this research has gathered data both from the onsite visits as well as by email after the onsite visits. The information gathered by email was often additional information not easily available during the interview. The OEE measure or the necessary data to calculate a theoretical OEE measure is one example. However, the lead time to gather the additional data by email was longer than expected. Hence, the researchers were unable to analyze these areas until all the information was collected. This problem was especially evident since the onsite visits were postponed as well. The researcher would attempt to gather all the necessary data at each onsite visits if a similar study were to be conducted.

Moreover, this research has used two methods, one to gather the level of Lean implementation and one to establish the level of resource utilization. Since the Lean questionnaire was formulated specifically for this study, the researchers argue that all questions related Lean questions should be asked if another study were to be conducted. Moreover, the Productivity Potential Assessment method is argued to be slightly modified. This research aims to investigate the relationship between resource utilization and Lean implementation as well as to evaluate the strategic implication with regards to Lean production. The PPA model however, evaluates several parameters that do not have a direct impact to the aim for this research. Work environment is one such area that the PPA model evaluates but that have less impact on this research purpose and aim. Therefore, if a similar study were to be conducted in the future, all parameters assessed by the PPA model needs to be evaluated with regards to this particular research.

CHAPTER 5 - EMPIRICAL FINDINGS

In this chapter the empirical findings will be described. The participating companies are briefly described in order to give the reader some context of their production. Furthermore, the findings from both the Lean questionnaire as well as findings from the PPA evaluation model are given.

5.1 Company facts

In order to make comparisons between the participating companies, similarities and differences between the participating manufacturing firms had to be accounted for. This was enabled by compiling company facts such as industry, number of employees, revenue, margin and level of automation in the production for each individual firm. Since companies have different strategies and ways of doing business it is important to take into account things that are similar as well as areas that separate them from each other. Based on the interviews, most of the participating companies actively pursue Lean production in some form. Information regarding when these manufacturing firms initiated their "Lean journey" was however not gathered in this research since the production managers at each company seldom had that kind of information. Based on the delimitation regarding number of employees and sales, the average sales figure for this research is 711 million SEK and the average number of employees is 248.

Table 4. Company facts compiled from the company visits

Company	Level of automation	Operating margin	Industry	Measure scrap rate?	Measure inventory turnover?
Company A	Semi-Automated	4%	Industry A	Yes	Yes
Company B	Automated	54%	Industry B	Yes	No
Company C	Semi-Automated	1%	Industry C	Yes	Yes
Company D	Semi-Automated	13%	Industry D	Yes	Yes
Company E	Manual	1%	Industry E	No	No
Company F	Manual	0%	Industry F	No	Yes
Company G	Automated	-1%	Industry G	No	Yes
Company H	Semi-Automated	20%	Industry G	No	Yes
Company I	Semi-Automated	6%	Industry D	Yes	Yes
Company J	Automated	5%	Industry G	Yes	Yes
Company K	Semi-Automated	10%	Industry C	Yes	Yes
Company L	Automated	3%	Industry G	No	Yes
Company M	Automated	6%	Industry A	Yes	Yes

Table 4 demonstrates a comparison between the participating companies. This information is received from each participating firm but the *level of automation* is established by the researchers. Moreover, the participating firms represent a range of industries and produce different products, both business to business (B2B) as well as business to customer (B2C). The intuitive way to organize the results would be to sort the companies based on industry. However, one of the initial findings in this research, based on the firm visits, was that the product and the industry matter less than the way the products are manufactured. There are more commonalities between two companies that have a high level of automation that produce different products than two companies within the same industry that uses different levels of automation. Due to this conclusion, the following results will be presented either for each individual company or divided into groups based on their level of automation.

5.2 Findings from the Lean questionnaire

The researchers gather and evaluated the level of Lean implementation at all participating sites. The level of Lean implementation was assessed with the Lean questionnaire. The results vary among the companies and are illustrated in Figure 10. The figure presents the companies' percentage of Lean implementation with regards to the highest maximum score achievable i.e. 195 points. The combined average for all participating companies was 50 percent and the median was 47 percent. One firm, *Company C*, had a Lean implementation above 70 percent and one firm, *Company B*, had a Lean implementation below 40 percent.

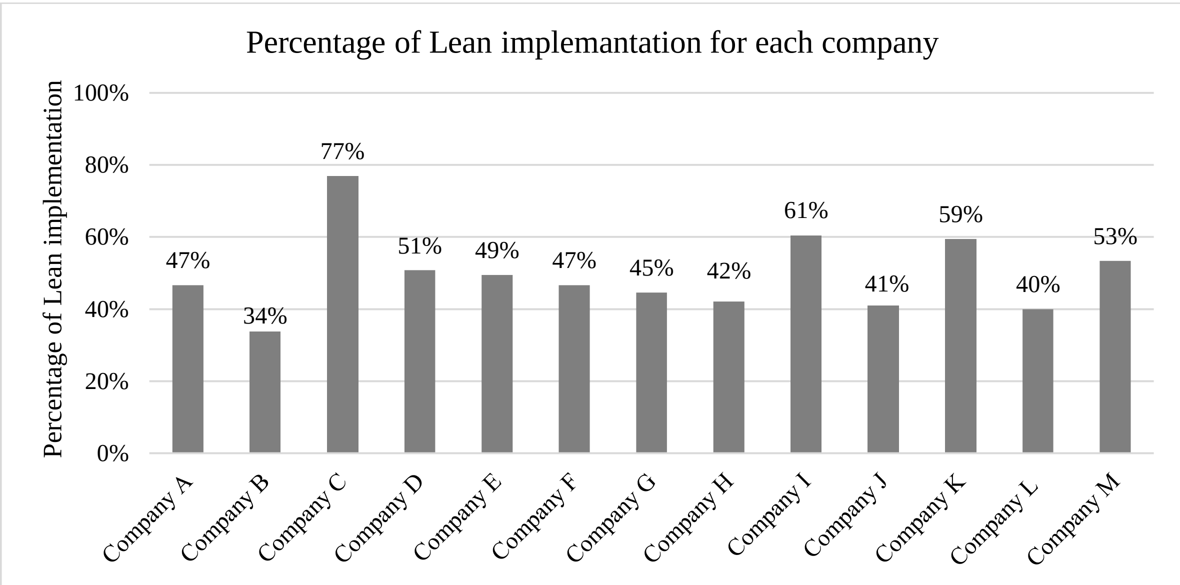

Figure 10. Total score received as a percentage of the maximum score for each company evaluated with the Lean questionnaire

As stated above, all 39 questions from the Lean questionnaire was evaluated and assessed based on a scale from 0-5. Hence, the percentage of the Lean implementation for all participating firms, see Figure 10, have been further decomposed to show the distribution of scores from 0-5 for each company, see Figure 11. This distribution shows that the total degree of Lean implementation can be achieved in various ways. As an example, *Company F* and *Company G* roughly have the same degree of Lean implementation, 47 percent and 45 percent respectively. However, the decomposing of zeroes to fives for these two firms differ. Of the 39 question asked, 30 percent of the question assessed at *Company F* were marked as zeroes. The same score for *Company G* is only 13 percent. *Company F* instead have more fours and fives, 18 percent and 5 percent respectively.

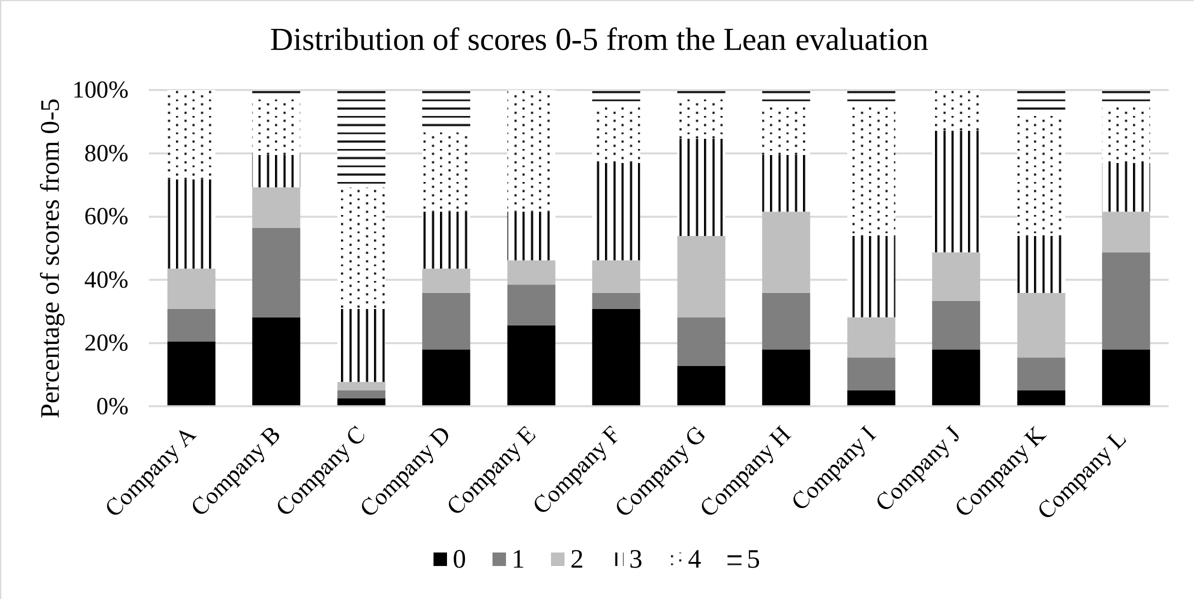

Figure 11. Distribution of scores from 0-5 for each company evaluated with the Lean questionnaire

The results illustrated in Figure 10 and Figure 11 show of a difference regarding the degree of Lean implementation and the Lean score distribution between the participating firms. However, in order to compare the different companies, it is important to have in mind that the production vary by degree of automation. The level of Lean implementation is therefore divided based on the level of automation and is presented in Figure 12 and Figure 13. The average degree of Lean implementation is presented in Figure 12 and average distribution of score from 0 to 5 is presented in Figure 13. These two figures show that the companies that have a semi-automated production have the highest level of Lean implementation. Further, Figure 12 and Figure 13 show that manually oriented production has a higher degree of Lean implementation than fully automated production. This despite the fact that manual production, on average, have a higher degree of 0 point questions.

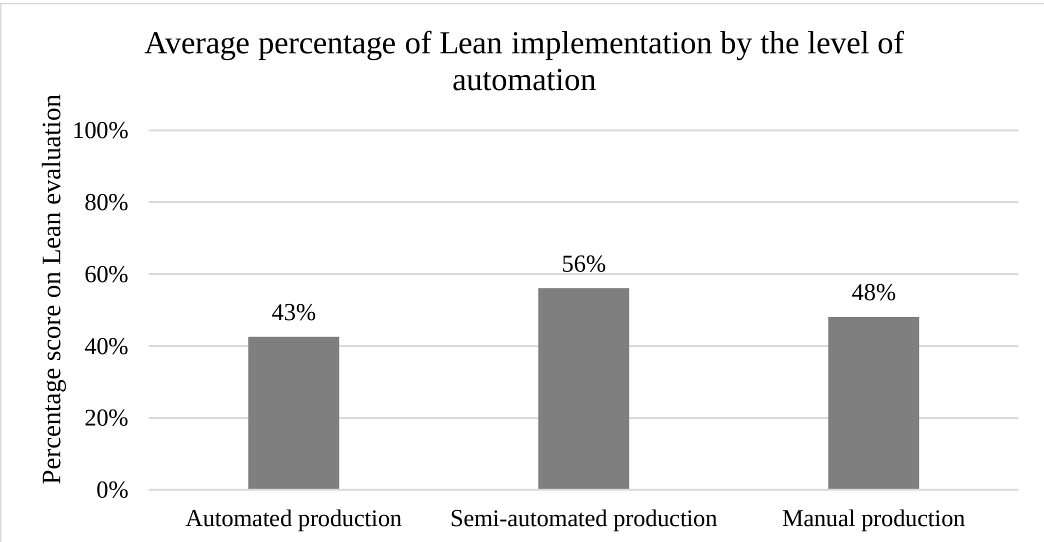

Figure 12. Distribution of the average degree of Lean implementation by the level of automation

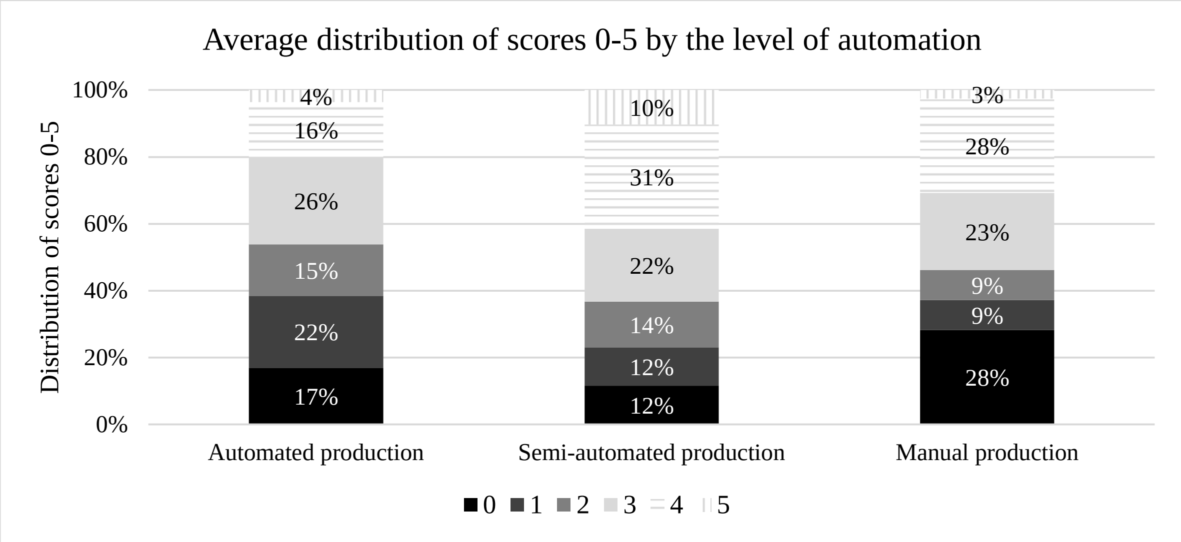

Figure 13. Average score 0-5 from the Lean questionnaire divided by the level of automation in the production

Hitherto the results from the Lean questionnaire have been oriented towards the participating companies and the level of automation. These figures have shown some differences, both between the participating companies as well as between the level of automation. The results have been presented as the total degree of Lean implementation and as a decomposition of the score from 0-5.

To get a better understanding of the degree of the Lean implementation, the following results are oriented towards the different areas of Lean production and how the participating companies scored in each separate area. Figure 14 presents the degree of implementation for every individual category from the Lean questionnaire. The highest score achieved is 61 percent in the area of continuous improvement. Most areas are implemented between 52 percent and 59 percent. The areas in which the companies have scored the lowest are changeover, material handling and planning, where changeover have the lowest degree of implementation, 27 percent.

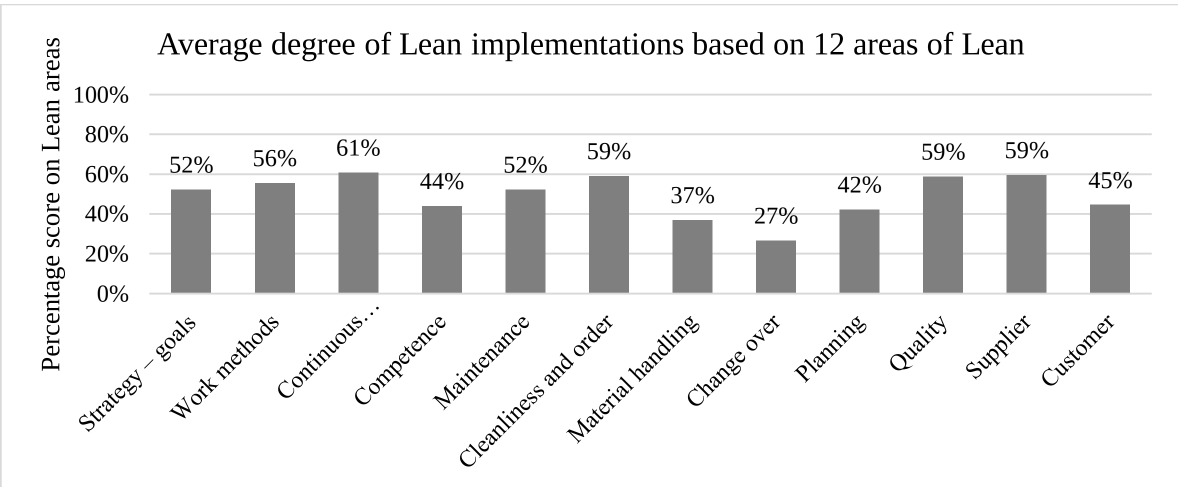

Figure 14. The average degree of Lean implementation from the Lean questionnaire illustrated by Lean areas. The changeover has been adjusted for the companies with manual production.

5.3 Findings from the productivity potential assessment

The productivity potential assessment evaluates several different aspects of the company's production, as described in the literature review. In this section, the researchers present all data related to the productivity potential assessment tool. The productivity potential assessment tool will be divided and presented in three categories; the frequency study, OEE and PPA questionnaire.

5.3.1 Frequency study

The first part of the PPA method is, as described earlier, to conduct a frequency study. The result of this study is shown in Figure 15 where the distribution of operator time is compiled for each company. The 480 gathered samples are divided into three areas, value adding, supporting and non-value adding. A more thorough explanation of the three categories is described in the litterature chapter.

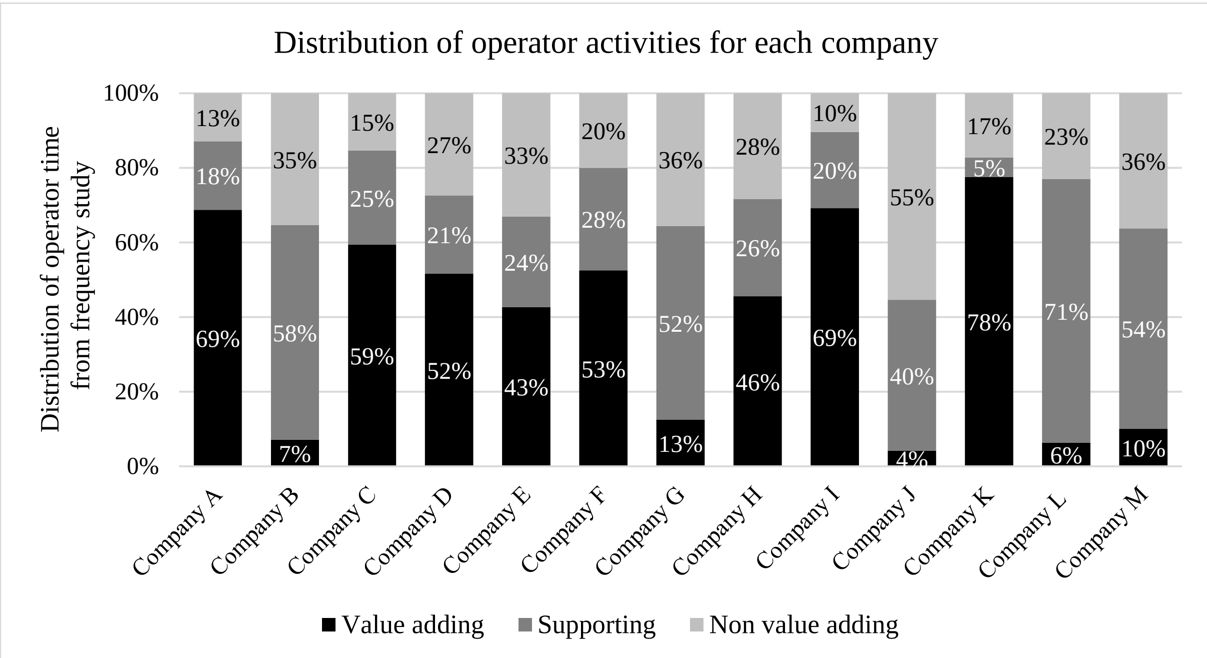

Figure 15. Distribution of operators' performed activities from the frequency study conducted at each company

The results show that one company, *Company K*, have value adding activities that accounts for more than 70 percent (78%) of the operators used time. The average precentage of value adding activities is however 39 percent. Moreover, if the sum of supporting activities are bundled together with those of value adding activities, five companies score above 80 percent. The researchers argue that this illustration is needed since the non-value adding activities is the only activity that are directly linked with productivity improvement. Both the value-adding and supporting activities are necessary with the current production method.

Further notable is that *Company B, Company G, Company J, Company L and Company M* all have value-adding activities below 15 percent. This can be somewhat better understood with Figure 16 which illustrates the average distribution of operator activities diveded per level of automation. The five companies listed (*Company B, Company G, Company J, Company L and*

Company M) all are manufacturing firms with a high degree of automation. Consequently supporting activities is a larger part than the one of value adding activities. Notable is also that the distribution of activities for manual production and semi-automated production is similar. However, value-adding activities is somewhat higher with a semi-automated production.

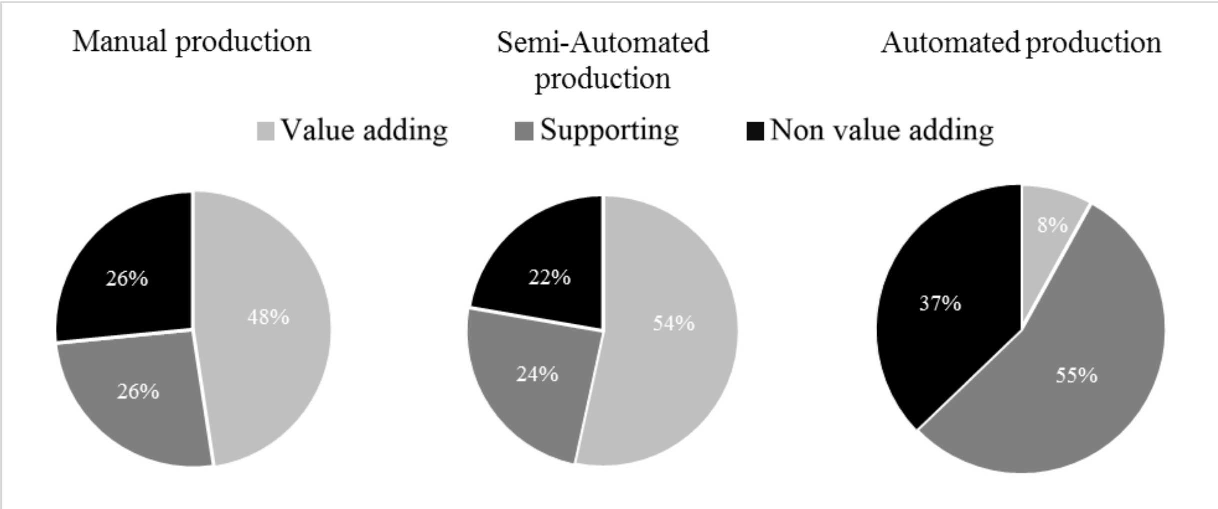

Figure 16. Distribution of operator activities divided by the level of automation

5.3.2 Overall Equipment Efficiency

An additional measure of the PPA model is the overall equipment efficiency. This measure is similar to the utilization of labor but instead evaluates to which degree the company utilize their machinery. Figure 17 illustrates the OEE measure at each company. The presented OEE measure is from the machine related to the observed production area. Company E and Company F is excluded for this section since these two firms have manual production.

The OEE measure was commonly known among the interviewees at most visited companies. However, to actively conduct and measure OEE was not that common. Most participating firms did not measure OEE at any level. At these firms, the researchers gathered the necessary input data to calculate a theoretical OEE measure. The necessary input data was:

a) The ideal cycle time for each product that passes through the chosen machine during one week
b) The actual output of all products produced during that same week.
c) Planned production time for that same week.

By multiplying the ideal cycle time for each product with the number of products, the ideal production time is given. By dividing the previously given number with the planned production time (that excludes planned stops), a theoretical OEE measure is given. These calculated OEE measures are indicated with grey bars in Figure 17. Moreover, some of the participating firms did measure the OEE at their machines. These firms are indicated with black bars in Figure 17. In addition, Company C even had real-time updated OEE measures at all their machinery.

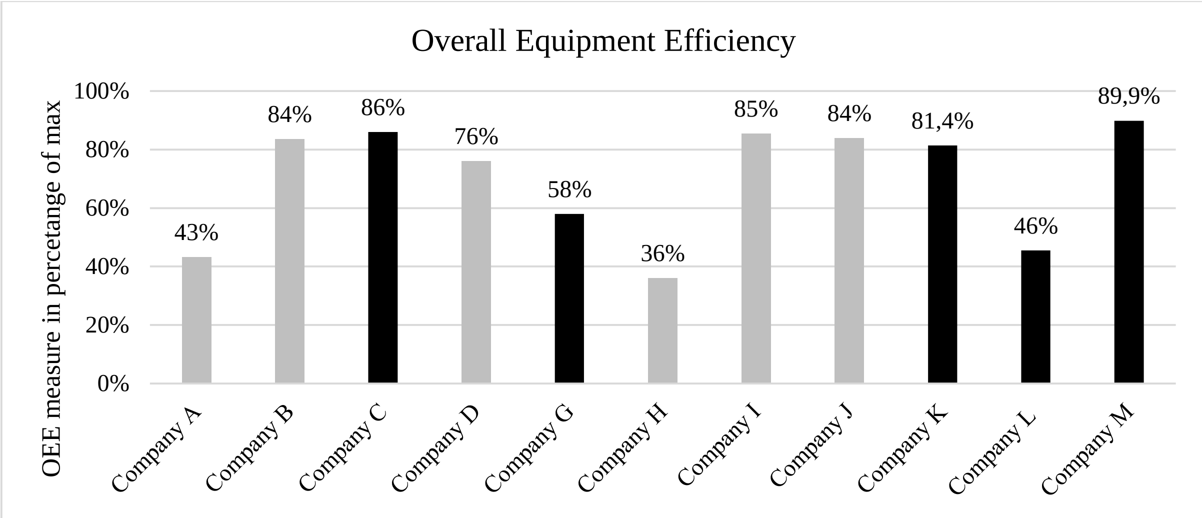

Figure 17. Overall Equipment Efficiency for a selected machine at each company. The black bars indicate of firms that measure OEE and the grey bars indicate of firms that provided with raw data.

Figure 17 presents that the OEE measurement vary among the participating companies. The highest OEE measure for investigated machinery in this research can be found at Company M, with an OEE at 89,9 percent. The average OEE for all participating firms, with either a semi-automated or an automated production, was 69,9 percent.

Moreover, the OEE measure varies both within and between the two types of automation. Figure 18 illustrates the OEE measure where the participating companies are divided based on their level of automation. Figure 18 further presents that in both levels of automation some companies provided OEE figures and some companies provided raw data. Further, there are similar variations within the two levels of automation. Some companies have a high OEE measure while some have a low OEE measure, in both the levels of automation.

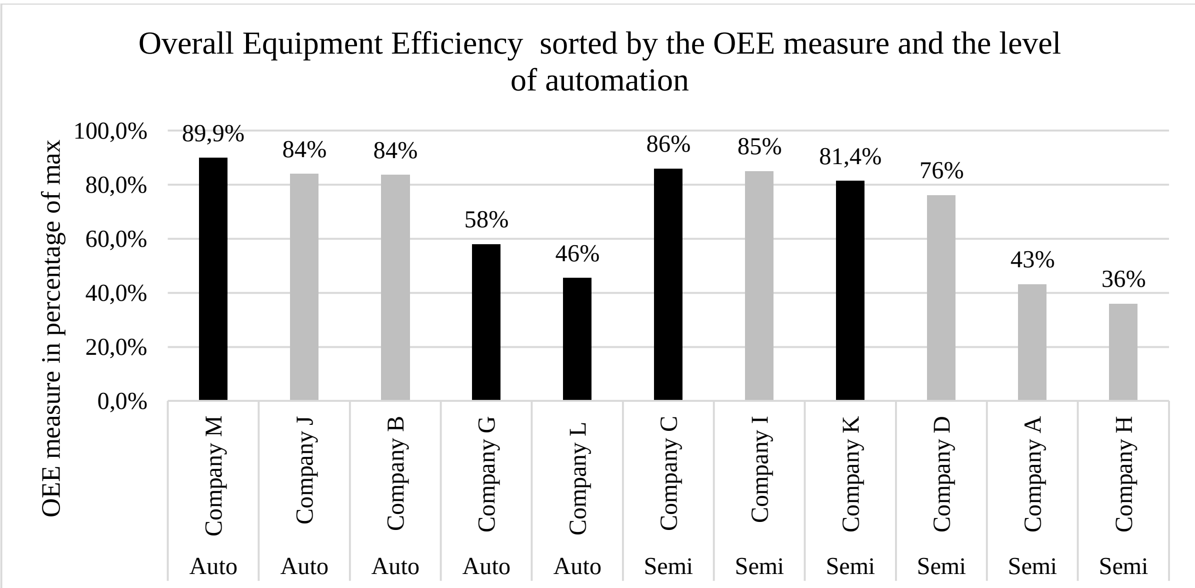

Figure 18. OEE sorted by score and level of automation. The black bars indicate firms that measure OEE and the grey bars indicate firms that provided raw data.

5.3.3 Productivity Potential Assessment questionnaire

The third part in the PPA method consist of the 40 PPA questions, evaluated in the same interview as the Lean questionnaire. These two separate questionnaires were combined into one questionnaire and was formulated and marked as during the interview session with the production manager. The PPA score and the Lean score are however accounted for separately. As is illustrated in Figure 19, three companies achieved a score above 60 percent yes and three companies achieved a score below 40 percent yes. The average set of yes among all participating firms were 49 percent or 19 yes.

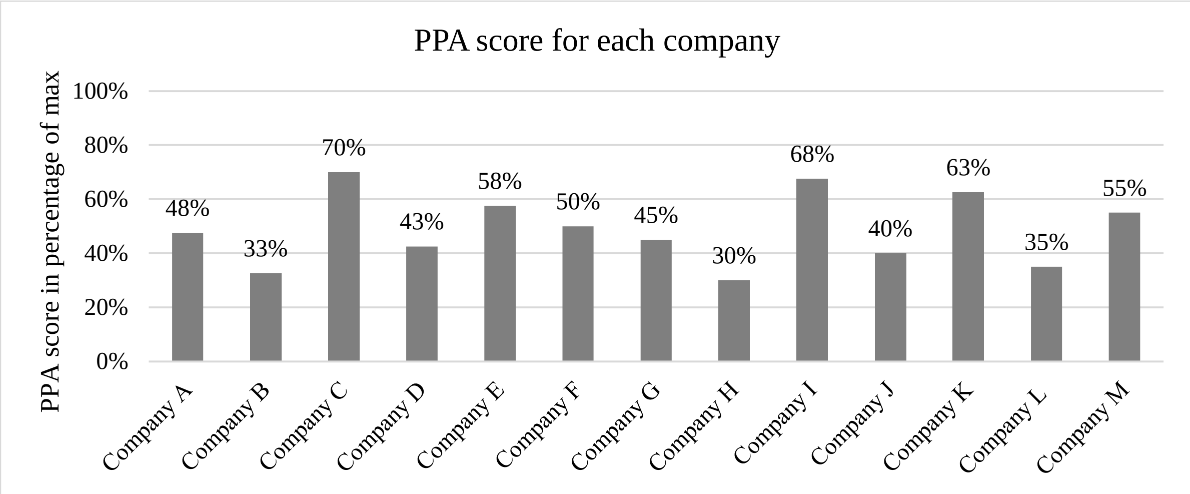

Figure 19. The number of marked yes as a percentage to the maximum score evaluated from the PPA questionnaire

The PPA questionnaire is, in similarity to the Lean questionnaire, divided into a set of production areas. The average score within each area vary between 11 production areas presented in Figure 20. Generally, the companies score higher within the areas of *Quality* and *Continuous improvement* and lower in the areas of *Planning* and *Maintenance*.

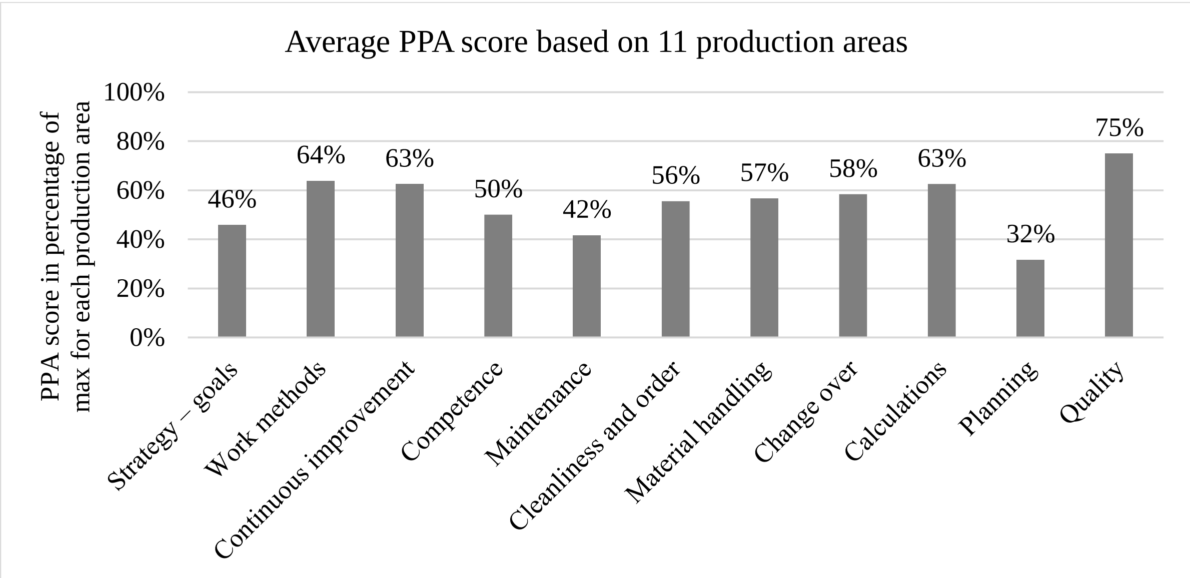

Figure 20. The average score from the PPA questionnaire illustrated by PPA area.

CHAPTER 6 - ANALYSIS

This section will evaluate the empirical findings in relation to the literature review for both research questions. The chapter will be divided based on these two research questions. The relationship between the degree of Lean implementation and resource utilization will be described and analyzed prior to the analysis related to if Lean production can be regarded as a sustainable competitive advantage.

6.1 Relationship between Lean implementation and resource utilization.

In this section, the researchers will evaluate the relationship between resource utilization and the degree of Lean implementation at 13 manufacturing firms in the western region of Sweden. The results from the Lean assessment tool and the productivity potential assessment method have already been stated in the empirical findings and will now be evaluated and analyzed with regards to earlier research presented in the literature review. This relationship will be divided into two parts; the first section will cover the relationship between the degree of Lean implementation and the results gathered from the frequency study. The second part of this section will analyze the relationship between the level of Lean implementation with the overall equipment efficiency.

6.1.1 Relationship between Lean implementation and the frequency study

This section aims to present the findings from the Lean questionnaire with regards to the findings from the frequency study. The frequency study evaluates, as described in the literature, the distribution of the operators' activities based on three main categories. These categories are value adding activities, supporting activities and non-value adding activities. A high degree of value adding activities are preferred since these activities actually adds value to the product and something the customer is willing to pay for.

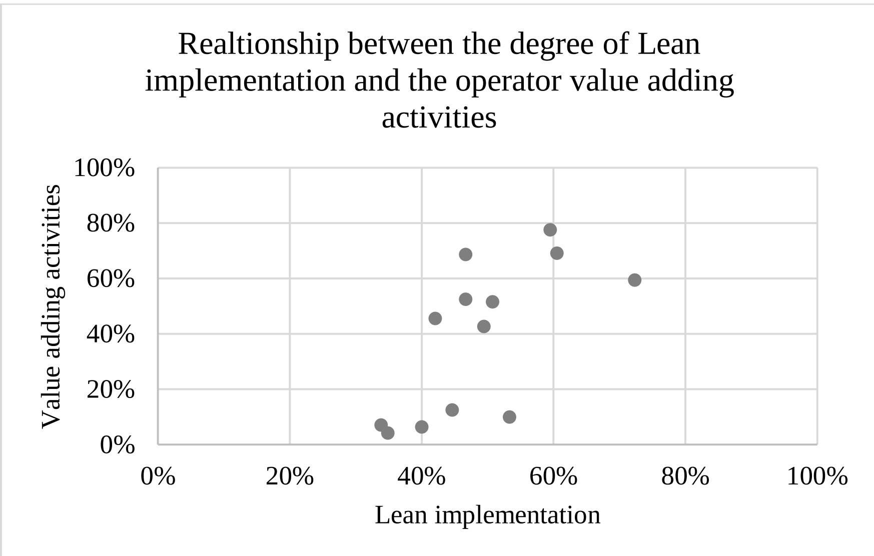

Figure 21. The relationship between percentage score on the Lean questionnaire and the percentage of activities being value adding for operators

Based on the empirical findings from all 13 manufacturing firms, Figure 21 presents the relationship between the percentage of value adding activities and the percentage of maximum pointes received from the Lean questionnaire. This relationship does not show any particular trend but there are some indications that there is a positive correlation between the level of Lean implementation and the degree of resource utilization. What is interesting however is that five companies stand out with an exceptionally low degree of value adding activities. Efforts were therefore made to establish the root cause for these findings. The result and explanation to these low scores can be found in the level of automation. The researchers therefore argue that a separation based on the level of automation for these 13 manufacturing firms is needed.

In Figure 22, the same companies and relationships are illustrated with the difference that these 13 manufacturing firms are grouped by level of automation i.e. *automated production, semi-automated production* and *manual production*. This clearly shows that a high degree of automation offers a low degree value adding activities. This since these operators mainly attend the machinery and suffice as backup in case of a breakdown or production stop. However, within the automated production group, a trend is shown that higher degree of Lean implementation shows a higher degree of value adding time. In comparison to the automated production, the semi-automated production and the manual production show a much higher level of value adding activities. The reason for this is that value adding activities are needed at each production cycle and naturally show a much higher percentage compared to an automated production.

Moreover, an interesting finding in the comparison between manual production and semi-automated production is that manual production shows a lower percentage of value adding activities. The reason for this might be that a manual production is not bound by any machines why the operators can plan their activities more individual. This scenario can either maximize the operators level of output or create the risk of underutilization. However, the results presented by Kinnander and Almström (2008), show that manual production has the highest percentage of value adding activities, 64 percent. There are therefore reason to question the comparison between semi-automated production and manual production for this research since the population of firms with manual production only consist of two companies. Moreover, the relationship between the percentage of Lean implementation and the percentage of value adding time shows some correlation, especially for the semi-automated production. As for the manual production, there is a negative correlation between the percentage of Lean implementation and the percentage of value adding time. Again, the researchers argue that the two firms in this group is too few to draw any conclusions.

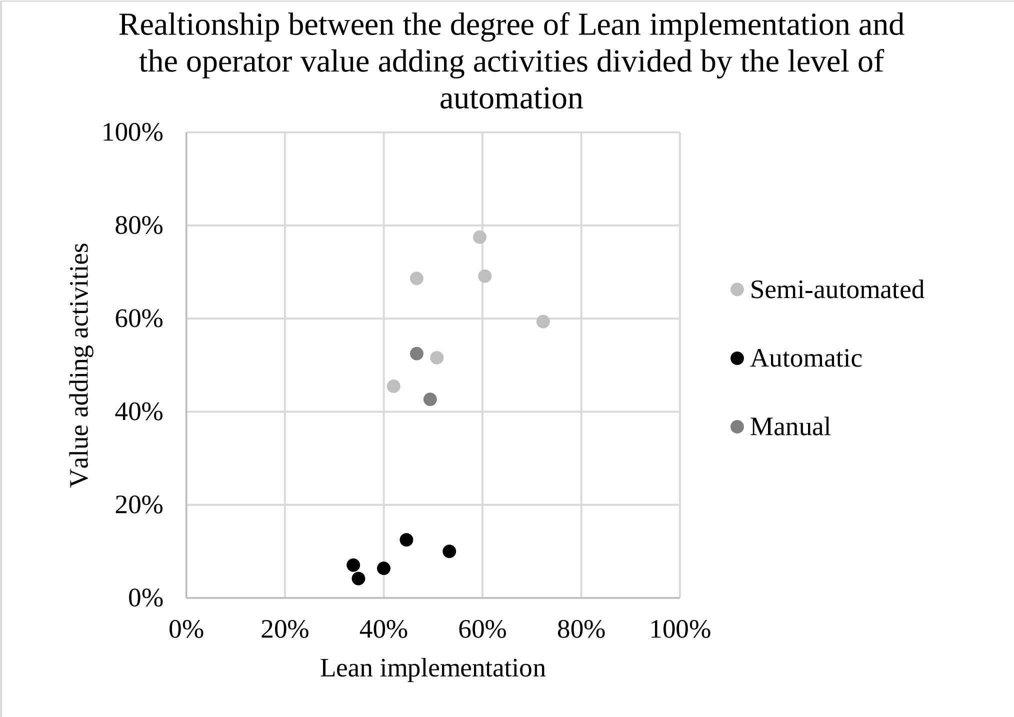

Figure 22. The relationship between the percentage of Lean implementation by the Lean questionnaire and the percentage of activities being value adding for operators, illustrated by level of automation.

Comparing value adding activities with the degree of Lean implementation is one way of illustrating the relationship between degree of Lean implementation and resource utilization. This relationship is, as illustrated above, clearly dependent on the level of automation. Therefore, a more interesting perspective is to compare the degree of Lean implementation with the degree of non-value adding time. One of the principles of Lean production is elimination of waste. Non-value adding activities are activities that neither add value to the product or support the production process and is therefore argued to be waste. If Lean is practiced within the production process, it is reasonable to argue that the degree of non-value adding activities should be minimized independently of the level of automation. This relationship is illustrated in Figure 23. This figure shows a clear correlation between the two aspects and shows that there is in fact a relationship between the percentage of Lean implementation and non-value adding activities. In average, manufacturing firms that have a higher percentage of Lean implementation show of a lower percentage of non-value adding activities and vice versa. This result indicates that Lean production helps manufacturing firms remove unnecessary waste in their processes.

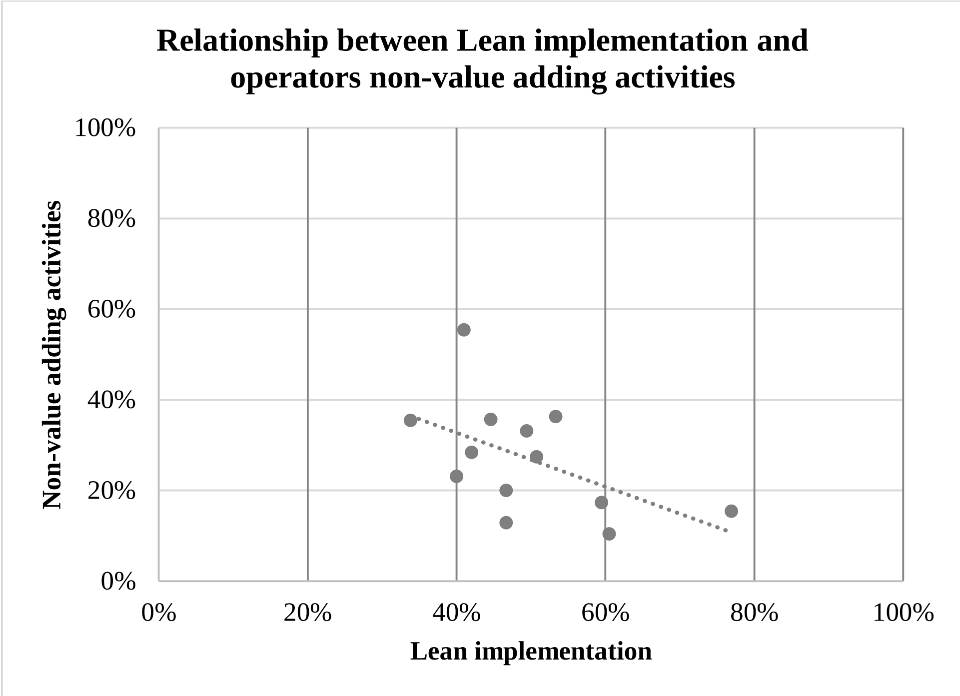

Figure 23. The relationship between the degree of Lean implementation and the percentage of activities being non-value adding for operators

6.1.2 Relationship between Lean implementation and the Overall Equipment Efficiency

The relationship between Lean implementation and value-adding, supporting and non-value adding activities have been accounted for. This section will instead analyze how the overall equipment efficiency measure relate to the degree of Lean implementation. This relationship is illustrated in Figure 24.

As illustrated in Figure 24, there is some evidence to support that a higher degree of Lean implementation correlates with a higher OEE measure. The results however vary between the participating firms, more than the comparison between the level of Lean implementation and non-value adding activities. This is especially evident for firms with a Lean implementation of between 40-50 percent. These firms have a lower OEE measure compared to the two firms with a Lean implementation of 41 percent and 34 percent respectively. This results may be of several reasons.

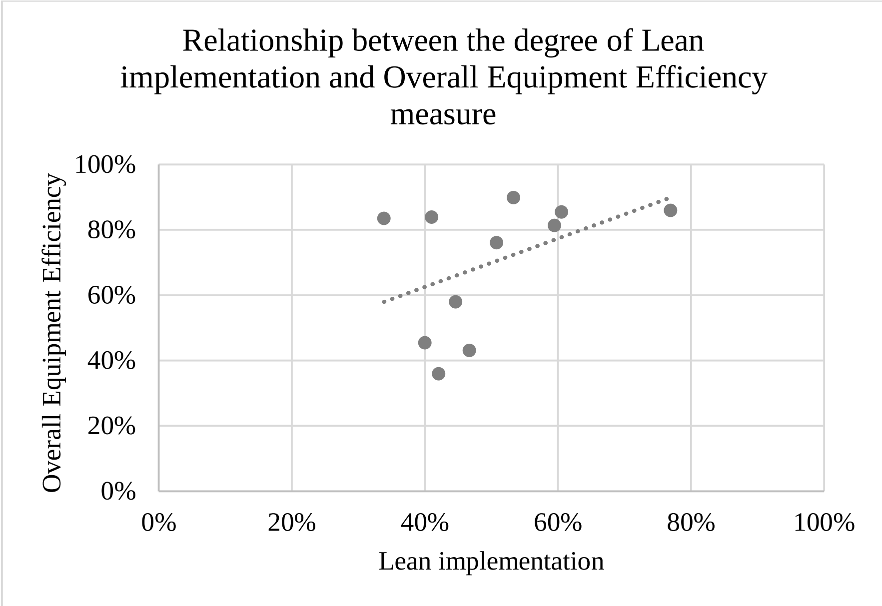

Figure 24. Relationship between the degree of Lean implementation from the Lean questionnaire and the OEE measure for each company

Intuitively is that a highly automated production process should correlate with a higher OEE measure since the machines account for the majority of the production value. However, based on the illustration from Figure 18, no conclusion can be drawn that the level of automation relates to a high or low OEE measure. Further, there is also reason to believe that firms that measure their OEE also relates to a higher OEE score. However, there are no relationship between the firms who measure their OEE and the firms that do not measure their OEE, illustrated in Figure 17. The variance between the firms' level of OEE may also result from the machines potential over capacity. If the investigated machine is faster than the surrounding steps with a well-defined takt-time, the OEE measure naturally is lower. However, since this research required to observe a bottleneck, the researchers argue that this scenario is less likely. Hence, the most possible scenario to the variation between the participating firms OEE is related to the operators. It is often inevitable that a machine stops, breaks down or need some kind of change over. These activities need to be performed by the operators. Their knowledge and well-defined procedures determine the length of the activities that lowers the OEE measure i.e. fix the stops. The researchers argue that the variation found between the participating firms level of OEE relates to each firm's ability to handle break downs, stops and change over.

To conclude this section, there is some evidence that a higher degree of Lean implementation relates to a higher OEE measure. The elimination of waste is an important part of Lean production and Hines, Holweg and Rich (2004) argue that OEE is an important tool to measure waste. The five observed firms with the highest level of Lean implementation all have a high OEE measure. Therefore, the researchers argue that Lean production indeed correlates with a higher OEE measure.

6.1.3 Tradeoff between Lean production and resource utilization

The relationship between Lean implementation and resource utilization, both with regards to operators as well as machinery, have been accounted for. This section aims to compare this result with regards to the literature review. Modig and Åhlström (2012) discuss the relationship between Lean implementation and resource utilization as flow efficiency and resource efficiency respectively. They further argue that there is a tradeoff between to maximize the level of flow efficiency within a process and to maximize the utilization of staff and machinery. This trade-off or relationship is presented in their efficiency matrix. The researchers aimed to plot all of the participating companies according to a slightly modified efficiency matrix. Instead of flow efficiency, the modified efficiency matrix would have had the level of Lean implementation on the x-axis. This trade is supported and argued for in the literature review mainly since a major aspect and cornerstone of Lean production is to establish flow. Moreover, instead of presenting the resource efficiency on the y-axis, the modified matrix would have had the level of resource utilization. Since the majority of the participating firms need machinery in their process, their level of resource utilization is assessed both with regards to the frequency study as well as to the OEE measure. From discussions with Peter Almström the researchers conclude that these two parameters are interdependent. Therefore, it is not possible to give an overall or a total level of resource utilization for the semi-automated and automated firms in this research. Based on this argument, the researchers cannot plot the participating firms in the efficiency matrix.

There is however a possibility that each participating firm, thanks to their deeper knowledge about their process, indeed find an overall or a total level of their resource utilization. In this case, the participating firms can estimate their position in the efficiency matrix with regards to the overall resource utilization and the degree of Lean implementation. Based on their current position (*Efficient island, Wasteland, Efficient ocean or Perfect state*), Modig and Åhlström (2012) argue that the *Perfect state* is achieved if firms emphasize on flow efficiency over resource efficiency. Once the *Efficient ocean* is achieved, firms can turn their attention towards resource efficiency to reach the perfect state.

6.2 Strategic implications with regards to the level of Lean implementation

In addition to the relationship between resource utilization and Lean implementation, this research also aims to answer if Lean production can be regarded as a sustainable competitive advantage. This analysis will be based on the presented findings of the relationship between Lean production implementation and resource utilization as well as on related theory.

As been stated in the literature review, increased global competition has created a need for new types of production philosophies. Lean production emerged as one of the most accepted strategies to be able to produce and deliver the right product, on time and with sufficient quality requirements. Säfsten, Winroth and Löfving (2014) further argue that there are different areas that relates to competitiveness. These competitive targets are quality, deliverability, flexibility and cost. Clearly, there are synergies between the implementation of Lean production and the future competitiveness of the manufacturing firm. However, Lewis (2000) argue that there are debates within academia whether Lean is a mean to establish a competitive advantages or not.

Grant (2010) argues that there are various ways that a company can be competitive. This can be related to the firm's resources or their internal capabilities. Grant (2010) further argue that in order to remain competitive, firms need to establish advantages that last. One of the most prominent tools to assess competitive advantages is the VRIO model. This model assess the resources and capabilities based on four questions. Is it valuable? Is it rare? Is it hard to imitate? Is the firm organized around it? Lean production can be viewed upon in different ways. It could be an internal capability and should therefore be assessable using the VRIO model Lewis (2000). Hence, to evaluate if Lean production can be related to long term competitive advantage, all possible scenarios for these four questions need to be analyzed. The following sections aim to analyze the competitiveness of Lean production with regards to the empirical findings from this research.

6.2.1 Is it valuable?

In order for a company´s resource or capability to be an advantage it has to add value. By nature, Lean production aims to eliminate waste which can be argued to add value to the company. Likewise, a better working processes that improves quality and that establish a better flow can be argued to add value as well. In addition, there is more aspects of value. Value can also be measured in monetary terms. However, the additional income or savings need to outweigh the costs associated with the implementation. Further, the potential savings from the implementation of Lean also need to be reinvested into the company, to achieve actual value. In order to evaluate whether Lean production contributes to an increased overall efficiency and value, Lewis (2000) compared the implementation of Lean production with a set of key performance indicators at three manufacturing firms. Lewis's (2000) findings vary however. One of the investigated firms, with a high degree of Lean implementation, was unable to realize the benefits of cost savings from elimination of waste etc. Lewis (2000) further explains that these savings were shifted to their customers due to their low bargaining power within the value chain. Out of Lewis's (2000) three investigated firms, the most prominent company regarding financial performance was the one that focused least on Lean production and instead focused on strengthening their bargaining power towards both customers and suppliers.

The relationship between Lean implementation and value will now been analyzed based on the participating firms for this research. Hence, the degree of Lean implementation has been evaluated with regards to KPIs for a certain point in time. The most obvious way to evaluate whether Lean correlates with value is to compare the degree of Lean implementation with the participating firms operating margin. The operating margin was received from the participating firms during the onsite visit, as stated in the empirical findings. The relationship between the degree of Lean implementation (Lean score on the Lean questionnaire) and operating margin is illustrated in Figure 25.

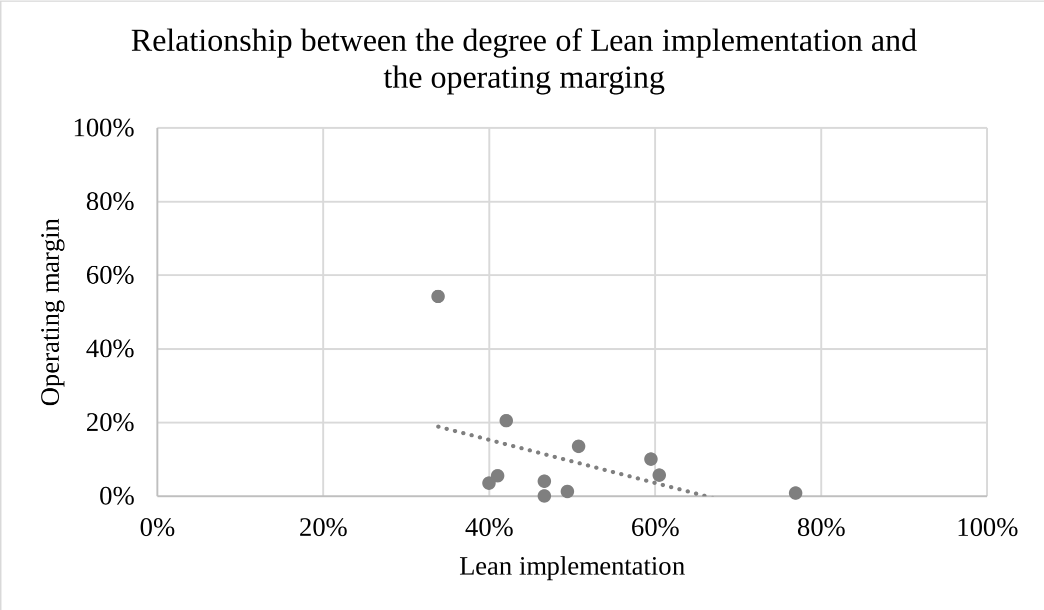

Figure 25. Relationship between the degree of Lean implementation and the operating margin (%) for each company

Whether Lean production provide companies with value that can be exploited in monetary terms, such as operating margin, is difficult to confirm. In Figure 25 the trend line shows the opposite. The higher degree of Lean implemented in the production the lower the operating margin. This result indicates that it is an advantage not to implement Lean production. However, this figure, provides too little information regarding the context of the specific companies. There are of course many factors that affect the operating margin apart from Lean production. The elapsed time from the starting point of the Lean production initiative might be one reason and is closely related with Lewis's (2000) argument about reinvestments. The elapsed time could affect the margin since the initial phase of the implementation might be linked with higher costs than the later phases of implementation. Hence, the participating firms that initiated their Lean implementation earlier might have more benefits presently than companies that have just started their Lean implementation. However, due to difficulties regarding the elapsed time since the Lean implementation was initiated, this research will not consider this aspect further. Other aspects that affect the operating margin is the level of automation and the competitiveness of the industry.

Moreover, a question that should be considered prior to concluding that Lean production lowers the operating margin is whether the companies that have implemented Lean to a high degree and still have a low margin would have ceased to exist without Lean production. In highly competitive industries, Lean production is a necessity to be able to compete. The automotive industry is one if these industries. These findings might in fact underline the findings of Lewis (2000), where a low bargaining power towards customers limits the possibility to capitalize the savings of Lean production.

In addition, one of the core principles within Lean production is elimination of waste. It is argued that the elimination of waste is one way of providing value to the company. Within a production process, waste can be many things. One form of waste, as previously discussed, is non-value adding activities. Another form of waste is material scrap. To be able to minimize material scrap from the process, manufacturing firms need to measure the scrap rate. The empirical findings show that five participating firms do not measure their scrap rate. Figure 26 illustrate the relationship between percentage of Lean implementation and the measurement of scrap rate.

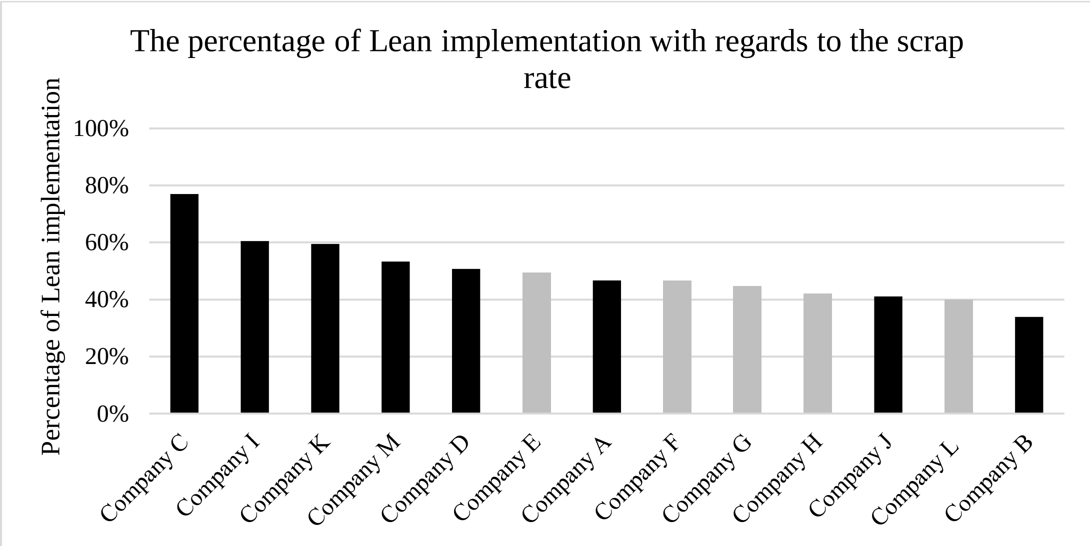

Figure 26. Percentage of Lean implementation for each company. The black bars indicate companies that measure scrap rate and the grey bars indicate companies that do not measure scrap rate.

There is some correlation between the level of Lean implementation and the measure of scrap rate. The black bars indicate the firms that measure scrap while gray bars indicate firms that do not measure scrap. The five companies with the highest level of Lean implementation all measure scrap rate whereas firms that do not measure the scrap rate have a lower degree of Lean implementation in general. It is however difficult to draw any conclusion based on this correlation since the population size for this research is rather low and that the actual scrap rate was hard to establish.

Furthermore, findings regarding the relationship between resource utilization and Lean implementation might explain another perspective of value. As previously mentioned, there is a negative correlation between the percentage of Lean implementation and the percentage of non-value adding activities. This relationship indicates that a high degree of Lean production implementation indeed relates to the elimination of waste, as described in the literature. The earlier analysis also show that a higher degree of Lean implementation has a positive correlation with the OEE measure at the participating firms with a semi-automated or automated production process. The outcome from this relationship is that manufacturing firms with a higher level of Lean implementation may also improve the competitiveness against other similar production sites. Waste; such as production stops, waiting time, defects etc., should be as low as possible. Firms that minimize the non-value adding activities naturally have an edge compared to firms with a higher percentage of non-value adding activities which can be consider valuable.

From these findings, the researchers argue that Lean production is valuable if the savings made by Lean production are reinvested to provide greater value to the process. Lean production can also be argued to be valuable since the percentage of non-value adding activities decreases and the OEE measure increases with a higher degree of Lean implementation. Further, different companies find value in different aspects of Lean production, beyond the most obvious performance aspect. The researchers argue that scrap rate might be such an example. Nonetheless, evidence also show that some area has a negative impact from Lean production. The operating margin and Lewis (2000) case studies is two examples. It is however hard to establish the root cause for a firms specific operating margin and their contextual surrounding in their value chain. Therefore, the researchers argue that Lean production indeed is considered valuable.

6.2.2 Is it rare?

Whether Lean production can be viewed upon as a rare capability is questionable. As described in the literature, there are many interpretations and publications describing Lean production and knowledge about the production philosophy is widespread. There is a plethora of books and courses within the area of Lean and how to implement it. One example of the obvious lack of rarity is that the "founders" of Lean production, Toyota, openly spread the knowledge of their production system (TPS) in various ways. The book, *Toyota Production System (TPS)* by Taiichi Ohno is just one example (Shah & Ward, 2007). This is somewhat contradictory to the criterion of rareness in the VRIO model, but Lean production is undoubtedly a competitive advantage for Toyota.

The rarity of Lean can also be questioned with regards to the findings of this research. This study provides information that shows that Lean productions is commonly known among manufacturing firms in the western region of Sweden. Figure 10 illustrates the breakdown of the percentage of Lean implementation for all participating companies. The average degree of Lean implementation is 50 percent. Although, this percentage is far from a maximum score, it underlines that Lean production is not rare. Moreover, based on the company facts presented in the empirical findings, most of the participating companies actively pursue Lean production in some form. This finding also indicates that Lean production in general is not rare.

Moreover, Lewis (2000) argue that educating your employees in the concept of Lean production might be useful in order to improve the use of Lean principles within a company. The question however is whether education and knowledge is regarded as rare. Lewis (2002) state that gained knowledge is valuable not only for the specific company but also for individual managers. Educating mangers in the concept of Lean production increases the managers bargaining power. This since their gained knowledge is attractive to other competing companies. As a result, companies that educate their staff in Lean principles may risk losing this acquired knowledge rather quickly. As a results, Lewis (2000) argue that manufacturing firms should focus on making their processes Lean rather than emphasizing on educating specific individuals. Hence, the success of the Lean implementation is not limited to individual managers. Emphasizing on a Lean processes instead of specific individuals can be argued to raise the degree of rareness.

However, based on the arguments presented above, the rareness of Lean production is still argued to be relatively low in general.

6.2.3 Is it hard to imitate?

It is arguable that both the rarity criterion and the difficulty to imitate criterion are related when discussing the competitive advantage of Lean production. The previous part state that Lean production is not rare but rather a widespread production philosophy. Toyota have been open with their way of working and it has become somewhat of a global standard, at least in the automotive industry. However, a question to consider is whether Toyotas competitors have been able to utilize the full potential of Lean production in the same way as Toyota due to the fact that it is difficult to imitate the complete concept of Lean production. Lean production, as described above, is more than a couple of techniques that make the production process more clean and more standardized. It is a philosophy that involves the whole organization and imitating it is both costly and challenging for the organization.

Findings from the empirical data show that Lean tools and methods are widely spread within manufacturing firms in the western region of Sweden. In Figure 14, the average level of Lean implementation, for each of the 12 categories found in the Lean questionnaire, is presented. Some areas are relatively widespread while others are used to a very little extent. This may indicate that specific techniques are relatively easy to imitate, such as cleanliness and order. However, when evaluating the degree of Lean implementation, including all Lean areas, the average was 50 percent. This may indicate that imitating and implementing all Lean production techniques indeed is difficult. Moreover, the varying degree of implementation of Lean areas is also illustrated in Figure 11 representing the percentage of scores 0-5 for each participating company. This illustration also supports the claim that some areas indeed are more difficult to imitate than others since all companies have at least on questions marked as zero. Therefore, the researchers argue that Lean production indeed is hard to imitate.

Moreover, in his research Lewis (2000) evaluated the Lean implementation at three companies and found that the organizational context, both internal and external, had an impact one the ability to implement Lean production. Lewis (2000) further elaborates that a company's contextual position will affect the journey of the implementation. As presented in the empirical findings, most companies strive to become more Lean. Each participating company however, have different internal and external context that affects the level and the pace of their Lean implementation. Due to the complexity regarding the conceptual position for each participating company, this analysis has been excluded from this research.

6.2.4 Is the firm organized around it?

The fourth criterion in the VRIO model evaluates whether the resource or capability is suitable and fits with the organization in terms of goal and strategy. As been illustrated above, the example of the gold mine and the furniture manufacturer provides some guidance to the relationship between the valuable, rare, hard to imitate and organizational fit criteria. However, when evaluating the fit of Lean production from an organizational point of view, one could argue that it is of great importance that Lean is in close relation to the company strategy. As described earlier, a potential risk of implementing Lean production is that the company fails to facilitate the advantages of Lean. There are probably various reasons for this. One reason could be that when manufacturing firms implement Lean production, firms focus on their staff rather than on the processes. Hence, firms risk losing their educated staff and therefore miss out on the full potential of Lean production. Since each company visit lasted less than a day, the researchers cannot conclude that firms with a higher degree of Lean implementation had a better organizational fit or vice versa. Mainly due to the fact that only one aspect of the organization was assessed; the production. To gain all advantages of Lean production, the process and the whole organization need to be wrapped around the concept of Lean.

Moreover, Toyota is a great example of a company where Lean is intertwined with the organization as a whole. Toyota use their Toyota Production System (TPS) as a mean to manage their production system in a lean manner. This is also their way of ensuring that Lean permeates the whole organization. Examples of Swedish organizations that have modified the concept of Lean to better fit with their existing organization is Scania (Scania Production System), Volvo Cars (Volvo Production System) and Autoliv (Autoliv Production System). The organizational fit is crucial for the success of Lean production.

6.2.5 Summary of the VRIO model

In order for a resource or capability to be sustainable it has to meet all the criteria of the VRIO model. This chapter has analyzed Lean production based on four criteria with regards to the empirical findings as well as earlier studies within the area. This research conclude that Lean production can be valuable if the savings are facilitated, but this is not guaranteed. Findings from the relationship between Lean implementation and resource utilization indicate that Lean production helps to minimize waste. Furthermore, the concept of Lean production is not rare. However, if companies focus to improve their process instead of educating specific individuals, Lean production is argued to be rarer. Although Lean production is not considered rare, the difficulty to imitate Lean production is argued by the researchers to outweigh this fact. The average degree of Lean implementation in this research (50 %) support this fact. However, the researchers argue that the most important criterion to evaluate if Lean production is a sustainable competitive advantage or not relates to the organizational fit. The organizational fit determines if the organization can facilitate the full potential of Lean production and whether it is a competitive advantage that will last. Autoliv is an organization that is successfully organized around Lean. Therefore, the researchers argue that Lean production indeed is related to a sustainable competitive advantages.

CHAPTER 7 - CONCLUSIONS

This chapter aims to fulfill the purpose and answer research questions for this research. The conclusions are based upon the theoretical framework, the empirical findings and the analysis section.

Many organizations strive to implement Lean production with the anticipation to establish flow, shorter lead times and reduced waste. Different experts argue that implementing Lean production might lower the firm's degree of resource utilization while others argue that Lean production is close to a necessity for some companies to survive. Moreover, the level of utilization among Swedish manufacturing firms is provided by Statistics Sweden. However, since this assessment of the resource utilization is self-assessed, there are reason to question this gathered data. Therefore, the purpose of this report has been to analyze the relationship between the implementation of Lean production and the resource utilization, in a Swedish manufacturing setting. In addition, the researchers have also investigated if Lean production can be regarded as a sustainable competitive advantages based on the empirical findings.

The findings show that there is indeed a relationship between Lean production implementation and the utilization of resources. The comparison of frequency study with the degree of Lean implementation shows that that the percentage of non-value adding activities were lower in companies that had implemented Lean production to a higher degree. Likewise, the comparison of the OEE measure and the Lean implementation shows that companies with a higher degree of Lean implemented had a higher OEE measure. These findings are reasonable since one of the key areas within Lean production is to eliminate waste and non-value adding time as well as a low utilization of the machinery is waste. The relationship between resource utilization and Lean production is therefore argued to have a positive correlation.

The VRIO model has been used to conclude if Lean production indeed is a sustainable competitive advantage. Lean production is regarded as valuable if the savings related to the implementation of Lean is reinvested into the firm. Lean production is also related to a higher OEE measure and a lower percentage of non-value adding activities which is considered valuable as well. However, the empirical data show that this is not always guaranteed. It is further argued that Lean production is rather widespread and therefore not a rare capability. However, it is rare in terms of a successful implementation. Few firms manage to implement Lean production organization wide and to capitalize the savings it enables. Lean production is therefore argued to be hard to imitate. Moreover, the most important criterion for companies to achieve a sustainable competitive advantage from Lean production is the organizational fit. Without organizational fit, all benefits of Lean production will never be capitalized. The findings in this research show that many companies manage to implement some Lean techniques, but no organization manage to implement it widely. As a result, the researchers argue that Lean production indeed can be a sustainable competitive advantage if there is an organizational fit and if the values related to Lean is capitalized.

CHAPTER 8 - DISCUSSION

This chapter discuss the findings in this research from a broader perspective in terms of limitations and possible concerns. This chapter also discuss the findings from this research in comparison to earlier PPA studies.

Comparison between this research and earlier PPA studies.
To gather the necessary information regarding resource utilization, a productivity potential assessment was conducted at each firm visit. This section aims to analyze how well the researchers for this study conducted the PPA assessment. Hence, the results from this research will be compared with the results from earlier studies made by Almström and Kinnander (2008) in three different areas; the PPA questionnaire, the frequency study and the OEE measurement.

The result from the previous studies shows that the average score on the PPA questionnaire is 17 out of 40 yes (Almström & Kinnander, 2008). This correspond to 42,5 percent out of the maximum score. The findings in this research has an average of 49 percent (19 yes). This is a somewhat higher score compared to earlier studies. The researchers argue that there might be two reasons for this. One reason might be that the participating companies in this study is better in average. The result from earlier PPA studies was conducted eight years ago why there are reason to argue that manufacturing firms in general might have improved during this time period. Moreover, the second reason might be that the criteria for achieving a yes has been lower in this study compared to earlier studies. This was not the intention. The researchers argue that lack of experience in combination with a subjective decision-making process might have rendered the slightly higher score.

Moreover, the result from earlier PPA-studies related to frequency study is presented in Table 1. The result from earlier frequency studies together with the result from this research is presented in Table 5. Table 5 shows that there are some differences between the results from Almström and Kinnander's (2008) findings and the findings from this research.

Table 5. A comparison between the results from the frequency study made by Almström and Kinnander (2008) and the results from the frequency study conducted in this research.

	Automated production			**Semi-automated production**			**Manual production**			**Total average**		
	Original	This study		Original	This study		Original	This study		Original	This study	
Value adding	40,6%	8,0%	↓	40,9%	53,3%	↑	64,0%	47,6%	↓	45,1%	39,0%	←
Supporting	28,1%	54,8%	↑	24,3%	24,4%	←	19,7%	25,9%	↑	24,3%	34,0%	↑
Non-value adding	31,4%	37,2%	↑	34,8%	22,3%	↓	16,3%	26,6%	↑	30,6%	27,0%	←

The following comparison will be based on the level of automation. With regards to the automated production, the most obvious difference is the degree of value adding activities. The value adding activities in this research is much lower (8 percent) compared to earlier studies (40,6 percent). The degree of non-value adding time is more similar, 31,4 percent compared to 37,2 percent for this research and earlier studies respectively. Consequently, the degree of supporting activities is much higher in this research compare to earlier studies. How come the results differ so significantly? There can be several explanations to this fact. One possible reason, related to all comparisons, is that the sample size for this research is smaller compared to the results provided by Almström and Kinnander (2008). The companies participating in this research might be different than the overall average from earlier studies. Interesting would be to compare companies with their respective industry's average. However, this data is unfortunately not accessible. This could be an area for future research in order to evaluate a possible difference between industries.

Moreover, the degree of automation within the automated level might also affect the results. Although a specific manufacturing firm is categorized based on these three levels of automation, there is some variation within each category. Hence, the companies with automated production that have been evaluated in this research might be more automated than the average level of automation from earlier studies i.e. have a slightly higher degree of automatization. This can also explain the fact that the supporting activities constitute a higher degree in this study compared to earlier results. Even though this fact might explain some difference to the original study, the difference (32 percentage points) may have other reasons. Since the five investigated companies in this level of automation clearly differ from the findings of Almström and Kinnander (2008), the researchers argue of two additional possibilities. Firstly, activities that this research has considered as supporting activities (or non-value adding) should have been categorized as value adding activities instead. This will naturally lower the degree of supporting activities in favor for value adding activates. Secondly, based out of the observation made at these five highly automated production processes, there is reason to question whether too many activities from earlier studies were considered as value adding activities. In this research, operators at a highly automated process exclusively observed and supported the machinery, why the percentage of value adding activities is low. Based in these findings, the researchers argue that value adding activities at around 40 percent might be too high.

Moreover, there were some differences between the other two levels of automation as well. The semi-automated level has the same level of supporting activities in both the original study and in this study. The degree of value adding activities is higher in this study and the non-value adding activities is consequently lower. The reason for this difference is difficult to interpret. Again, one possible reason might be that the participating firms in this research is better compared to the evaluated firms from earlier studies. From the assessment of Lean implementation, the participating companies with a semi-automated production scored relatively high on the level of Lean implementation. This might indicate that these companies actually utilized their resources in a better way.

The difference in the manual level is accounted for in the analysis part. The fact that this category only consisted of two companies made it unreliable to compare and to make conclusion with regards to the breakdown of value adding, supporting and non-value adding activities. Therefore, this discussion is limited to this brief part.

Interestingly, the total average of the value adding, supporting and non-value adding activities presented in Table 5 show less difference between this research and earlier studies. However, since the results for value adding, supporting and non-value adding activities for the three levels of automation variy between this research and earlier studies, no conclusions have been made to further explain this finding.

In addition, when conducting the frequency study at each participating firm, the researchers studied and observed between two and five objects. Objects are either operators or workstations. There is an advantage when studying few objects since the risk of missing any abnormal activity will decrease. With a high number of observed objects, each object will naturally be studied less frequently. However, since the most common scenario was to investigate either two or three objects, the researchers argue that the number of observed object will not have a sizable impact on the results in general. The number of objects may however explain some of the variations between this research and earlier studies conducted by Almström and Kinnander (2008). The information regarding how many objects that were observed in earlier studies is not presented in their article. Hence, a comparison between the number of object for this research and earlier studies is not possible.

Moreover, the overall equipment efficiency measure between this research and earlier studies show some variation. The average OEE found in this research is 69,9 percent. The OEE measure found from earlier studies is slightly lower. Almström and Kinnander (2008) found an average of 63 percent. The variation in population size can be one explanation. Almström and Kinnander (2008) observed the OEE measure at 29 sites whereas this research investigated the OEE at 11 sites. Another explanation might be that five firms in this research presented their OEE measure directly while six firms only distributed the necessary raw data to calculate a theoretical OEE. These two ways of gathering the OEE data might affect the average. However, since the difference between these two measures is rather low, the researchers argue that a further investigation between the result from this research and the results from earlier studies is not needed.

Levels of automation

This research has assessed the resource utilization at the participating firms with the Productivity Potential Assessment method. According to this method, all participating firms should be divided into four levels of automation; manual production, semi-automated production, automated production and process production. This research has visited firms related to the first three levels of automation i.e. manual, semi-automated and automated production. However, with basis in the earlier discussions related to a possible variation within each level of automation, the researchers argue that increasing the number of levels might be preferable. Frohm et al (2008) argue for a new scale of automation for computerized and mechanized tasks within manufacturing. Instead of a single scale to assess the level of automation, Frohm et al (2008) argue of two independent continuums, one for *Mechanical and Equipment* and one for *Information and Control.* This assessment scale would categorize the participating firms in a suitable way. However, since this research have a rather small population size, this assessment scale might be too detailed for this research.

The relationship between the Lean Questionnaire and the PPA results

A further interesting aspect to discuss is the relationship and correlation between the evaluation of Lean implementation and the PPA findings. This relationship is illustrated in Figure 27 and demonstrates a clear correlation. This indicates that a high score on the Lean questionnaire indicates a high score on the PPA questionnaire and vice versa. This finding is perhaps not that strange since the two questionnaires evaluate the companies' performances in a rather similar way. There are some differences between the two methods, but they both aim to evaluate the manufacturing firm.

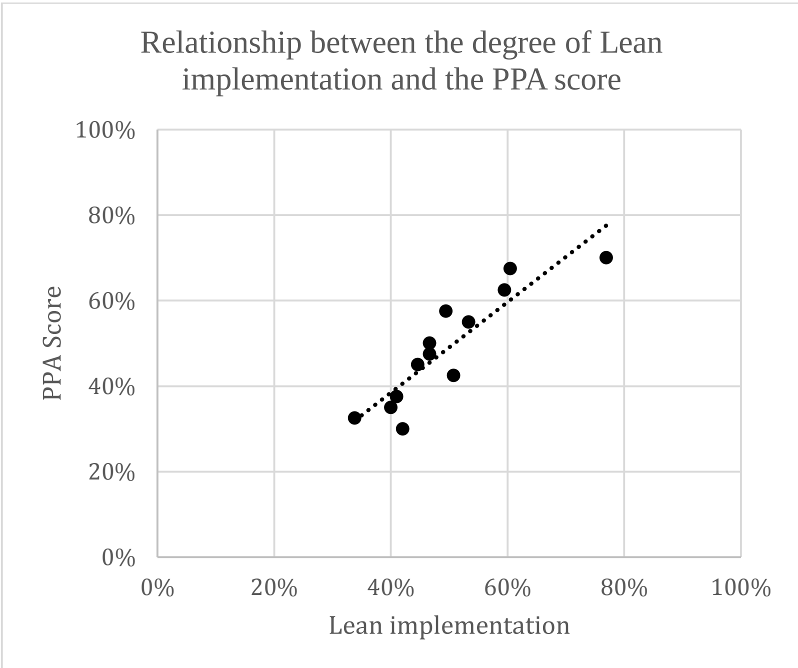

Figure 27. The relationship between the degree of Lean implementation and the percentage of yeses from the PPA questionnaire for each company.

Lean production versus. Lean implementation

A further discussion to be made is whether the degree of Lean production implementation relates to Lean production. A key area of Lean production is to continuously improve. This research establishes a degree of Lean production implementation on a specific instance in time and does not account for the continuously improvement in general. Thus omit one of the key areas of Lean production. This limits the value and usefulness of this study. Therefore, the researchers advocate that the study should be repeated again in a certain period of time to evaluate whether the companies improved or not. An initial assessment of the degree of Lean production implementation will explain one part of the companies use of Lean. However, a second assessment would explain if the company has a Lean production culture permeated in their organization.

Bottleneck

A further important aspect to discuss is whether the investigated production indeed is a bottleneck. The necessity to investigate a bottleneck is of great importance. This since the PPA-method assumes that manufacturing firms focus heavily on their bottlenecks why these areas can represent the rest of the production process. This assumption enables the comparison between the frequency study and OEE measurement, that are evaluated at the bottleneck, and the percentage of Lean implementation, that are evaluated for the whole manufacturing plant. However, if the evaluated area in fact is not a bottleneck, this comparison will lose some of its value. Since the studied area was chosen in consultation with the production manager, with the aim to study a bottleneck, the evaluated area at each participating firms is most likely a bottleneck. However, since a bottleneck often is hard to establish without a proper investigation, this is not guaranteed. Hence, this might call for further investigation.

CHAPTER 9 - SUGGESTIONS FOR FUTURE RESEARCH AND IMPLICATIONS FOR PRACTITIONERS

This chapter aims to discuss areas of future research as well as to discuss what implication this research might have for the participating manufacturing firms.

The findings in this study are, as described earlier, limited by time. This limitation has affected the scope of this study. The researchers would therefore suggest that a similar study should be conducted over a longer period of time, in order to compare differences between the participating companies over time as well as to compare a specific company in several different time periods. This would enable a more thorough understanding of both the use of Lean principles and the complexity regarding Lean implementation. Such a study would also enable a more thorough investigation of the impact Lean production has on the performance of the company, which in turn would provide means for a better understanding of Lean production as a sustainable competitive advantage.

Another suggestion for future research is to widen the scope for all onsite visits at all participating firms. This research focus on a specific production area and a specific bottleneck. An interesting investigation would be to evaluate if other areas reflect the findings from this study. It is argued that the bottleneck represents the rest of the production. However, this should be further investigated by widening the scope of the research. Moreover, this would be interesting not only for other production areas, but for other areas of the organization as well. Lean is most often associated with production for understandable reasons, however the philosophy of Lean can be applied to many areas. Therefore, it is argued that further research should be conducted to include other parts of the organization.

An interesting relationship that should be further explored is the relationship between the OEE measure and the findings from the frequency study. It is argued that resource utilization is difficult to define when manual work is combined with machines. Due to this limitation it is difficult to compare resource utilization with other measures. Research dedicated to investigate the relationship between man and machine could provide an understanding of this relationship and thus provide a better mean for measurement and comparison between Lean production implementation and resource utilization.

This study provides a status indication of the implementation degree of Lean production in the production process at large companies within the western region of Sweden. This study also provides an indication to practitioners that implementing Lean production could provide means to lower non-value adding activities for the operators and to increase the OEE measure of the machinery. Therefore, the researchers argue for companies to further implement Lean in their production processes. In addition, the Lean assessment tool established in this study can also provide the participating firms with a simple measurement tool to evaluate their degree of Lean production implementation. Hence, it would be interesting for the participating firms to make another study after a certain period of time to evaluate whether the company improves or not in terms of Lean production implementation.

REFERENCES

Adan, I., & Resing, J. (2002). Queueing theory.

Alexanderson, K. (2012). *Källkritik på internet*. . SE: s Internetguider.

Almström, P., & Kinnander, A. (2006). PPA-en metod för att bedöma produktivitetspotentialen i verkstadsindustrin.

Almström, P., & Kinnander, A. (2008). Results and conclusions from the productivity potential assessment studies. In *Proceedings of the 2nd Swedish Production Symposium*.

Almström, P., & Kinnander, A. (2011). The Productivity Potential Assessment method: assessing and benchmarking the improvement potential in manufacturing systems at shop-floor level. *International Journal of Productivity and Performance Management, 60*(7), 758-770.

Autoliv (2016), Autoliv Production System, available at: https://www.autoliv.com/ProductsAndInnovations/Pages/Manufacturing/AutolivProductionSystem.aspx.

Bartezzaghi, E. (1999). The evolution of production models: is a new paradigm emerging? *International Journal of Operations & Production Management*, *19*(2), 229-250.

Barney, J. (1991). Firm resources and sustained competitive advantage. Journal of management, 17(1), 99-120.

Bellgran, M., & Säfsten, E. K. (2009). *Production development: design and operation of production systems*. Springer Science & Business Media.

Björklund, M, & Paulsson, U. (2003). *Seminarieboken-att skriva, presentera och opponera*. Studentlitteratur.

Cobham, A. (1954). Priority assignment in waiting line problems. *Journal of the Operations Research Society of America*, *2*(1), 70-76.

Cochran, D. S., Arinez, J. F., Duda, J. W., & Linck, J. (2002). A decomposition approach for manufacturing system design. *Journal of manufacturing systems, 20(6*), 371-389.

Corrado, C., & Mattey, J. (1997). Capacity utilization. *The Journal of Economic Perspectives*, *11*(1), 151-167.

Doolen, T. L., & Hacker, M. E. (2005). A review of lean assessment in organizations: an exploratory study of lean practices by electronics manufacturers. *Journal of Manufacturing systems, 24*(1), 55.

Dubois, A., & Gadde, L. E. (2002). Systematic combining: an abductive approach to case research. *Journal of business research, 55*(7), 553-560.

Fasth, Å. (2011). Comparing methods for redesigning, measuring and analysing Production systems. In *Proceedings of the 4th Swedish Production Symposium (SPS), Lund, Sweden*.

Frohm, J., Lindström, V., Winroth, M., & Stahre, J. (2008). Levels of automation in manufacturing. *Ergonomia*.

Grant, R. M. (2010). *Contemporary Strategy Analysis 7e Text Only*. John Wiley & Sons.

Goodson, R. E. (2002). Read a plant-fast. *Harvard business review, 80*(5), 105-113.

Hallward-Driemeier, M., Iarossi, G., & Sokoloff, K. L. (2002). Exports and manufacturing productivity in East Asia: A comparative analysis with firm-level data *(No. w8894). National Bureau of Economic Research.*

Hansen, R. (2001). Overall Equipment Effectiveness (OEE): A Powerful Production/Maintenance Tool for Increase.

Hines, P., Holweg, M., & Rich, N. (2004). Learning to evolve: a review of contemporary lean thinking. International journal of operations & production management, 24(10), 994-1011.

Howell, G., Ballard, G., & Hall, J. (2001, August). Capacity utilization and wait time: A primer for construction. In *Proceedings of the 9th Annual Meeting of the International Group for Lean Construction* (Vol. 1). Singapore: Faculty of Engineering, National University of Singapore.

Holweg, M. (2007). The genealogy of lean production. *Journal of operations management*, *25*(2), 420-437.

Huber, G. P. (1991). Organizational learning: The contributing processes and the literatures. *Organization science*, *2*(1), 88-115.

Karlsson, C., & Åhlström, P. (1996). Assessing changes towards lean production. *International Journal of Operations & Production Management*, *16*(2), 24-41.

Katayama, H., & Bennett, D. (1996). Lean production in a changing competitive world: a Japanese perspective. *International Journal of Operations & Production Management*, *16*(2), 8-23.

Koho, M. (2010). Production system assessment and improvement: a tool for make-to-order and assemble-to-order companies. Tampereen teknillinen yliopisto. Julkaisu-Tampere University of Technology. Publication; 885.

Krafcik, J. F. (1988). Triumph of the lean production system. *MIT Sloan Management Review*, *30*(1), 41

Larsson, S. (2005). Om kvalitet i kvalitativa studier. *Nordisk pedagogik*, *25*(1), 16-35.

Lewis, M. A. (2000). Lean production and sustainable competitive advantage. *International Journal of Operations & Production Management*, *20*(8), 959-978.

Marin-Garcia, J. A., & Carneiro, P. (2010). Questionnaire validation to measure the application degree of alternative tools to mass production. *International Journal of Management Science and Engineering Management*, *5*(4), 268-277.

Modig, N., & Åhlström, P. (2012). *This is lean: Resolving the efficiency paradox*. Rheologica.41.

Ohno, T. (1988). *Toyota production system: beyond large-scale production*. crc Press.

Rahani, A. R., & al-Ashraf, M. (2012). Production flow analysis through value stream mapping: a lean manufacturing process case study. *Procedia Engineering*, *41*, 1727-1734.

Rinehart, J. W., Huxley, C. V., & Robertson, D. (1997). *Just another car factory? Lean production and its discontents*. Cornell University Press.

Scania Group (2016), Scania Production System, available at: http://se.scania.com/scania-group/philosophy/scania-production-system/ (accessed April 2016)

Shah, R., & Ward, P. T. (2007). Defining and developing measures of lean production. *Journal of operations management*, *25(4)*, 785-805.

Shah, R., & Ward, P. T. (2003). Lean manufacturing: context, practice bundles, and performance. *Journal of operations management*, *21*(2), 129-149.

Sitkin, S. B. (1992). Learning through failure: The strategy of small losses. *Research in organizational behavior*, *14*, 231-266.

Statistics Sweden (2016), *Capacity of utilization in industry 2015*, available at: http://www.scb.se/en_/Finding-statistics/Statistics-by-subject-area/Business-activities/Industrial-capacity-utilisation/Industrial-capacity-utilisation/Aktuell-Pong/11392/277848/ (accessed April 2016).

Sundkvist, R., Hedman, R., & Almström, P. (2012). A model for linking shop floor improvements to manufacturing cost and profitability. *International Journal of Computer Integrated Manufacturing*, *25*(4-5), 315-325.

Susilawati, A., Tan, J., Bell, D., & Sarwar, M. (2013). Develop a framework of performance measurement and improvement system for lean manufacturing activity. *International Journal of Lean Thinking*, *4*(1), 282-286.

Susilawati, A., Tan, J., Bell, D., & Sarwar, M. (2014). Fuzzy logic based method to measure degree of lean activity in manufacturing industry. *Journal of Manufacturing Systems*, *34*, 1-11.

Säfsten, K., Winroth, M., & Löfving, M. (2014). *STRATEGO-Manufacturing strategies supporting competitiveness in small and medium-sized manufacturing enterprises-A Handbook*. Jönköping University.

Van Teijlingen, E., & Hundley, V. (2002). The importance of pilot studies. *Nursing Standard*, *16*(40), 33-36.

Volvo Group (2016), Volvo Production system, available at: http://www.volvogroup.com/group/global/en-gb/career/career%20paths/manufacturing/Pages/manufacturing.aspx (accessed April 2016)

Wallén, G. (1993). *Vetenskapsteori och forskningsmetodik*. Studentlitteratur.

Womack, J. P., Jones, D. T., & Roos, D. (1990). *Machine that changed the world*. Simon and Schuster.

Appendix 1 – Complete set of the PPA questionnaire

Table I. Illustration of the 40 yes or no questions from the PPA questionnaire (Almström & Kinnander, 2011, p9)

Topic	Question
Strategy – goals	1. Can the management present a clear production strategy, based on qualifying and order winning criteria? 2. Is the strategy converted into measurable goals for production? 3. Are the goals measured regularly and are these measures available to the shop-floor personnel? 4. Is the fulfilment of the goals connected to any kind of reward?
Work methods	5. Is a standardised work method used and is it documented? 6. Is the standardised work method changed if the workers find a better method? 7. Do operators serve several machines?
Maintenance	8. Is down time measured and are causes for stoppages documented? 9. Is down time measured by an automatic system? 10. Are small stoppages monitored and actions taken to eliminate them? 11. Is preventive maintenance used? 12. Is condition based maintenance used?
Competence	13. Is there anyone responsible for and competent to measure manual work? 14. Has the first line manager knowledge about the work to lead improvement actions? 15. Is there a competence development plan?
Cleanliness and order	16. Have all material, tools etc. fixed positions and is everything in place when not used? 17. Is there enough space around the workplace to move all material as planned? 18. Are the floor and other surfaces free from waste material, scrap products, etc.?
Material handling	19. Are the load carriers (pallets, etc.) adapted to the components? 20. Does the batch size correspond to the delivery pace? 21. Is the same load carrier used for a component as far as possible? 22. Is material stored close to the point of use? 23. Is the shop independent of trucks, cranes etc. to move the material?
Changeover	24. Are changeover times measured? 25. Is there a continuous effort to reduce changeover time in the bottleneck? 26. Are tools, fixture etc. stored close to where they used?
Continuous improvements	27. Is the continuous improvement work carried out systematically, and is it documented and visualised? 28. Are the workers engaged in the improvement work? 29. Has the management a realistic idea about the productivity potential? 30. Is knowledge from previous development projects used systematically?
Calculations	31. Are investment calculations revised? 32. Are product calculations revised?
Planning	33. Is the ideal cycle time known and is it based on facts? 34. Are real operation times reported to the planning system? 35. Are the operation times in the planning system updated based on the real operation times? 36. Is the production planned according to pull principle when possible? 37. Are lead times measured in order to reduce them?
Quality	38. Is there a standardised quality system in use (e.g. ISO 9001)? 39. Is the single operator responsible for the quality of his own work? 40. Are there systematic methods used to eliminate the occurrence of errors?

Appendix 2 - Key characteristics of the TUTKA model

Table II. Illustration of the 33 key characteristics (Koho, 2010, p85)

Decision area	Key characteristics	Production objectives					
		Q	T	R	VF	PF	C
Product architecture	Product architecture is modular	X	X			X	X
	Product platforms are used		X			X	X
	Product structure consists of predefined parts and subassemblies		X	X		X	X
	Levels in product structure simplify the structure of the production system and support production control		X	X			
Production system structure	Production system consists of production units that are responsible for certain parts of a product	X	X	X		X	X
	Production system structure corresponds to the structure and production process of products	X	X	X			X
	Distances between production units and distances between production equipment are short	X	X	X			X
	Production system structure makes it possible to observe the state of and the prerequisites for production	X		X			
	Layout and organisation of workplaces eliminate non-value-adding work and support value-adding work		X				X
Production processes and management	Dissimilar main processes of production are identified and separated from each other		X	X			X
	Processes of production units are defined	X	X	X			X
	Processes and procedures between production units are defined			X			X
	Plans and procedures for responding to production disruptions, problems and delays are in place	X		X			
	Cost-efficient and flexible processes are combined by late-point differentiation and appropriate positioning of order penetration point					X	X
	Responsibility for production control is allocated to production units			X	X	X	
	Close cooperation between production units is supported and enabled	X	X	X			X
Production equipment	Production equipment fits the requirements of the products and processes and the objectives of production	X	X		X	X	X
	Changeover and set-up times of equipment are short		X			X	
	Production equipment enables integration and reduction of production phases	X	X	X			
	Production equipment is reliable and available for use	X	X	X			
	Production equipment is easy to use		X		X	X	X
	Production equipment supports occupational safety and ability to work		X	X			X
	Value-adding work, transportation and handling are supported and simplified by appropriate tools and auxiliary devices		X				X
Information and communication	Information and communication support and enable decision-making	X		X			
	Information transfer and communication follow systematic and predefined principles and procedures		X	X			
	Information and communication systems used in the production system are compatible and integrated	X	X	X			X
	Information and communication systems are reliable and available for use	X	X	X			
	Visual information and control systems are used in the production system	X	X	X			
Human resources	Teamwork and team organisation are used in production	X		X	X	X	
	Employees are cross-trained and skills of employees meet the requirements of work tasks and processes	X		X	X	X	
	Personnel policy and arrangement of working time support operational flexibility and reliable deliveries			X	X		
	Commitment to work and involvement in improving production system and production processes are promoted	X	X	X			X
	Occupational safety and ability to work are emphasised and ensured			X			X

Appendix 3 - Questionnaire for the Rapid Plant Assessment

Table III. Illustration of the 20 questions from the Rapid Plant Assessment (Goodson, 2002, p7)

		yes	no
1	Are visitors welcomed and given information about plant layout, workforce, customers, and products?	○	○
2	Are ratings for customer satisfaction and product quality displayed?	○	○
3	Is the facility safe, clean, orderly, and well lit? Is the air quality good, and are noise levels low?	○	○
4	Does a visual labeling system identify and locate inventory, tools, processes, and flow?	○	○
5	Does everything have its own place, and is everything stored in its place?	○	○
6	Are up-to-date operational goals and performance measures for those goals prominently posted?	○	○
7	Are production materials brought to and stored at line side rather than in separate inventory storage areas?	○	○
8	Are work instructions and product quality specifications visible at all work areas?	○	○
9	Are updated charts on productivity, quality, safety, and problem solving visible for all teams?	○	○
10	Can the current state of the operation be viewed from a central control room, on a status board, or on a computer display?	○	○
11	Are production lines scheduled off a single pacing process, with appropriate inventory levels at each stage?	○	○
12	Is material moved only once and as short a distance as possible? Is material moved efficiently in appropriate containers?	○	○
13	Is the plant laid out in continuous product line flows rather than in "shops"?	○	○
14	Are work teams trained, empowered, and involved in problem solving and ongoing improvements?	○	○
15	Do employees appear committed to continuous improvement?	○	○
16	Is a timetable posted for equipment preventive maintenance and ongoing improvement of tools and processes?	○	○
17	Is there an effective project-management process, with cost and timing goals, for new product start-ups?	○	○
18	Is a supplier certification process – with measures for quality, delivery, and cost performance – displayed?	○	○
19	Have key product characteristics been identified, and are fail-safe methods used to forestall propagation of defects?	○	○
20	Would you buy the products this operation produces?	○	○

Appendix 4 – Lean self-assessment survey

Table IV. Illustration of the 70 question from the Lean survey (Garcia & Carneiro, 2010, p 4)

Factor	Question	No.	Min	Max	Average	Standard deviation
Visual Management	At our plant, we are concerned about keeping all components, tools and instruments in their place	128	0	5	3,9	1,28
	We make an effort to keep the working area clean and tidy	128	0	5	3,99	1,26
	There are updated graphs near the equipment indicating the run-down times	128	0	5	0,77	1,49
	There are updated graphs near the workstations indicating the % of defective parts manufactured	128	0	5	0,77	1,41
	There are updated graphs near the workstations indicating the section productivity level	128	0	5	0,88	1,57
	There are visual systems that warn about any incidences in the line (Andon, systems using lights of different colours, horns and sirens...)	128	0	5	1,17	1,74
	Value Stream Mapping is used to represent the manufacturing or packaging lines	128	0	5	0,4	1,07
Continuous improvement	The people in charge in the company value and take seriously all the suggestions made by workers on processes, service/product improvement.	128	0	5	3,2	1,62
	Useful suggestions made by workers or supervisors (managers) are introduced.	128	0	5	3,23	1,44
	In order to improve processes and, services and products, problem resolution teams formed by workers are used	128	0	5	2,05	1,67
	Active personnel group participation to make suggestions on processes/ products improvement or problem resolution (quality circles, suggestion systems).	128	0	5	2,57	1,62
	Amount of production/service problems to be solved via work sessions of the personnel teams	128	0	5	2,26	1,55
TQM	The people in charge in the company lead and are actively involved in services/product quality improvement	128	0	5	3,72	1,51
	The different departments accept the responsibility of keeping and improving product and service quality	128	0	5	3,5	1,56
	The manufacturing or servicing machinery and the processes used are controlled via SPC	128	0	5	1,02	1,56
	Graphs are used to indentify whether our processes are within "control limits"	128	0	5	1,34	1,81
	Defect detection systems are used to detect them the moment they occur (JIDOKA, POKA YOKE...)	128	0	5	0,96	1,63
	Workers may stop or halt the line or a service if a quality problem is detected.	128	0	5	3,07	1,83
JIT/Kanban	Department managers encourage "just in time" production	128	0	5	1,71	1,81
	Efforts are made to reduce the size of the manufacturing or assembly batches	128	0	5	1,23	1,64
	Kanban cards or containers are used to control the plant production	128	0	5	0,38	1,08
	Kanban cards or containers are used instead of filling in supplier order forms	128	0	5	0,36	1,07
	Suppliers directly send orders in Kankan containers (so that no picking, unpacking and moving material to smaller containers is required)	128	0	5	0,45	1,19
Standardized operations	All workstation procedures have been studied and standardized	128	0	5	2,89	1,77
	Standardized procedures are continuously and periodically updated	128	0	5	2,38	1,77
	Standardized procedures are updated based on workers contributions (complementing those by managers and engineers)	128	0	5	2	1,71
SMED	An effort is made to reduce the time spent changing batches (time spent making preparations to manufacture/assemble another product or to perform a different service)	128	0	5	1,91	1,90
	Most of the SMED have become "external operations" performed at the same time other workers make a product or a service	128	0	5	1,32	1,69
	Workers are trained to make quick batch changes and they practice to reduce the time they invest in this task	128	0	5	1,61	1,82
	Company managers give importance to batch change time reduction	128	0	5	1,85	1,91
	The machinery used is always ready to be used manufacturing	128	0	5	2,51	2,04
Line balancing	There are updated graphs near the workstations indicating the degree of compliance to production programs	102	0	5	1,24	1,74
	At the beginning of the working day/week, a work schedule (work orders) for all products or services to be completed during the day/week is available	103	0	5	2,93	2,04
	The work schedule is calculated taking into account time for line shutdown time (due to machinery shutdown, quality problems or any unexpected event)	103	0	5	2,38	1,96

	The production program is balanced so that every day/week the same "MIX" of products is manufactured or "MIX" of services is performed. Changes in orders are satisfied by adjusting the "MIX" repetition frequency	101	0	5	1,89	1,85
	The processes/processing bottle necks are identified and efforts are made to solve them	128	0	5	2,37	2,03
	The "takt" time for each line (the maximum time per unit allowed to produce a product in order to meet the customer demand) is calculated and the processing time of each workstation is adjusted according to that "takt"	128	0	5	1,96	1,93
	The production time or work is directly related to the customer rate demand	80	0	5	3,2	1,72
Continuous flow and Cell manufacturing	The machines are grouped according to the product family they produce	128	0	5	2,05	2,00
	The workstations are arranged so that they are close to each other and the material movements and trips the workers need to make are reduced	128	0	5	2,59	1,95
TPM	Workers dedicate part of their working hours to perform the maintenance of the machines they use	128	0	5	1,89	1,65
	We consider that adequate machine maintenance helps reaching high quality levels for our products or services and that it helps us comply with the production program	128	0	5	3,02	1,91
	Maintenance department workers (if any) focus on helping production workers to perform a preventive maintenance of the production machines they use	128	0	5	1,5	1,90
Supplier relationship	Our company operations are integrated with those of our suppliers (logistic collaboration, integrated information systems, mutual technical assistance)	128	0	5	2,21	1,70
	Part of our manufacturing processes or services is subcontracted	128	0	5	1,27	1,60
	We establish long term relationships with our suppliers	128	0	5	3,46	1,46
	We prefer having a reduced group of suppliers	128	0	5	2,96	1,60
	We have close work relationships with our suppliers (frequent and direct contact, mutual visits to our respective plants, collaboration agreements)	128	0	5	2,89	1,53
	We work together with our suppliers to improve the quality of the parts provided	128	0	5	2,5	1,68
	Commercial and technical data and information is exchanged with our supplier in order to develop together production programs or demand predictions	128	0	5	1,98	1,63
	Which amount of components used in the company is daily provided by our suppliers?	128	0	5	2,15	1,75
	How many of our suppliers hold a quality certificate?	128	0	5	2,5	1,94
	We use work equipment that work together with those of our suppliers	128	0	5	1,19	1,65
Customer relationship	We have close work relationships with our customers (frequent and direct contact, mutual visits to our respective plants, collaboration agreements)	128	0	5	3,83	1,34
	We survey or diagnose our customers needs or requirements	128	0	5	2,89	1,70
	Our company processing is integrated with that of the customer (logistic collaboration, integrated information systems, mutual technical assistance)	128	0	5	2,44	1,86
	Customers provide us with feedback on product quality, delivery timing	128	0	5	3,12	1,83
Automatization and propriety equipment	The machines used to manufacture products/give services have been solely developed and built for your company	128	0	5	0,94	1,50
	Our company has the patent of product and service machinery and equipment	128	0	5	0,33	0,99
	Most of the workers have skills and knowledge that are only useful for the company	128	0	5	1,57	1,60
	Suppliers or investors have made specific investments that would be of no use in companies other than ours	128	0	5	0,7	1,24
	New workers can easily learn how to perform their tasks when they refer to experienced workers	128	0	5	2,85	1,81

	We use flexible systems (FMS) such as automatized multimachine systems (CAM or CNC) connected by an automatized material handling system	128	0	5	0,65	1,40
	How frequently continuous training and machine update are performed after a new machine has been set up?	128	0	5	1,57	1,73
	There are automatic material storage and dispensing systems in the company	128	0	5	0,47	1,20
	There are bar codes/automatic identification systems in the company	128	0	5	0,56	1,34
	We share integrated information systems with suppliers, distributors of final customer, for example EDI	128	0	5	0,58	1,27
	The different department in the plant share integrated information, for example ERP	128	0	5	0,57	1,37
	Manufacturing resources planning (MRPII) is used in the company	128	0	5	0,53	1,30
Design integrated with manufacturing	Components/services are designed so that they are easy to manufacture and assemble in the company lines (in case of services, they are easy to offer)	56	0	5	0,72	1,45
	Different departments or functions (I+D, production, marketing and sales) involved since the very beginning in developing new products/services	56	0	5	0,63	1,33
	New product/service designed are completely reviewed before the manufacturing and sale	56	0	5	1,08	1,89
	During the design process an effort is made to ser only those specifications that are clearly necessary	56	0	5	1,1	1,81
	We stress obtaining designs that reduce the amount of components/stages in products/services	55	0	5	0,87	1,62
	Computer assisted design and/or engineering (CAD/CAE) is used	56	0	5	0,76	1,64
	The customer is involved in the design and development process of new products/services	56	0	5	1,2	1,94
	We work together with suppliers during the product/service design and development process	56	0	5	0,74	1,52
Knowledge management	In the company there are regulations supporting innovative ideas research and exploitation	128	0	5	1,82	1,66
	We use information systems or data bases that allow knowledge to widespread through the company	128	0	5	1,71	1,72
	There are groups of workers that continuously have access, put into practice and update their working knowledge	128	0	5	1,41	1,60
	We use all formal mechanisms in order to share the best practices amongst the company personnel	128	0	5	1,91	1,61

Appendix 5 – Lean assessment survey

Table V. Illustration of the 48 questions from the Lean assessment survey (Shah & Ward, 2007, p19)

Please indicate the extent of implementation of each of the following practices in your plant. (1) no implementation; (2) little implementation; (3) some implementation; (4) extensive implementation; (5) complete implementation.

Item no.	Item label	Final CITC score
Suppfeed_01	We frequently are in close contact with our suppliers	0.40
Suppfeed_02	Our suppliers seldom visit our plants (reverse coded) [a]	
Suppfeed_03	We seldom visit our supplier's plants (reverse coded) [a]	
Suppfeed_04	We give our suppliers feedback on quality and delivery performance	0.54
Suppfeed_05	We strive to establish long-term relationship with our suppliers	0.45
SuppJIT_01	Suppliers are directly involved in the new product development process	0.48
SuppJIT_02	Our key suppliers deliver to plant on JIT basis	0.48
SuppJIT_03	We have a formal supplier certification program	0.45
Suppdevt_01	Our suppliers are contractually committed to annual cost reductions	0.51
Suppdevt_02	Our key suppliers are located in close proximity to our plants	0.52
Suppdevt_03	We have corporate level communication on important issues with key suppliers	0.41
Suppdevt_04	We take active steps to reduce the number of suppliers in each category	0.54
Suppdevt_05	Our key suppliers manage our inventory	0.40
Suppdevt_06	We evaluate suppliers on the basis of total cost and not per unit price	0.47
Custinv_01	We frequently are in close contact with our customers	0.40
Custinv_02	Our customers seldom visit our plants (reverse coded) [a]	
Custinv_03	Our customers give us feedback on quality and delivery performance	0.48
Custinv_04	Our customers are actively involved in current and future product offerings	0.42
Custinv_05	Our customers are directly involved in current and future product offerings	0.43
Custinv_06	Our customers frequently share current and future demand information with marketing department	0.42
Custinv_07	We regularly conduct customer satisfaction surveys [a]	
Pull_01	Production is "pulled" by the shipment of finished goods	0.47
Pull_02	Production at stations is "pulled" by the current demand of the next station	0.50
Pull_03	We use a "pull" production system	0.54
Pull_04	We use Kanban, squares, or containers of signals for production control	0.43
Flow_01	Products are classified into groups with similar processing requirements	0.44
Flow_02	Products are classified into groups with similar routing requirements	0.45
Flow_03	Equipment is grouped to produce a continuous flow of families of products	0.53
Flow_04	Families of products determine our factory layout	0.48
Flow_05	Pace of production is directly linked with the rate of customer demand [a]	
Setup_01	Our employees practice setups to reduce the time required	0.59
Setup_02	We are working to lower setup times in our plant	0.45
Setup_03	We have low set up times of equipment in our plant	0.49
Setup_04	Long production cycle times prevent responding quickly to customer requests (reverse)[a]	
Setup_05	Long supply lead times prevent responding quickly to customer requests (reverse coded) [a]	
SPC_01	Large number of equipment / processes on shop floor are currently under SPC	0.48
SPC_02	Extensive use of statistical techniques to reduce process variance	0.52
SPC_03	Charts showing defect rates are used as tools on the shop-floor	0.59
SPC_04	We use fishbone type diagrams to identify causes of quality problems	0.52
SPC_05	We conduct process capability studies before product launch	0.61
Empinv_01	Shop-floor employees are key to problem solving teams	0.57
Empinv_02	Shop-floor employees drive suggestion programs	0.50
Empinv_03	Shop-floor employees lead product/process improvement efforts	0.58
Empinv_04	Shop-floor employees undergo cross functional training	0.62
TPM_01	We dedicate a portion of everyday to planned equipment maintenance related activities	0.42
TPM_02	We maintain all our equipment regularly	0.44
TPM_03	We maintain excellent records of all equipment maintenance related activities	0.47
TPM_04	We post equipment maintenance records on shop floor for active sharing with employees	0.42

[a]Eliminated during item purification in exploratory phase.