VALUE STREAM ANALYSIS AT ROL PRODUCTION

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VALUE STREAM ANALYSIS AT
ROL PRODUCTION

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This thesis work is performed at the School of Engineering, Jönköping University within the subject area Production systems. The work is part of the university’s two-year master degree. The author is responsible for the given opinions, conclusions and results.

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Summary

This report is the result of the final project work in the Production System Master’s program, at the School of Engineering in Jönköping. The project was conducted from week 4 to week 33 during 2010 and aims at performing a value stream analysis for two production companies within the ROL Group, which primarily works within retail solutions and store fixtures.

The final project work mainly focuses on identifying and mapping a value stream of a table leg. The overall purpose with the work is to identify and evaluate tools suggested in the literature and to create suggestions of suitable tools to be used to analyze a value stream with the aim of maximizing customer satisfaction while maximizing the financial result. The tasks to perform are:

- To map the predefined value stream.
- To identify improvement areas.
- To find out how this knowledge can be used at other companies.

The work is related to the theoretical areas of production, production systems, Toyota Production System, Lean Production, and more specifically Value Stream Mapping.

The project was designed as a longitudinal case study, where a mix of quantitative and qualitative methods was used for data collection and data analysis. The quantitative methods mainly consist of time measurements while the qualitative methods focuses on observations and discussions. The methodology primarily focuses around the Value Stream Mapping procedures as described in the literature.

It is found that actual processing time is less than 18.5 minutes out of the production lead time, which is 16.7 days. This means that great improvements can be achieved by implementing a true lean transformation strategy. The main problem, for the company observed, lies in the communication between management and workers when it comes to implementation of changes. It would be beneficial to appoint a change agent to be responsible for the change management and make sure to educate the employees in lean and lean tools.

Improvement suggestions provide focus both on very detailed aspects, such as hanging the product differently on the painting conveyor, and on more general issues such as increasing communication and focus on creating a multi-skilled workforce.

The findings made here can to some extent be applicable on other companies. Further research is suggested to focus on the usage of lean tools in SMEs.

Key Words

Value Stream Analysis, Value Stream Mapping, Value Stream Management, Material- and Information Flow
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1 Introduction

This chapter presents a short company description, the background to the problem, the purpose, along with the delimitations.

This report is the result of the final project work (thesis) in the Production System Master’s program, with focus on Production Development and Production Management at the School of Engineering in Jönköping. The project was conducted from week 4 to week 33 during the year 2010. The project work aims at, based on theoretical references, preferably within the field of Lean Production, develop, test, and validate a methodology to minimize lead time, tied up capital, and costs in the value stream of the two ROL Group companies, ROL Ergo AB and ROL Production Sweden AB.

1.1 The company

ROL Group is a company which primarily works within the retail solutions and store fixtures. The company was established in 1985 as a product supplier to the convenience store industry and has since then evolved into an international provider of innovative retail solutions. Within the group ROL Ergo focuses on the production of height adjustable table stands and it is within this field this thesis is.

Due to extensive expansion, the ROL Group today has a complex organization, with many of the independent companies heavily involved with each other.

This thesis relates to the production part of the ROL Group, ROL Production International AB, and its Swedish subsidiary ROL Production Sweden AB, which produces sheet metal and tubular components, and ROL Ergo AB, which develops and produces multifunctional columns for height adjustable tables.

1.2 Background

The information in this section is based on semi-structured interviews and continuous dialogue with company representatives during the thesis period.

A couple of years ago the management of ROL Production Sweden AB implemented some lean tools, such as 5S, autonomous work groups, and kanban cards. However, the implementations did not fully reach the level they were intended to and has since faded away and to a large extent been forgotten. Recently the production management has taken new steps to try to reinforce the lean thinking into the organization and this time they are emphasizing on doing things in the right order and trying to follow a predefined structure for lean implementations. Even though the management has rough ideas about the problem areas and good intuition on where the efforts first should be placed, there is a need for a more structured work method and for proofs on where the problems actually are, and which of them that are the most important ones.

There is no project group responsible for these improvements; the Managing Director of ROL Production International AB and the Production Manager of ROL Production Sweden AB are in charge while they also are the project owners.
Also at ROL Ergo AB has the production management recently, lead by the Production Manager of ROL Ergo AB and with help from the Managing Director of ROL Production International AB, started to pay more attention to lean thinking and implementing ideas, and improvements that are in correspondence with the lean philosophy.

However, the production, both at ROL Production Sweden AB and at ROL Ergo AB, is set up with functional layout (Olhager, 2000, p. 119; Bellgran & Säfsten, 2009, p. 220) and there are no plans on changing this.

In a first attempt to structure and measure the problem areas, the management calls for an analysis of the entire value stream for one specific product. This product is chosen based on its typical characteristics. It is a high volume product that goes through many production steps and involves all three European production facilities.

The product that will be analyzed is a table leg for a height adjustable table stand, consisting of three main parts; one house and two tubes. One example of one whole table stand can be seen in Figure 1.

Figure 1 Table stand (ROL Ergo, 2010b)

1.3 Purpose

The final project work focuses on identifying and mapping the predefined value stream. The work aims at providing ROL Production Sweden AB and ROL Ergo AB with enough information to be able to start working on reaching as lean production as possible while meeting customer demands more rapidly.
The overall purpose with the thesis work is to identify and evaluate tools suggested in the literature and to create suggestions of suitable tools to be used to analyze a value stream with the aim of maximizing customer satisfaction while maximizing the financial result. This means that the method being used during the thesis work shall be applicable on other product families and manufacturing units within the ROL Group. Furthermore, it would be beneficial if the work procedures also could be applicable for other companies and organizations within the same type of industry.

To structure the work the purpose was narrowed down into the following tasks:

- To map the predefined value stream.
- To identify improvement areas.
- To find out how this knowledge can be used at other companies.

1.4 Delimitations

The study is limited to one specific product, which can be seen as representing a typical flow within the organization, and its three main parts.

The part of the value stream that is located in Lithuania is not included in the analysis. This is due to lack of time.

Further limitations are related to the choice of method. Based on requirements from the company the method is based on the Lean literature and the Value Stream Mapping (VSM) technique, among others explained in Learning to See (Rother & Shook, 2003), is adopted.

1.5 Outline

The report starts with the introductory chapter, where a brief company presentation and a background clarify the context of what situation the company is in today and what this report is concerning. Further, the purpose and research questions are described and delimitations explained.

The second chapter, Theoretical background, is based on the performed literature review and focuses on Lean production, implementation of Value Stream Management, and Value Stream Mapping. Furthermore, the chapter explains methods and research areas that are important as a background for the result and analysis.

Chapter 3, Methodology, describes the used methods. It informs about how the literature review was conducted and how the data analysis was performed.

Chapter 4, Current state – description, describes the company in general; what products are produced, what the market looks like, and how the ROL Group is organized.

Chapter 5, Current state – analysis, includes the presentation of the conducted measurements and the analysis of them.

Chapter 6, Analysis, consists of a general analysis of the situation at the company.
Chapter 7, Improvement suggestions, describes the suggestions that are given to the company regarding how to improve the current situation.

Chapter 8, Discussion and conclusions, does not only give a general discussion on the thesis topic and how to generalize the knowledge gained from this specific company, but also includes discussion about the chosen methodology; its reliability and validity. Furthermore, the chapter wraps the report together in the conclusions.

Chapter 9, Applicability for others, presents how the knowledge retrieved from this study can be useful for others.

Lastly, a list of references and appendices are presented.
2 Theoretical background

This chapter presents the theoretical framework upon which the result and analysis are based. The theory first comprises an introduction to the topic of production and its history and characteristics. It is further narrowed down through Toyota Production System and Lean Production to the theory concerning the tools and methods applied in this project, primarily related to the theory of Value Stream Mapping.

2.1 Production of today

There is no doubt that during the past 100 years the world has gone through some major changes, so also in the area of production. For centuries manufacturing had been associated with craftsmanship; skilled craftspeople who hand-built products in small volumes where they never could guarantee that two products with the same specifications would look the same. In early 20th century, Henry Ford introduced the innovative concept of mass production, and for forever changed manufacturing practice. He introduced a user-friendly product that was designed to be produced by interchangeable unskilled workers in a system where parts were interchangeable and easy to fit together. He introduced the idea of letting assemblers only perform one task at each product and let them move from product to product, something he later improved by letting the products move between the assemblers on the world’s first moving assembly line. This did not only decrease the cycle time and discipline the workers, but also made it possible to reduce inventory and lower costs per product. Further, Ford reduced set-up times dramatically by using one task machines and he put them in sequence close together, to get the maximum output (Björkman, 1996; Womack et al., 1990).

Even if Ford’s ideas in many cases are the starting point for all manufacturing of today the business climate has changed dramatically, especially in the last couple of decades; business success is no longer guaranteed through mass production. It is no longer enough to provide low cost and high quality to sustain a competitive position in the global market (Hedelind & Jackson, 2007). Today, the business environment is characterized by fierce global competition where change and uncertainty dominate and customers are becoming more demanding (Almgren, 1999a; Chen & Cheng, 2007; Hedelind & Jackson, 2007). Time is one of the most significant competitive advantages (Almgren, 1999a); decreasing product life cycles, increasing investments in new products and processes and fast changing demands from worldwide customers call for rapid provisioning of customized and innovative products to the market (Almgren, 1999a; Almgren, 1999b; Chen & Cheng, 2007, Kim et al., 2008).
According to Chen & Cheng (2007, p. 1237) these market conditions implies that manufacturing companies, to stay competitive, must “produce high-quality products at a low cost with increasing variety, over shorter lead times”. Hedelind & Jackson (2007, p. 2) support this by stating that there is a need for a “high degree of flexibility, low-cost/low-volume manufacturing skills and short delivery times”. The reasoning is further supported by Chen et al. (2006, p. 335), who state that the main focus to reach success should be to understand the client while striving to “manufacture sophisticated products at a low cost while maintaining high quality and providing outstanding customer service”. In addition to above mentioned authors, Almgren (1999a; 1999b), Denkena et al. (2006), Kim et al. (2008), Thun (2008) and Vink & Stahre (2004) also testify similar conditions affecting companies within their research areas. To respond to these market conditions it is important for companies to monitor the production performance.

2.2 Production performance

In this global market, it becomes increasingly important for companies to improve their performances in order to stay competitive while technology moves forward rapidly (Chen & Liaw, 2006; Denkena et al., 2006). Therefore, performance measurement has become an important part of production management (Denkena et al., 2006). Performance of production has always been measured in some way; in early production time measurements were used. In the 1960s the use of short term financial criteria was popular, while during the 1980s and 1990s the options increased and “self-assessment, quality awards, benchmarking, ISO 9000, activity-based costing, capability maturity model, balanced scorecard, workflow-based controlling” were some of the popular methods used for evaluation of the performance (Denkena et al., 2006, p. 191). This progress is also explained by Almgren (1999a) who states that there are different models to use when analyzing efficiency within a production system. He further brings up a few of them; motion and time study models determine the standard operating time for assembly operations, OEE (overall equipment effectiveness) is used to analyze equipment utilization within mechanized systems, different types of cost models determine costs related to different activities, and line balancing models decide how assembly systems can be designed in a cost-effective way. In evaluating performance of manual assembly, which is one of the essential tasks for improving production systems, Peterson (2000) focuses on MAE (manual assembly efficiency), based on the concept of standard times.
When it comes to production performance and how to measure it, Bellgran & Säfsten (2005) find the two main issues to be; what to measure and how to do it. Chen & Cheng (2007, p. 1236) write that “performance measures are defined as a tool for assessing how well the activities within a process or the process outputs achieve a specific goal. Performance measures have been defined as a tool to compare actual results with a pre-determined goal and measure the extent of any deviation. A target performance level is expressed as a quantitative standard, value or rate”. Denkena et al. (2006) emphasize the importance of goals; in order to evaluate the performance it is important to have an explicit definition of the company’s goals. Jonsson & Lesshammar (1999, p. 56) further stress the need for a company to emphasize its competitive priorities through “corporate, business and manufacturing strategies, as well as in measures on various hierarchical levels”. Tangen (2003, p. 347) points out that if appropriate performance measures are chosen they can assure that “managers adopt a long-term perspective and allocate the company’s resources to the most effective improvement activities”. In order for the measurements to be effective they need to be based on the company’s strategic objectives, otherwise employees’ behavior does not match the corporate goals. They further need to provide feedback both from a short-term and a long-term perspective; which is relevant and accurate. Also, it is important that the measurements are easily understood by the employees who are being evaluated. Lastly, Tangen (2003) emphasize that a limited number of measurements should be used and that they should be both financial and non-financial.

2.3 TPS

Toyota Production System (TPS) is the production system used at Toyota and initiated in the 1920’s and 1930’s by the founder of the company, Sakichi Toyoda, and his son, Kiichiro Toyoda, with the ideas of Jidoka and Just-in-Time (Bellgran & Säfsten, 2009; Womack & Jones, 1996). These ideas were brought together and conceptualized by Taiichi Ohno. He was the factory manager with the mission to boost Toyota’s productivity and did this by applying and developing the different ideas and tools that were already existing within the company (Bellgran & Säfsten, 2009; Womack & Jones, 1996). This work started in the late 1940’s and continued during Ohno’s entire employment at Toyota, until his retirement in 1978, and is still today an ongoing process within the company (Womack & Jones, 1996).

When Ohno was promoted to the managing position he became responsible for a classic batch-and-queue operation with a functional layout. He came to his most fundamental and well known insights shortly after installing himself in the new settings (Womack & Jones, 1996, p. 231).
The first insight was related to the fact that workers spent a majority of their time watching machines performing while a lot of bad parts could be produced before inspectors detected them. To solve this problem Ohno, based on ideas from Sakichi Toyoda, implemented devices that made it possible to run production without human involvement, but which stopped as soon as the machine detected an error in its own performance. This allowed for reduction in amount of operators needed; one operator could easily monitor several machines while also conducting quality controls and only interrupt the process when there was a need for refilling of materials (Womack & Jones, 1996, p. 232).

As a second insight, Ohno realized that even though a company keeps lots of inventory there is always one part missing. The salvation of this problem was to make sure that every processing step frequently went to the previous processing step to pick up exactly the amount of parts needed for the next production step. Ohno added the rule that the previous step never was allowed to produce more than what was just withdrawn; creating a JIT system. In 1953 a further step was taken to formalize this system by introducing kanban cards. The second element that was needed to completely be able to follow the just in time ideas was the quick changeover of tools, which was initiated during the late 1940’s but did not reach full perfection until the late 1960’s (Womack & Jones, 1996, p.232).

The third insight was related to the factory layout. Ohno realized that the machines on the shop floor should be moved from the process villages they were currently placed into cells. The cells should be laid out in a horseshoe pattern and the machines placed in the exact sequence needed to produce the product. This implied a change in focus; from “the maintenance needs, the traditional skill sets and work methods of the work force”, and “conventional thinking about scale economies” (Womack & Jones, 1996, p. 232) to the needs of the object moving through the production. Ohno focused on the value stream and launched the theory of single-piece flow. The introduction of single-piece flow not only allowed for larger flexibility in meeting customer demands by adding and subtracting workers from cells, but also decreased the need of JIT links within the company (Womack & Jones, 1996, p. 232).

Liker (2004, p. xii) takes a slightly different grip when presenting Toyota’s system, which he refers to as the Toyota Way; reflecting not only the production system but all other aspects of Toyota as a company. “The Toyota Way /…/ is the fundamental way that Toyota views its world and does business. The Toyota Way, along with the Toyota Production System, make up Toyota’s ‘DNA’”.

Further, Liker (2004, p. xii) summarizes The Toyota Way through the two pillars that support it. These are “Continuous Improvement” and “Respect for People”, where the continuous improvement, which often is called kaizen, defines the basic approach Toyota has to do business. It consists of a company culture where everything shall be challenged and where an atmosphere of continuous learning and change is embraced. This type of environment can only be created where there is respect for people.
Toyota’s achievements and its stability in world-class performance relies on operational excellence, which has become the strategically most valuable weapon. The excellence of operations is based on tools and quality improvement methods, but also, and maybe most importantly, on an “understanding of people and human motivation” (Liker, 2004, p. 6).

Liker (2004, p. 6), based on his longitudinal study of Toyota, presents the 14 principles that he believes constitute the Toyota Way. He explains that these principles are the foundation for TPS and further, that he divides the principles into four categories, all starting with P. While Liker was developing his 4 P model, Toyota worked on its internal training documents. Therefore, Liker has in his model included and correlated the four high-level principles from Toyota (Figure 2).

![Figure 2 Liker’s 4 P model of the Toyota Way (Liker, 2004, p. 6)](image)

**2.4 Lean Production – introduction**

The last decades’ manufacturing trends world-wide have been highly influenced by the Toyota Production System, which is the basis for much of the movements associated with lean production (Liker, 2004, p. 7).

According to the Lean Lexicon (The Lean Enterprise Institute, Inc. [LEI], 2008, p. 53) lean production is “a business system for organizing and managing product development, operations, suppliers, and customer relations that requires less human effort, less space, less capital, less material, and less time to make products with fewer defects to precise customer desires, compared with the previous system of mass production”.

9
Lean production, as an expression, was first used by Krafcik in 1988 (Bellgran & Säfsten, 2009). It was introduced wider in *The Machine that Changed the World* (Womack et al., 1990) and further described in *Lean Thinking, Banish Waste and Create Wealth in Your Corporation* (Womack & Jones, 1996 [2nd ed. came in year 2003]). The objective of the authors to launch the first book was to “send a wake-up message to organizations, managers, employees, and investors stuck in the old-fashioned world of mass production” (Womack & Jones, 1996, p. 9). The reason they labeled the new way of manufacturing lean production was because “it does more and more with less and less” (p. 9). Further, the purpose of writing the second book was to summarize the principles of lean thinking to provide a North Star for the people who wanted to transform their businesses (p. 10). Moreover, they wanted to link all the different lean methods together into a complete system, where the people would be able to understand the whole and not just the technical pieces (p. 10).

“Lean thinking is counterintuitive and a bit difficult to grasp on first encounter (but then blindingly obvious once ‘the light comes on’)” (Womack & Jones, 1996, p. 28).

Lean manufacturing is taking a holistic approach to reach world-class manufacturing environment. According to Feld (2001, p. 3) “the concept of holistic is meant to imply the interconnectivity and dependence among a set of five key elements.” The five primary elements in Feld’s definition for lean manufacturing are Manufacturing Flow, Organization, Process Control, Metrics, and Logistics. Feld further says that each of these element is “critical and necessary for the successful deployment of a lean manufacturing program” (p. 3) but that it is important to know that none of the elements alone can reach the same performance level as the five can do combined; hence, it is important to find a coordination between them.

Womack & Jones (1996, p. 10) also present five important ingredients to become lean. They introduce them as the Five Principles; a summary of lean thinking:

- Precisely specify *value* by specific product
- Identify the *value stream* for each product
- Make value *flow* without interruptions
- Let the customer *pull* value from the producer
- Pursue *perfection*

In the same manner as Womack & Jones (1996), Tapping et al. (2002) structures the key lean management principles in the following way:

- “Define value from your *customer’s* perspective.
- Identify the *value stream*.
- Eliminate the seven deadly *wastes*.
- Make the work *flow*.
Theoretical background

- *Pull* the work, don’t push it.
- Pursue to *perfection.*” (Tapping et al., 2002, p. 10)

Further, Womack & Jones (1996, p. 15) introduce the concept of waste and value and its relation to lean thinking. The authors say that lean thinking is the antidote to muda (waste); that “it provides a way to specify value, line up value-creating actions in the best sequence, conduct these activities without interruption whenever someone requests them, and perform them more and more effectively”. It is a way of doing more and more with less and less and at the same time be able to get closer and closer to what the customer really wants (Womack & Jones, 1996, p. 15). In addition, lean thinking gives the employees the chance to a more satisfying job; it provides immediate feedback on the attempts that are made to change muda into value (Womack & Jones, 1996, p. 15).

Tapping et al. (2002, p. 1) say that “many organizations are *doing* lean without necessarily *becoming* lean”. By this the authors mean that these organizations implement improvements that are not clearly linked to an overarching strategy. The authors further add to this reasoning by stating that they have found that isolated applications of specific lean tools do often not result in changes that are kept for a longer period of time.

To become lean, it is, according to Tapping et al. (2002, p. 2), important to use the tools in a way that allows everyone in the value stream to work together to decrease waste and improve the flow to the customer. Further, Tapping et al. (2002, p. 2) write that the overall lean process can be divided into eight steps which will help companies to “accelerate, coordinate, and most importantly, sustain your efforts and assure that everyone is on the same page.” These eight steps are:

1. Commit to Lean
2. Choose the Value Stream
3. Learn about Lean
4. Map the Current State
5. Determine Lean Metrics
6. Map the Future State
7. Create Kaizen Plans
8. Implement Kaizen Plans

The concept of Value Stream Management, as developed by Tapping et al. (2002, p. 2), is a “process for planning and linking lean initiatives through systematic data capture and analysis. Value Stream Management is a synthesis of best practices used at Fortune 500 companies that have not only successfully implemented lean manufacturing practices, but also sustained them”. The eight steps by Tapping et al. (2002) have large similarities with Womack & Jones’ (1996) specific sequence of steps and initiatives to follow during the transformation towards lean.
Womack & Jones (1996, p. 27) present a couple of rules of thumb, based on their long experience and observations, for short term benefits of lean thinking. If a classic batch-and-queue production system is converted to continuous flow with effective pull by the customer the labor productivity will be doubled all the way through the system; for direct, managerial, and technical workers, from raw materials to delivered product. This conversion will also cut production throughput times by 90 percent and reduce inventories in the system by 90 percent.

The time it takes to bring new products to the market will in most cases be cut by half, and with the conversion to continuous flow comes the possibility to be able to provide a larger variety of products, within product families, at a small additional cost. The number of errors that reach the customer along with the scrap within the production process will typically be cut in half. Job-related injuries will also decrease by 50 percent (Womack & Jones, 1996).

Maybe most importantly, the capital investments associated with this conversion “will be very modest, even negative, if facilities and equipment can be freed up and sold” (Womack & Jones, 1996, p. 27).

In addition to these changes, which will appear a relatively short time after the conversion, lean thinking gives the ability for continuous improvements through *kaizen*. Womack & Jones (1996, p. 27) claim that companies which have gone through the first radical steps can normally “double productivity again through incremental improvements within two to three years and halve again inventories, errors and lead times during this period”.

### 2.5 Transformation to lean

Through their long time experience Womack & Jones (1996, p. 247), along with eg. Tapping et al. (2002), have learned that following a specific sequence of steps and initiatives during the transformation to lean gives the best results. Womack & Jones (1996, p. 247) state that core factors for success are to “find the right leaders with the right knowledge and to begin with the value stream itself, quickly creating dramatic changes in the way routine things are done every day”. Tapping et al. (2002, p. 13) add that it is management’s responsibility to lead the commitment to lean and set the example for how this work is to be done.

Further, Tapping et al. (2002, p. 3) explain that when implementing, what they call Value Stream Management, it is “important to ensure that everyone has a good understanding of lean concepts”. The authors conclude that “many organizations have implemented pieces of the process, but few have taken the initiative or spent the time to complete it in its entirety. As a result, relatively few organizations have created a sustainable lean manufacturing system” (Tapping et al., 2002, p. 5).

It is important to have in mind that reaching a true lean production system, the world class level, is about never being satisfied, about continuous improvement, and a constant struggle to increase value for the customer by reducing waste. Tapping et al. (2002, p. 13) define a world class organization as one that:
Theoretical background

- “Operates by the cost-reduction principle.
- Produces the highest quality in its business sector – zero defects.
- Meets quality, cost, and delivery requirements.
- Eliminates all waste from the customer’s value stream.”

The steps that Womack & Jones (1996) and Tapping et al. (2002) suggest to follow to become lean are briefly described in the following sections. They differ from each other in the sense that Tapping et al. (2002) introduce a practical sequence of eight steps which are associated with the actual execution. Their description is sometimes very detailed and includes the exact usage of specific lean tools, while Womack & Jones (1996) applies a more holistic view with a less detailed transformation procedure. To create a coherent implementation sequence out of the two procedures they have been combined as shown in

*Table 1*. The structure presented in the table is followed throughout the rest of this chapter.

<table>
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<tr>
<th>The Five Principles (Womack &amp; Jones, 1996)</th>
<th>The key lean management principles (Tapping et al., 2002)</th>
<th>The eight steps for the lean process (Tapping et al., 2002)</th>
<th>A combination, as perceived within this framework</th>
</tr>
</thead>
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<tr>
<td>• Precisely specify value by specific product</td>
<td>• Define value from your customer’s perspective</td>
<td>• Commit to lean</td>
<td>• Commitment to lean</td>
</tr>
<tr>
<td>• Identify the value stream for each product</td>
<td>• Identify the value stream</td>
<td>• Choose the value stream</td>
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<td>• Make value flow without interruptions</td>
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<td>• Let the customer pull value from the producer</td>
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<td>• Map the future state</td>
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*Table 1* Lean implementation perspectives
2.5.1 Commitment to lean

Before any type of change management can start the commitment to lean needs to be in place. At this stage, it is the management that needs to take the lead. To be able to succeed in the transformation everyone needs to be fully committed to the work of change. This is done by an open dialogue between management and all levels of the organization. Especially at this initial stage, but also throughout the entire period of work of change, management must constantly communicate the importance of the lean transformation (Tapping et al., 2002).

According to Womack & Jones (1996, p. 247) “the most difficult step is simply to get started by overcoming the inertia present in any brownfield organization.” To be able to start there is a need for a change agent, also referred to in the literature as a value stream manager, a person that is capable handling the transformation and has a mind-set that makes things happen. In addition, it is important to have the knowledge about lean, it is beneficial if this detailed knowledge is possessed by the change agent, but if not it is useful to have additional expert help at the start. Even if the expertise is in-house it is almost always necessary to get external help from consultants, preferably the change agent should be connected to a sensei as an external advisor (Rother & Shook, 2003; Tapping et al., 2002; Womack & Jones, 1996).

Tapping et al. (2002, p. 16) state that in addition to finding and appointing the person responsible for the change management, there is a need for a core implementation team.

Further, before the transformation can start, it is essential for management to fully understand the organization it is about to change. “Managers must understand their organization’s activities by ‘going to the floor’ and observing production first-hand” (Tapping et al., 2002, p. 18).

2.5.2 Getting started

Womack & Jones (1996) describes that it is important to find a trigger for the transformation by seizing an existing crisis. Most organizations are not prepared to take the steps towards lean unless there is a real crisis to trigger it. Therefore, if the organization is not in crisis, it is beneficial for the transformation if the management actually create a situation where the conditions are as such that “there will be a firm-threatening crisis unless lean actions are taken” (Womack & Jones, 1996, p. 251). If this solution is too extreme, there are the options of focusing all the efforts on a subunit that is in crisis, or to find a lean customer or a lean supplier to trigger the need for lean.

Identification of value

The starting point of every lean effort should be the value; as it is defined by the end customer. It is only “meaningful when expressed in terms of a specific product (a good or a service, and often both at once) which meets the customer’s needs at a specific price at a specific time” (Womack & Jones, 1996, p. 16).
Value is very difficult for producers to identify and the business climate in many companies today push managers to focus on the short-term needs of shareholders and senior management instead of constantly, and in the long run, focus on specifying and creating value for customers (Womack & Jones, 1996, p. 16).

According to Womack & Jones (1996, p. 19) it is very important to “form a clear view of what’s really needed”. This can be done by ignoring the existing assets and technologies at the same time as creating dedicated product teams.

Further, Womack & Jones (1996, p. 31-32) suggest, based on an example from the Wiremold Company, that it is beneficial to form a team, consisting of a product engineer, a marketer, and a tooling/process engineer, for each product. This team should stay with the product during its entire production life and have a continuous dialogue with leading customers, focusing on the value that the customer really needs.

After defining the product, the most important task in specifying value, according to Womack & Jones (1996, p. 35), is to set a target cost; which is the muda-free cost of the product; hence, the cost the company has when all the unnecessary steps in development, order-taking, and production are eliminated and the value is flowing.

**Learning about lean**

For the transformation to be successful in the long term everyone within the organization should be taught lean thinking and skills (Rother & Shook, 2003; Tapping et al., 2002; Womack & Jones, 1996). To make the teaching as useful as possible it is vital to not stress or give away too much, the workforce needs to be trained in the skills that are required for the next phase in the implementation. Womack & Jones (1996, p. 264) further explains that “lean learning and policy deployment can be carefully synchronized so that knowledge is supplied just-in-time and in a way that reinforces the commitment of managers and all employees to doing the right thing. Everyone learns the same approach to problem solving and everyone experiences the direct benefits of continuous learning, even though they may have left formal education many years ago.”

Tapping et al. (2002) recommend management to assure that everyone involved possess the right knowledge of lean before going further in the transformation. It is important to not go further before the knowledge is broad enough to make changes, and the people feel confident enough to execute them.

There is a fine balance between training and doing. Tapping et al. (2002, p. 37) state that the concepts must be understood before proceeding to the next step, but it is important to reach the applying stage as fast as possible.
It is important as a first step to assess the core implementation team members’ level of lean knowledge and overlap the gap between current knowledge and required one through intensive training. Further, to structure this training, it is important to have a detailed plan, a defined agenda, and targets to reach (Tapping et al., 2002, p. 38). Tapping et al. (2002, p. 38) suggest that a variety of sources shall be used; using simulations, benchmarking, demonstrate in-house projects, using resources already available, using consultants, and using books and videos.

**Identification of value stream**

Once the leadership, the knowledge, and the sense of urgency are in place, the current value streams need to be identified and mapped by product family (Womack & Jones, 1996, p. 252).

Rother & Shook (2003) define a value stream as all the actions, both value added and non-value added, that are needed to be able to take a product from raw materials to customer. Further the authors state that “taking a value stream perspective means working on the big picture, not just individual processes, and improving the whole, not just optimizing the parts” (Rother & Shook, 2003, p. 3).

Womack & Jones (1996, p. 19) define the value stream as “the set of all the specific actions required to bring a specific product (whether a good, a service, or, increasingly, a combination of the two) through the three critical management tasks of any business: the problem-solving task running from concept through detailed design and engineering to production launch, the information management task, running from order-taking through detailed scheduling to delivery, and the physical transformation task proceeding from raw materials to a finished product in the hands of the customer.”

The value stream can be predefined by the customer, but if that is not the case Tapping et al. (2002, p. 27) present two different methods to identify which value streams that are most suitable to start with; the Product-quantity analysis and the Product-routing analysis.

Further, Rother & Shook (2003, p. 6) stress the importance of identifying the product family from the customer end of the value stream. The authors define a family as a group of products that go through similar processing steps and common equipment downstream. If the product mix is complicated Rother & Shook (2003, p. 6) suggest to create a matrix to clarify the connections, and in that way identifying product families (Figure 3).
Figure 3 Example of matrix to identify product families (Rother & Shook, 2003, p. 6)

Tapping et al. (2002, p. 31) recommend that when choosing the first value stream to target, it should not be too simple nor too complex. Womack & Jones (1996) add that it is important to look at the entire value stream, to not get caught in the trap of implementing lean tools on small parts of a value stream where the problems were easily fixed. Hence, focus on what the customer needs, which in most cases is a whole product.

**Value Stream Mapping**

When possessing the right knowledge it is time to map the current state. According to Tapping et al. (2002) this is done through a sequence of steps which briefly can be summarized as a mean to show how materials and information flow through production. The purpose for this mapping is to “gather accurate, real-time data related to the product family, or value stream” (Tapping et al., 2002, p. 77). When collecting this data it is important for the core team to work together on the factory floor, and to not rely on second-hand data (Tapping et al., 2002). Womack & Jones (1996) describe value stream mapping as a way to identify all the specific activities occurring along a value stream for a product or family”, while Rother & Shook (2003) explain that value stream mapping is “a pencil and paper tool that helps you to see and understand the flow of material and information as a product makes its way through the value stream”. That is, value stream mapping is a tool to follow a product’s way through production, from customer to supplier, by drawing a visual representation of the materials and information flow.

Tapping et al. (2002, p. 77) write that “there are numerous ways to determine the scope of a value stream map” and describe the most common ones:

- “You can define activities and measure the time it takes to go from conceiving a product to launching it.

- You can define the activities and measure the time it takes from receiving raw materials to shipping finished parts to a customer.

- You can define the activities that take place from the time an order is placed until cash is received for the finished order.”
Rother & Shook (2003) introduce Value Stream Mapping in their work book, *Learning to See*, as “a vital yet simple tool that can help us make real progress toward becoming lean”; and further as “a means to tie together lean concepts and techniques”.

Value stream maps are one of the most essential tools to visualize the transformation work; they give a visual representation of both material and information flow and forces management to not only observe the processes but also identify and understand them. Through the mapping, the waste will become evident. Tapping et al. (2002, p. 78) state that it is important to remember that “a key to establishing a lean material flow is understanding how information flows – that is, how production scheduling is achieved”.

Tapping et al. (2002) systematically describes all the steps to conduct the current state map. They advice to prepare thoroughly before getting started with the actual mapping; to draw rough sketches of the main production operations, to go to the shop floor and collect data starting from the most downstream operation, and to gather the group to discuss the results and assure that sufficient information has been captured. Also Rother & Shook (2003) give a similar sequence of steps on how to conduct the value stream mapping task. Rother & Shook (2003) further stress the importance of not making the mistake of letting area managers map individual areas which are joint together later.

In conducting the actual creation of the map, Tapping et al. (2002, p. 84) advice the usage of an eight step approach, involving the drawing of icons, drawing of data boxes, entering of shipping and receiving data, drawing of the manufacturing operations, entering of process attributes such as the processing time, illustration of the information flow, drawing of inventory icons, and finally, if such are present, drawing of push, pull, and FIFO locations. Further, Tapping et al. (2002) give clear instructions on what to include as available time, what to consider as changeover time, and how to calculate uptime.

Rother & Shook (2003, p. 4) list a set of reasons why value-stream mapping is an essential tool in the lean transformation:

- “It helps you visualize more than just the single-process level, i.e. assembly, welding, etc., in production. You can see the flow.
- It helps you see more than waste. Mapping helps you see the sources of waste in your value stream.
- It provides a common language for talking about manufacturing processes.
- It makes decisions about the flow apparent, so you can discuss them. Otherwise, many details and decisions on your shop floor just happen by default.
- It ties together lean concepts and techniques, which help you avoid ‘cherry picking’.
Theoretical background

- It forms the basis of an implementation plan. By helping you design how the whole door-to-door flow should operate – a missing piece in so many lean efforts – value-stream maps become blueprint for lean implementation. Imagine trying to build a house without a blueprint!

- It shows the linkage between the information flow and the material flow. No other tool does this.

- It is much more useful than quantitative tools and layout diagrams that produce a tally of non-value-added steps, lead time, distance traveled, the amount of inventory, and so on. Value-stream mapping is a qualitative tool by which you describe in detail how your facility should operate in order to create flow. Numbers are good for creating a sense of urgency or as before/after measurements. Value-stream mapping is good for describing what you are actually going to do to affect those numbers.”

Waste

In most cases, when value stream mapping is performed, every action that is identified can be sorted into one of three categories (Womack & Jones, 1996, p. 20):

- Actions which create value for the customer.

- Actions which do not create any value but are required in the current production system and therefore cannot yet be eliminated; Type One muda.

- Actions which do not create value for the customer and therefore can be eliminated immediately; Type Two muda.

Since waste is so difficult to identify, especially within the own firm, “lean thinking must go beyond the firm” and instead look at all the activities that are needed to create and produce a product, irrespective of the individual firms involved in the value chain (Womack & Jones, 1996, p. 21).

Identification of lean metrics

When the current state value stream map is in place it is time, according to Tapping et al. (2002), to identify the lean metrics, which will help in achieving the future state goals. The lean metrics shall work as a simple way for the people to understand the impact that their change efforts have. Tapping et al. (2002, p. 96) call the lean metrics for the fundamentals and say that it is dependent on each individual company’s situation what metrics that are best to use. However, important to remember is that the metrics that are adopted shall be easy to stratify so that individual cells or operations, as well as the entire value stream can receive feedback.
Planning for implementation

The next step in the approach suggested by Tapping et al. (2002) is to create the future state plan, which is basically a planning of what lean tools to use and what improvement methods to adopt to meet the customers’ requirements; a way of identifying the opportunities available to create a more waste-free value stream. The first thing to do when creating this map is to gain understanding in what the customer demand look like, next step is to implement continuous flow, and the last step is to level the work.

Rother & Shook (2003, p. 4) advice, in order to be able to draw the future state map, to “ask a set of key questions”, this helps to decide how the value should flow through the processes.

In the approach by Tapping et al. (2002), it is now time for the two last steps; the creation and implementation of kaizen plans. Tapping et al. (2002, p. 137) suggest to create detailed plans of how to improve the value stream; that “without solid planning, the chances for a successful lean transformation are slim”. Further they say that it is important with comprehensive planning, but that it is important to keep in mind that the plans will never be perfect; hence, it is normal to continuously modify the plans. Womack & Jones (1996, p. 253) add that there is no need to “conduct a lengthy planning exercise. Your value-stream maps can be completed in only a week or two”. Further; “the best way to communicate the changes under way is simply to take everyone to the scene of the action and show precisely what is happening” Womack & Jones, 1996, p. 254).

Again, it is important to refer to the concepts of customer demand, process flow, and leveling of production. All improvements implemented need to have a focus on these three aspects in order to make the transformation successful (Tapping et al., 2002).

Implementation

When the implementation of improvements finally take place, it is important to be aware of that everyone connected to the targeted value stream will be affected. Moreover, they will have difficulties understanding the changes and accepting them. Therefore, it is very important to have an open dialogue and to “make sure that everyone upstream and downstream of the area where a kaizen event is taking place knows what is happening and why” (Tapping et al. 2002, p. 147). Further, address negative behavior directly; show consideration about people’s concerns, but be sure to show that these are improvements that will take place and explain how they will make the company stronger. For the transformation to be successful it is important that top managers and implementation team regularly visit the shop floor to keep an open dialogue with the workers.
To activate the change management and make it obvious for the entire organization it is important for the change agent to, as soon as possible, focus the efforts on a specific activity. In this work “the direct work group, along with the all the related managers, at all hierarchical levels, senior executives, the sensei, and the change agent need to be directly involved” (Womack & Jones, 1996, p. 253). The authors recommend to start the efforts “with a physical production activity because the change will be much easier for everyone to see” (Womack & Jones, 1996, p. 253). In addition it is best to start with an activity that is important for the company, but which at the current state is performing very poorly. It makes it to an incentive not to fail, it has a high potential for improvements, and it helps finding resources and strengths that has been hidden within the company.

When reached this far it is essential to have immediate feedback; to demand immediate results. It should be possible to see things change in order to create the psychological sense of flow for the workforce and to create a momentum for change (Womack & Jones, 1996, p. 253)

Create flow

The third principle, out of the five lean principles identified by Womack & Jones (1996) and Tapping et al. (2002), flow, involves, after identifying value, mapping the value stream and eliminating the obvious wasteful steps, to make the remaining steps flow. At this stage, the steps still existing shall be value-adding and the task is to, by completely changing the mind-set of the organization, make the products flow through the production steps (Womack & Jones, 1996, p. 21).

Human beings inherently have the mind-set of grouping items. Womack & Jones (1996, p. 21) explain that “we are all born into a mental world of ‘functions’ and ‘departments’”, where we are convinced that the best way to group activities is by type, where they can be managed more easily while performed more efficiently. Further, the authors explain, the most efficient way to perform these activities is perceived to be in batches within the departments.

As a response to these common-sense-ideas Womack & Jones (1996, p. 22) say that batches “always mean long waits as the product sits patiently awaiting the department’s changeover to the type of activity the product needs next. But this approach keeps the members of the department busy, all the equipment running hard, and justifies dedicated, high-speed equipment.” Further, the authors state that “tasks can almost always be accomplished much more efficiently and accurately when the product is worked on continuously from raw material to finished good”.

In order to battle the ideas of departmentalized batch thinking it is important to keep focus on the individual products and their needs, and to assure that the activities required to produce the products take place in continuous flow (Womack & Jones, 1996, p. 22).

During the work of making value flow it is important to form a lean enterprise where traditional boundaries, such as careers and functions, are set aside, to focus on the actual object, and to rethink specific tools and work practices (Womack & Jones, 1996, p. 52).
Theoretical background

This is accomplished by reorganizing the business by product families, where each product, or product family, has its own manager. At this stage it is important to have everyone on board and remove the managers that are not willing to accept the new way. This requires that a mind-set “in which temporary failure in pursuit of the right goal is acceptable” (Womack & Jones, 1996, p. 256) is created.

To be able to make the products flow smoothly it is important to focus on takt time. The takt time is important in order to coordinate the rate of production with the rate of sales. As demand change, there is a need for adjustment in takt time; to always be able to run the production at the right speed. One way of assuring that the takt is followed is to use some sort of load-leveling system (Womack & Jones, 1996).

To further enable true flow it is vital to organize every step of production into production areas by product families; if possible, due to noise levels, the product manager, the parts buyer, and the scheduler along with the other support function immediately connected to the product family, should be located in direct contact with production (Womack & Jones, 1996, p. 59).

One further important aspect of continuous flow is the right-sizing of tools, to fit the machines directly into the production process. This often calls for simpler, slower, and less automated machines than the massive machines traditionally used in a production system with large batches. Further, to achieve flow when producing many variants within one family the change-over time must be very short, something that often is easier to implement on small, more dedicated machines (Womack & Jones, 1996, p. 60).

When it comes to right-sizing of a company’s tools, it does not only refer to the production equipment, but also information management systems, test equipment, prototyping systems, and organizational groupings (Womack & Jones, 1996, p. 265). The right-sizing of the tools can start from the very first step of transformation, but it is important to be aware of the complexity of changing and that much of it has to do with the mind-set of managers. Womack & Jones (1996, p. 265) state that the first thing that needs to be dealt with is “the ancient bias of your managers that large, fast, elaborate, dedicated, and centralized tools are more efficient”, which is the cornerstone of batch-and-queue thinking. The focus in the process of right-sizing the tools should be to make the products within each product family to flow smoothly through the tools. Hence, the question that needs to be addressed is which type of tools that will allow the products flow without delays and back loops in a system where the tools can be switched over instantly, allowing for one-piece flow.

Often, the right tools can be built within the company with excess material by freed-up workers. Further, it is often the case that several simple tools accommodated for the specific needs of the product family cost less in total than one big advanced one (Womack & Jones, 1996, p. 265).
Also needed to make a continuous flow system to actually flow is a cross-skilled production team in every task and machinery which is perfectly maintained through Total Productive Maintenance, further there is a need for standardization of work tasks and a mind-set of constantly working with poka-yoke; mistake-proofing. To make these approaches work there is a need for visual controls; for example 5S, andon boards, and standard work charts, so that everyone involved are given the possibility to see and understand what is happening at every point in time (Womack & Jones, 1996, p. 61).

**Start pulling**

Pull is the fourth principle, out of the five, towards lean and means that “no one upstream should produce a good or service until the customer downstream asks for it” (Womack & Jones, 1996, p. 67).

By achieving the preceding steps a significant decrease in throughput time can be seen. This decrease means that there is no need for sales forecasts since it is possible to produce what the customer wants when he wants it, hence, the customer pulls the product when the need appears (Womack & Jones, 1996, p. 24).

**Achieve perfection**

When reaching this fifth principle, “something very odd begins to happen. It dawns on those involved that there is no end to the process of reducing effort, time, space, cost, and mistakes while offering a product which is ever more nearly what the customer actually wants (Womack & Jones, 1996, p. 25).

Womack & Jones (1996, p. 26) believe that one of the most important drivers towards perfection is transparency; everyone can see everything and hence, it is easier to discover waste and find out how to create value.

Womack & Jones (1996, p. 94) state that “perfection is like infinity. Trying to envision it (and to get there) is actually impossible, but the effort to do so provides inspiration and direction essential to making progress along the path.” Further, when an activity has been improved, it is important to emphasize for the workers involved that “no level of performance is ever good enough” (Womack & Jones, 1996, p. 260), hence; there is always room for improvements, continuously.

Tapping et al. (2002, p. 148) further stress the need of patience by reminding that it has taken Toyota over 50 years to come to the point they have reached today. The essential is to focus on the daily environment and keep an open dialogue with everyone in order to encourage ideas and suggestions to improve the value stream further.
Further, to make the lean organization work, it is important to have a permanent lean promotion group which reports directly to the change agent. According to Womack & Jones (1996, p. 256) this group is needed as a home for the sensei, the process mappers, and the excess people that will be freed up by the efforts. It should also be a place to go for the improvement teams and operating managers to get support, education, and evaluation. Moreover, it is beneficial for the organization to bring the lean promotion function together with the quality assurance function to be able to consider all performance dimensions of the business simultaneously and equally (Womack & Jones, 1996, p. 257).

### 2.5.3 Going further

After three to four years of this transformation work, the change is starting to be complete within the firm, now, it is time to lead the suppliers and customers to the same transformation process, to convert to lean (Womack & Jones, 1996, p. 266). In order to make the entire value stream lean, Womack & Jones (1996, p. 266) emphasize that the only way to do so is to help the suppliers and customers to fix their product development, order-taking, and production by sending them a lean promotion team from the own organization. However they have a warning; “don’t do this until you’ve fixed your own activities which the supplier or downstream firm links into, but then go as fast as possible and accept no excuses” (Womack & Jones, 1996, p. 266).

### 2.5.4 Dealing with people

One of the problems with lean implementation is that excess people will be freed-up. It is vital for the transformation’s success to deal with these people in an appropriate way. Womack & Jones (1996, p. 257) say that, “Our rule of thumb is that when you convert a pure batch-and-queue activity to lean techniques you can eventually reduce human effort by three quarters with little or no capital investment. When you convert a ‘flow’ production setup [...] to lean techniques, you can cut human effort in half. [...] This is before your lean development system rethinks every product so it is easier to make with less effort.”

Since a crisis often is the trigger of the lean implementation, it is normal that some people have to be laid off. The right thing for management to do is to estimate how many people are needed to do the job the right way, cut the work force to this level, and then guarantees that no one, ever in the future, will lose their job because of the introduction of lean techniques. That promise has to be kept and it is important to know, and to communicate to the workforce, that “in a lean world there is no end to improvement: Jobs are always being eliminated in specific activities” (Womack & Jones, 1996; Tapping et al., 2002).
It is essential for the success of the transformation that everyone is on board; therefore, remove the anchor-draggers. Womack & Jones (1996, p. 260) say that in every organization that they have researched, there has been a small group of managers who have not been capable of accepting the lean ideas. The authors state that “hierarchical personalities needing a clear chain of command and something to control were particular problems”, and that, in every successful transformation that they have been observing, the change agents have wished that they had removed the non-cooperating managers faster. This small percentage of the management is a risk for the entire work of change, since they send opposite messages to the workers and are keen on highlighting any problems or mistakes that occur in the process of becoming lean, hence, put a great deal of stress on the majority of employees, who do not really know what to respond to.

To communicate the lean accomplishments it is important to make everything transparent; “benchmarking your internal performance, especially your rate of improvement, is critical” (Womack & Jones, 1996, p. 263). The authors further state that “it's vital to create 'score-board' which shows everyone involved in a value stream exactly what’s happening in real time” (Womack & Jones, 1996, p. 264).

Tapping et al. (2002, p. 5) agree with this idea, but call the visual tool for a storyboard; “a poster-sized framework for holding all the key information for planning lean implementation”. The idea is that the team places both value stream maps and data on it; it becomes a shared document both to see what has been done and what is planned to happen next.
3 Methodology

This chapter explains how the thesis work was performed; how the literature was found, which methods and tools that were used during data collection, and how this data was analyzed. The in-depth explanations of conducted measurements can be found in chapter 4 and chapter 8.1.

The project was designed as a longitudinal case study, where a mix of quantitative and qualitative methods was used for data collection and data analysis (Williamson, 2002). The qualitative methods; the discussions, dialogues, and semi-structured interviews, were used to create a clear structure for the value stream analysis, and as a starting point for the creation of the maps and as a tool how to know what to measure and where to measure it. The quantitative methods, the time measurements, were used to fill the value stream maps with data and to be able to reasoning around them.

The data collection at the company was conducted during the entire spring semester of year 2010, but with stress on the first 15 weeks. To simplify the collection and interaction with company representatives the student was located at the company (ROL Production Sweden AB) and also had access to the other facilities throughout the entire thesis period.

To learn more about the daily work, the student participated in work at the shop floor, accompanied by blue collar workers.

The methodology to use was already predefined by the project description and therefore the procedures were entirely based on the literature on how to map a value stream as it is presented in chapter 2.

3.1 Literature review

The literature review was conducted mainly by searching databases available at the University Library and Internet to find literature relevant to the field that was up to date and contained the latest information. The focus was on textbooks and workbooks, but also scientific journals were included to broaden the perspective and enable to go deep into details. Also, literature was taken from previous courses within the Master program and from information given by professors throughout the classes.

The majority of the books were found through the University Library, even though some workbooks had to be ordered from the U.K.
When conducting the literature search through the University Library, articles were found with the help of Google Scholar. The articles belonging to databases which the library have contracts with were found in full text. The most used databases were ABI/Inform, Academic Search Elite, Business Source Premier, Emerald and ScienceDirect. Google Scholar simplified the searching and provided worldwide articles, along with online books in full text. The searches were based on subject, title, author, ISSN, ISBN and year, depending on which information that was available from the beginning. The search terms used were mainly focused around production, production system, lean production, lean manufacturing, value stream management, value stream mapping and production development. This gave a wide variety of articles to scan through to find information related to the research. When the initial searches had been conducted it was easier to narrow the terms down, eventually ending up in search based on specific authors or specific terms associated with the field.

3.2 Dialogues

3.2.1 Dialogues with management

Throughout the entire thesis period the company supervisor, the Managing Director of ROL Production International AB, along with many employees at different departments and functions, have been available for discussions, questions and several presentations on so-far-findings. The dialogue has been constructive and feedback has been given.

This ongoing dialogue created the foundation for the value stream maps and an understanding of the complexity of the production at the both facilities.

3.2.2 Dialogues with operators

During the data collection of cycle times the operators were not only observed but also participated in discussions. The information they provided cannot be seen as anything else than their own personal opinions on their working conditions. It is not written down in a structured manner and it cannot be seen as based on real interviews.

However, the information from these discussions has been included in the analysis, and it has been very important as an aid for the student to be able to create an as truthful picture of reality as possible and it has supported the conclusions made.
3.3 Data collection

The input data for the value stream maps was collected at ROL Ergo from March 15 to March 22 and at ROL Production Sweden from March 23 to June 4. The reason that the period was so much longer at ROL Production Sweden was because the operations there to a much larger extent are automated. It was difficult to match the different operations to each other and to be able to measure them when they occurred. For example the operations that were to be observed in the punching machine were conducted for two hours each time at a couple of occasions per weeks and could appear at any time of the day; evening, night or weekend. Since the production of the product observed, the table leg, was run by kanban cards it was impossible to foresee long time in advance when the specific operation should be performed and it was therefore missed at a numerous occasions.

The possibility existed to trigger the system manually to be able to follow the product, but this was believed to exclude a lot of problem areas from the observations and to have a too great impact on the result. Hence, the data collection took much longer time than what was expected.

Each step of the production process was observed and as much data as possible was collected. The cycle time for each production step was manually clocked at each station.

Included in the observations was also to see how the operator moved and behaved. Notes were taken whenever something happened that could affect the cycle time.

3.3.1 Time measurements

Since a great part of the data collection work involved the measurement of different times, it became essential to have it clear in mind what the measured time stood for; how it was related to other times in the value stream, and how it related to literature.

The time measured in this data collection is the cycle time as it is defined by Tapping et al. (2002, p. 57) and Rother & Shook (2003, p. 19); “the time that elapses between one part coming off the process to the next part coming off”. This means that one cycle time in most cases in this study is measured from the time one product (or part) is placed on the finished goods pallet, until the next time a product is placed there. In this time is included the direct work that the operator is doing to the product, but also the work he or she has to perform to be able to work, i.e. bring materials to station, refill materials, clean the tools, move finished pallets.

All measured times were put into an Excel-file where they were structured according to work station, date, and part number, and where the average times were calculated.
3.3.2 Additional observations

At the same time as the cycle times were measured, thorough observations were performed. This means that the student, while measuring, observed every movement of the operator and took notes of anything that happened that could affect the cycle time. This information was added to the Excel-files with the cycle times to be further analyzed in the Value Stream Map analysis (see Appendix 2 for example of an Excel-sheet from the Welding station).

3.3.3 Special measurements of the welding station

Based on a request from the Production Manager at ROL Production Sweden, a one-day analysis of the welding station was performed on April 20. The idea for this in-depth analysis came after one of the mid-time seminars where data from the welding station was presented and found to not match the predefined cycle times that the operators were supposed to work according to.

These measurements took place on April 20 from 8 am to 5 pm and included all activities the operators conducted during that time. The time to measure was chosen by the company, and there was no reason to believe that it was not a random choice, hence, the student did not find it necessary to pick some other day or time. As in previous measurements, the base of the measurements was the cycle time, meaning that every time one finished product was placed on the pallet for finished products, the clock was stopped. Notes were taken about all the happenings of every cycle.

3.4 Secondary data

Due to problems in scheduling the measurements some data collection was not possible to conduct. To a great extent these were the collections of the set-up times. Either there was no set-up time at the occasion when the operation was observed, or the student did not manage to catch the start-up of the set-up time, but only subsequent steps.

In those cases, the data come from the company’s MRP system and cannot count for the same reliability as the primary data, collected at the shop floor.

The data related to inventory levels and forecasts were taken from the companies’ MRP system; the products in inventory were not counted manually at the shop floor as suggested by the literature (eg. Rother & Shook, 2003).

The literature (eg. Rother & Shook, 2003; Tapping et al., 2002) suggests that the value stream maps shall be drawn during a short period of time by a group of people; the data shall be taken at one occasion, regardless of how this level corresponds to the average. Since the measurements were conducted during a much longer timeframe and by one person, it has been seen as more valuable to calculate with an average of the inventory levels during the measurement time period, March-May 2010.
3.5 The value stream maps

The information from the dialogues, the data collection, and the secondary data was analyzed and functioned as the foundation for the creation of the value stream maps. The maps were first drawn by hand, using the symbols from the literature; primarily Rother & Shook (2003), as can be seen in Appendix 1. Later, the maps were created in Visio 2007, using the Value Stream Map predefined shapes. At some occasions the shapes had to be modified to fit the specific situations at ROL. The data that was filled into the data boxes was based both on the time measurements and on the secondary data, where necessary data was missing it was marked by a question mark to indicate that the analysis was not complete.

The creation of the maps was much more difficult than what was expected after reading and analyzing examples from the literature. The major reason for these difficulties was a complex value stream with multiple flows that merged and shared resources. Mostly, the work books Learning to See (Rother & Shook, 2003) and Value Stream Management (Tapping et al., 2002) were consulted to draw the complex flows, and when the books did not give sufficient answers the supervisor was at great help.

Creating a value stream map out of a production that in reality does not flow was a complex task and resulted in a somewhat confusing usage of symbols in the maps, in these cases it was important to clearly explain what is happening at every step and how the maps should be read. The maps were created to enable for the reader to understand the flow of the products through the different production activities. In both maps it was necessary to draw several parallel flows in the beginning (to the left on the maps), one for each component, and join them together later (to the right on the maps). It was not possible to have the separate flows on individual sheets since they all share resources and end up in the same product.

3.6 The drawings

Due to confidentiality requirements, the blueprints could not be included in this report. However, it was believed that drawings showing the product and its parts were essential to understand the complexity of the production and also to explain the different production steps and operations. Therefore, the section of the blueprints that was containing a three dimensional view of every part, was copied and modified in the Windows program Paint to show the part without any extra information, such as dimensions and angles.
4 Current state – description

This chapter presents the reader with a background for further reading; it presents the current state in the sense of what the organization looks like today. It includes a company presentation which explains the market, the products, the production planning, and the layout.

4.1 Company presentation

The information in this section is based on communication with employees at the different companies within the ROL Group, but also on presentation material provided by company representatives, material gathered at the Intranet and found on the official websites, www.rolgroup.com (ROL, 2010), www.rolproduction.com (ROL Prod., 2010), www.rolergo.com (ROL Ergo, 2010), and www.rolchectec.com (ROL Chec-Tec, 2010).

ROL started in 1985 as a product supplier to the convenience store industry and has since then evolved into an international provider of innovative retail solutions; a “premier turn key supplier of complete and complex solutions to the retail industry – integrating design, manufacturing, sales, and installation functions to meet the global requirements of the largest retail customers in existence today” (Hjelm, 2010). The company is currently one of the leading international store fixture suppliers. Further, ROL Ergo has focused on the market of height adjustable table stands.

ROL has during the years expanded from a small local company to a global group consisting of solid operating companies established in local markets. Today, the ROL companies together employ about 500 people.

Figure 4 Organization chart
As can be seen in Figure 4 the ROL Group has quite a complex organization structure with several branches in many countries. To add to the complexity, employees hired in ROL AB, ROL Project Support AB, ROL Retail Solutions Sweden AB, and ROL Production Sweden AB are all located in the same facilities outside Jönköping, and as the thesis work progressed, also the production parts of ROL Ergo was to be located in the same facilities.

ROL AB is the mother organization and employs staff within management, IT, and finance.

ROL Project Support AB is ROL’s internal consulting company which among others employs project leaders and constructors.

ROL Retail Solutions Sweden AB is the Swedish sales organization, which mainly is focused on constructing, projecting, and selling complete retail concepts as well as individual products for retail stores.

ROL Production Sweden AB produces sheet metal and tubular components both for external clients and for other companies within the ROL Group.

ROL Production Lithuania mainly produces tubes in different lengths. During the thesis work, some products have been moved for production in this facility.

ROL Ergo AB is developing and producing multifunctional columns; allowing furniture to be raised, lowered, and tilted. The most important product is the table stands with sit & stand function.

This report will be focused on the Production companies (see Figure 5), and more specific the Swedish production facilities; ROL Production Sweden AB and ROL Ergo AB.

![Figure 5 The part of the organization that is focused in the thesis work](image)

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ROL Production International AB has a clearly stated business plan which, according to the Managing Director of ROL Production International AB, says that the company “should deliver cost effective solutions according Group capabilities through world-class supply chain performance”.

4.2 The market

ROL is competing on a market with many competitors world-wide. Sheet metal products are often produced by a local supplier and can be find at most locations throughout the world. This means that to be able to compete on the global market a company needs to add something extra to its products, and in ROL’s case this additional thing is the design knowledge and the possibility to give the customer exactly what it wants; thus ROL is able to compete by producing customer specific products in small amounts to a variety of different industries.

“At the heart of ROL, people and technology come together to tackle complex retail challenges for regional and global clients. Since our inception, we have invested heavily in these key resources to deliver first class solutions to designers, retailers and marketers across diverse industry sectors.” (ROL, 2010)

4.3 The products

ROL Production Sweden produces a wide variety of metal sheet products. Many of the products produced at ROL Production Sweden are for ROL Retail Solutions and their retail concepts. The company has customers worldwide and often works in large scale products where it provides total solutions for many stores. The company has progressed from producing for the Fast Moving Consumer Goods (FMCG) sector to more high-end industries, such as cosmetic brands.

For UK’s leading health and beauty retailer, Boots, ROL in 2004 produced point of sales store fixtures for 610 stores to promote the brand No 7 (Figure 6).
For Chanel ROL supplied Duty Free units; unique and tailor made to fit the purpose of promoting one of the world’s most famous brands (Figure 7).

Figure 6 Point of sales unit to promote Boots’ brand No 7

Figure 7 Innovative store fixtures for Chanel
For the German pharmacy company Easy Apotheke ROL Germany has developed an entire store concept based on ROL’s standard system. The stores varied between 80 and 200 square meters (Figure 8).

In recent years ROL has also provided retail solutions for Esso and Chevron/Texaco, along with Swedish rental movie store Hemmakväll. Previously, and ongoing, ROL works and has worked with other companies within the convenience retail industry; Pressbyrån, Shell, and Agip, to mention a few.

Based on experience from the convenient retail industry ROL in the early 1990s approached the retail store industry. Within this field ROL designs and develops store concepts, as well as project manage and install them. Since 2005 ROL is a preferred supplier to the ICA Group, with retail stores in the Nordic countries (Figure 9).
Recently, ROL, together with some of its customers, has designed and developed a new range of checkout counters for supermarkets (Figure 10).

![Figure 9 Product stand at ICA](image)

![Figure 10 Checkout counter](image)
Furthermore, ROL has worked with the French fashion house Naf Naf, the international sport and fashion retail company Sport 2000, the specialist computer store chain PC World and PC City, and universities, public libraries, and banks both in Europe and Asia (Figure 11, Figure 12).
ROL Ergo produces a large variation of multifunctional columns. These can be used to adjusting height and tilting not only desks but also products like workbenches, sofas, and beds (Figure 13, Figure 14). Two of the customers for these products are EFG and IKEA.

Figure 13 Example from Martela

Figure 14 Example from Martela
4.4 Production

In general, the engineers and specialists at ROL have a deep knowledge in the production techniques needed to produce the wide variety of products that are being sold. However, the producing companies within the group cannot produce everything but there is a need to outsource operations associated with lighting systems, cash management systems, and some special surfaces.

The in-house production is focused on sheet metal products and components; robotic welding, bending, laser cutting, and powder coating.

4.5 Production layout

To simplify the understanding of the production process the layouts of the production facilities are presented in this section. For both facilities, ROL Production Sweden and ROL Ergo, the layout marked with the functional areas is presented (Figure 15, Figure 16).

More specified description of the layout and the functional areas is placed in chapter 5 to make the reading easier. However, it can be stated already here, that STOPA is the automated inventory that handles all the materials at ROL Production Sweden.
Figure 15 The layout marked with the functional areas of ROL Production Sweden
Figure 16 The layout marked with the functional areas of ROL Ergo
4.6 Planning and scheduling

All products that are to be produced are fit into the Master plan by the production planners. However, depending on which product that is being produced and who is the buyer; an internal or external customer, the production is differently planned. For minor projects and customized products the production is always performed based on customer order. When these customer orders are received the planner places the order into the Master plan, taking into consideration not only the production sequence and material usage, but also the specific customer’s requirements. Other production, for example high volume products and products in ROL’s base collections, is planned and produced based on a mix of forecast, customer order, and kanban; hence, a push/pull system.

How the planning and scheduling for the specific product, the table leg, that is explored in this report is handled is described in more detail in chapter 5.2.5 and 5.3.9.
5 Current state – analysis

This chapter describes the findings made at ROL Ergo and ROL Production Sweden associated with the production of the IZI table leg. It will thoroughly explain each work station, the findings made there, and the results from the discussions with the operators on site.

5.1 Introduction

The product, the table leg, which is examined in this thesis, is called IZI and is similar to the Ergo Drive 500/650 (Figure 17) which is part of ROL Ergo’s standard product range within the “Sit-and-Stand” concepts. It consists of a three-part column with the stroke of 500 or 650 millimeters. The lifting power is 100 kilo and the maximum speed is 40 millimeters per second. The table leg is part of the modular concept, which enables for both 2- and 3-leg frames. This increases the flexibility and makes the product usable for a wide variety of customers in a wide variety of settings. The table leg can be seen in Figure 18.

![Figure 17 Example of Ergo Drive stand](image)
The production of the table leg, from here on called IZI, starts at ROL Production Lithuania, where the metal tubes used for the leg are cut in the right lengths. The tubes come from an external supplier in Austria (Figure 19).

From Lithuania the tubes, three for each product, reach ROL Production Sweden and become one of the two main components along with the sheet metal. At ROL Production Sweden the sheet metal is punched or laser cut into four parts which are pressed, drilled, and bended. Hereafter, the parts are welded together, with each other and one of the tubes to become the house, before they are powder coated and shipped to ROL Ergo. Also the two remaining tubes are powder coated to get the same color as the house.
At ROL Ergo the house is put together with the two tubes. A spindle and a motor, together with plastic parts, are added to the product to enable for the table leg to be adjustable in height. This finished product, IZI, is packed together with sides, borders, and other accessories, and delivered to EFG, the customer. At EFG the product is packed together with other office furniture to be delivered to the end customer.

Based on findings in literature, the following description will start from the trigger point of the value stream. Since the product is produced based on customer order, the trigger point is at the customer EFG. Hence, the following description and analysis will start at the external customer and move upstream to the raw material entry point at ROL Production Sweden.

### 5.2 ROL Ergo

The starting point of the value stream is at the external customer, EFG in Tranås, the trigger of the production. EFG is an international company; one of the largest manufacturers of office furniture in Europe (EFG, 2010).

Every day, Monday to Friday, ROL Ergo delivers table stands to EFG. The product normally consists of two boxes (Figure 21, Figure 22, Figure 23, and Figure 24); one containing the accessories; the sides and stabilizers (boarders), and the other one containing the table leg and its special accessories; such as hand control and cables. Each box is already at the packing point at ROL Ergo identified to end up at one of EFG’s final customers. This means that EFG only has to add their own products (for example the table top and a chair) to be able to conduct their shipping of an office concept to their end customer.

At ROL Ergo (Figure 20, the same layout as shown in Figure 16) semi automated operations are conducted to mill the metal tubes and attach plastic parts to make the legs move in a smooth and coordinated way. Here are also the motor and the screwed spindle partly assembled, and assembled with the leg. The legs are finally tested to meet the quality requirements.
Figure 20 Layout marked with the functional areas of ROL Ergo
Figure 21 Modified blueprint of an example of a Foot

Figure 22 Modified blueprint of an example of a Boarder

Figure 23 Modified blueprint of an example of a Side support

Figure 24 Modified blueprint of an example of a Telescopic frame
5.2.1 Packing

The packing is performed at a work station where the operator works alone. A fixture is used to hold the corrugated board boxes in place while the parts are packed, and also to make the work easier from an ergonomic perspective. The fixture is movable between the two pallet racks that contain the parts to pack. The parts are placed in pallets with pallet rims on the floor and the inventory of each part is located higher in the same pallet rack. Due to the weight of the material the boxes become heavy and a vacuum lifter is used to move the boxes from the fixture to the finished goods pallet.

During the observations it was found that due to the location of the packing station, in the factory, the operator is exposed to a lot of interruptions by colleagues who pass either to start or finish their shifts, to go on break, moving to the offices, or just to stop and talk for a while.

Each order that is packed has to be registered in a shop floor computer. Since the products are packed directly for the end customer, many orders only contain one or two packages. This means that the computer registration is a non-value-adding task that is included in almost every cycle time. Due to the large need of computer access, one of the shop floor computers is located next to the packing operator. However, also other operators use the computer and surprisingly often the need for two or more operators to use the computer co-occurred, something that added waiting time to the already non-value-adding task.

Furthermore, a great part of the time spent in the packing station goes to wrapping of pallets and material handling. Since the products are heavy the operator cannot fill a pallet up to normal standard height, but has to finish at a height of about one and a half meter. This leads to frequently occurring changes of pallets. This task is not performed by the material handler, the supervisor, or the people working with shipments, but the operator has to drive the pallets to the wrapping station, located in a different part of the plant, wrap the pallet, and drive it further to the loading station.

Moreover, the refilling of materials, both from the positions higher in the pallet rack and from other parts of the inventory, if it is a part that does not have a frequent demand, is handled by the operator. During the observations the parts that were to be collected were not found right away and at several occasions, due to material problems with tubes along the entire value stream, the operator had to go straight to the previous operation, the Milling cutter, to find the needed table legs. This is something that further adds up to the non-value adding time at this station.

The production is initiated by kanban cards, but these are handled by the supervisor and not by the operator. The handling means that the card is not visually seen by the operator after it leaves the operator’s work station; hence, the operator has difficulties following the logic behind the kanban system.
5.2.2 Milling cutter

The station that is called the Milling cutter is operated by one operator and is semi-automated. To simplify the understanding of the somewhat complicated working procedures at this station, it is laid out in Figure 25, in a very simplified way that corresponds with reality only on the functional level. The station includes four internal work stations; one automated, the milling cutter, and three manual; hence, the three operators in Figure 25 only symbolizes the operator’s different positions during one cycle, hence, there is only one operator at the time running this station.

![Figure 25 Simplified schematic layout of the Milling cutter station](image)

In one cycle the house is first picked up by a robot from the House fixture, which has to be refilled manually, and placed in the milling cutter where the tool creates several deepenings. It is further moved by the robot to the first manual station’s fixture where the operator picks it and manually attaches plastic covers over the deepenings. Further, the operator places it back in the fixture and there the first tube is attached to the second one. In the next step the robot picks up the part and places it at the fixture at the second manual station where the two tubes are attached to the house. Also at this stage the operator performs manual tasks and then places the part back in the fixture where the functionality (extracting and compressing the table leg) is tested before the robot picks it up one last time to place it at the conveyor.
Current state – analysis

From the conveyor the operator moves the leg to the third manual station. Here the motor and the screwed spindle are assembled and tested. The leg is provided with a white paper cover, to protect it from scratches during transportation to the end customer, and packed on a pallet for further transportation to the packing station.

During the observations it was found that the machine constantly faces problems, both the robot and the milling cutter. This requires the operator to focus too much on the automated parts of the operations, hence, gets distracted from the own tasks and has to interrupt them to deal with machine problems. A lot of energy and time is put on observing the machine and adjusting its settings.

In this operation the machine is the bottleneck. If it works smoothly and without interruptions the operator has enough time to finish the manual tasks and also to refill material and perform other chores, like registering orders and clean. On the other hand, once the machine starts malfunctioning the operator has not enough time, hence, the machine stays idle in waiting for the operator.

The registration at the shop floor computer is not only used for new orders, but also to follow up on the operators working time. This means that whenever the worker changes the work task, for example from assembly to maintenance or cleaning, it is required to register this. This is a good system and a fine way of keeping track of the value-adding time, but in this case it is a time consuming procedure that further adds to the idle time since the operator needs to register every time a problem occurs with the machine, and every time the problem is fixed.

The operators at this station all use different tricks to fool the machine, primarily the robot, to believe that problems are fixed even when they are not entirely. This saves much time, but also jeopardizes the working procedures. Moreover, each operator handles the situations differently and do not follow the same work structure.

Every Friday, 45 minutes are spent on cleaning and maintaining the machine.

During the observations, it was discovered that the second conveyor, the one transporting the product out of the cell, does not start moving until the operator presses a key. This firstly leads to waiting time for the conveyor, before the operator has finished the tasks at the manual stations, and then to waiting time for the operator, since there is no point in moving away from the conveyor during the seconds it takes for the product to be transported.

5.2.3 Screwed spindle

The spindle assembly is a shared resource, which means that the spindles not only supply the IZI table leg, but also other products manufactured at ROL Ergo. The spindles can have different lengths depending on their stroke. The production of the double spindle for the table leg with a stroke of 650 millimeters includes nine assembly steps, while there are six assembly steps for the single spindle, used in the table leg with the stroke of 500 millimeters.
The tasks are, during a majority of the time, performed by two operators, and they are not balanced at all. There are severe problems in work division between the operators, mainly due to a poor layout (Figure 26) that makes it very complicated to fit two operators the way it is needed to make the production balanced. The number in the figure corresponds to the work tasks, in sequence, as they are performed. Due to the difficulties of fitting two people in the limited space, the tasks are often divided so that one operator only performs task 1 and 2, while the other operator performs the remaining ones, something that leads to overproduction in the first tasks. Also note that the operator performing the assembly of the motor is located in the same limited area, at the same work bench.

Further, not only are there problems with the quality of some of the components, but the refilling of materials is also associated with large stress to the human body, thorough its un-ergonomic positioning of inventories; often the components sits in pallets that are placed directly on the floor. Due to the limited production area, a limited number of components can be placed on the work bench; therefore, the operator has to bring material to the workstation very often. Refilling material and moving pallets around the workstation is a non-value-adding task that engages the operator a significant part of the total working time.
As at the other stations the production is initiated by kanban cards, and the supervisor is in charge of the production planning. This means that even though kanban is used, the operators are not directly connected to these, but they only get production instructions from their supervisor, who handles all the physical aspects of moving the kanban cards between the stations. At several occasions during the observations, it happened that the material handler, the supervisor, changed the production sequence with very short notice. This leads to an overproduction in the first production steps of the screwed spindle, the ones with shorter assembly time and performed by the operator with the least workload in the unbalanced production, and these half finished items stay idle until the next time there is a need for the spindle that needs them.

5.2.4 Motor

In the same way as with the spindles, the motor assembly is a shared resource. But in contrast to the spindle assembly, the motors are the same for all different table legs, regardless of the stroke.

At the motor assembly station, there are no complicated assembly tasks; the motor is picked from a box, a rubber ring is put on one spike and a circuit card is attached to its holder. Due to the simplicity of the tasks the cycle time is very short in comparison to all other operations at this factory’s value stream.

The short cycle time results in monotonic work procedures for the operator. Furthermore, the monotonic work is not only boring, but also increase the risk for work-related injuries since the operator sits in the same position for long hours. During the observation week the tasks at this work station were performed by an operator hired from a consultancy. This gave uneven results and very different work procedures, even by the same operator. Further, these work conditions put a lot of stress on the permanent staff.

Furthermore, during the observations it was discovered that the kanban cards were adopted in a confusing way. Instead of receiving kanban cards and producing accordingly, the operator went and searched for empty kanban bins, or for the ones that were half empty, to have something to work with. Additionally, even though, according to the kanban system, there was no need for more motors, the motors were still assembled and placed in temporary bins. This work procedure was motivated with the fact that the hired operator was paid per produced motor, and that there would always be a need for this product, but never the less, it lead to a large inventory of parts which were not needed at the time they were produced, leading to overproduction and waste.

5.2.5 Value Stream Mapping – ROL Ergo

As mentioned in chapter 3, where sufficient information is lacking in the map it is marked with a question mark.

At ROL Ergo (Figure 27) the planner receives a forecast from the customer, EFG. This forecast does not trigger any production; the production can only be triggered by a customer order. Normally ROL Ergo receives customer orders from EFG every day; these are collected by the planner from EFG’s MRP system.
There is a large deviation between the forecasted amount and the actual amount needed. On average the forecasted amount, from week 1 to week 23 year 2010, has been 482 stands, while the actual need, on average, has been 319 stands per week for the same time period. This means that the real demand only corresponds to 66 percent of the forecasted demand. Since a majority of the machines throughout the value chain are shared resources, and there is a great backlog, which has been existing during the entire observation period, this difference does not impact the machine utilization. However, to make the production planning more transparent and free up time to plan other production which is not run by kanban, it is important to, as far as possible, make the forecasts more accurate.

When the order is received the planner creates a work order for Packing. When the packing operator finishes one kanban batch of the stand he gives the kanban card to the supervisor who forwards it to the Milling cutter. The Milling cutter starts producing that kanban quantity and when the milling cutter operator finishes one kanban batch of the motors or the spindles he gives that kanban card to the supervisor who forwards it to the upstream workstations. When the operator at the Milling cutter finishes the ingoing product, the tube with house, from ROL Production Sweden, a customer order is placed from ROL Ergo to ROL Production Sweden.

In calculating the production lead time, only the longest of the times in inventory has been calculated. It is believed that this is the essential time to be aware of, since no finished product can come out of the parallel processes within a shorter time frame. For example, with this perspective, the time that the spindle stays in inventory is not important since it is a shorter time than the time that the motor pack is in inventory. The same goes for the processing time; the calculations have been performed with the longest processing times in the case when several processing steps occur simultaneously.

When it comes to the inventory after the Milling cutter, this calculation, 0.9 days, include both types of strokes.

Further, the inventory after the Packing is stated as less than one day since there are shipments to the customer daily; hence, a product is never waiting for shipment more than one day.
Current state – analysis

Figure 27 Value stream map – ROL Ergo

ROL Production
Sweden

Daily order

Common parts
suppliers

Production control

Packing

C/T = 361.1...

1

Daily order

Daily order

ROL Production
Lithuania

Weekly order

Daily order

Information flow

Material flow

Where the flows are
joined together

1.9 days

4.8 days

29.3 seconds

374.4 seconds

146.0 seconds

2 days

3 days

9.9 days

8.9 days

241.1 seconds

163.1 seconds

141.1 seconds

1.1 day

0.9 days

650

26

102

500

1

2

3

4

5

6

7

8

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5.3 ROL Production Sweden

At ROL Production Sweden (Figure 28 the same layout as shown in Figure 15) the production is triggered by orders from ROL Ergo. Every day, Monday to Friday, ROL Production Sweden delivers the house together with the tubes to ROL Ergo. The products are normally packed on pallets.

The production steps that the table leg follows are both fully automated and manual; some operations require the operator’s full presence while others can be run without any personnel involved. Associated with the table leg are the two tubes that are later assembled at ROL Ergo and only powder coated at this stage, they are not included further in this chapter. Further, and the parts of interest here, are the third tube, one plate (Figure 29), one cover back (Figure 30) and one cover front (Figure 31), together with one cover base (Figure 32).

Figure 28 Layout marked with the functional areas of ROL Production Sweden

Figure 29 The plate
The flow of material at ROL Production Sweden is not as easy to follow as at ROL Ergo. All the resources are shared with other products and product families, something that complicates the calculations.

The production of a table leg starts when the supervisor for the punching and laser cutter work group receives a kanban card from the welding station, which is the trigger point of the kanban system at this factory.
5.3.1 Painting

The painting is performed in a semi-automated painting facility, which sprays paint with powder coating. The products are hung on a 360 meters long conveyor, the hanging height is 180 centimeters, which means that the conveyor fixture is higher, but the possible spraying height is shorter depending on the position of the paint outlet and the size of the oven. The conveyor slowly, with a pace of 2.3 meters per minute, moves inside the painting station where the products are first washed, then painted, and finally dried. From a quick reference guide it has been found that the time to paint one table leg, that is, the cycle time if the conveyor is filled all way around with the same product, depending on the length of the product and the way it is currently hung, is 9.5 seconds. Each product needs the space corresponding to four hooks, with the space of one hook left between each product.

The station can handle all the colors that are used for ROL products, except the chrome, which is outsourced. Different painting boxes are used for different colors, or groups of colors, and therefore the conveyor has to stop while the boxes are changed. This work goes relatively fast. In order to be able to change the boxes a gap needs to be left on the conveyor when the color is changing.

The manual tasks at this operation consist of hanging products on the conveyor, and picking them down from the conveyor and packing them, divided into two separate stations along the conveyor. The work is labor intensive and demanding for the human body.

The operators working at the hanging station frequently stay idle when there is a need for a space between colors on the conveyor. The height of the conveyor, but more importantly the height of the pallets, makes the work procedures un-ergonomic, especially when packing. Further, the movements between stretching up to reach the products on the conveyor and bending down to pack them on floor level, is stressful for the back and will eventually lead to work related injuries.

The speed of the conveyor is dependent on the machines ability to paint with a sufficient quality; hence, it is not adjusted with respect to the working pace of the operators. Depending on which operators that work, during what time period of the day it is, and what else is interfering with the operators’ work, the pace of the conveyor is sometimes too fast. When this happens, the emergency stop is used. During one of the observations it was used so frequently that the operators at the hanging station staid idle for long periods of time or had to help out at the packing. The usage of the emergency stop also affects the products hanging inside the machine. Hence, the operators at the packing often become the bottleneck of the entire painting station.

The operators, especially at the hanging station, frequently move along the conveyor to adjust their work to the speed of the conveyor. If they fall behind due to change of pallets or registration of orders they have the possibility to move further down the conveyor and work faster to catch up until they reach their ordinary position. The possibility for these flexible movements is not as practicable for the packing operators due to lack of space and need for the pallets with finished goods to easily be transported away from the station.
The finished products are transported from the painting station, by the transporters, to the finished goods inventory, and once per day shipped to ROL Ergo.

### 5.3.2 Welding

At the welding station a robot is welding the parts of the table leg in three steps. There are two fixtures with three steps each, one on each side of the welding table, which enables the operator to load the fixture with components for the three welding steps on one side of the protective wall while they are welded by the robot on the other side. In the first step the tube (*Figure 33*) is welded together with the plate (*Figure 34*), in the second step the cover back and cover front are welded to the cover base (*Figure 35*), and in the last step the two parts from the first and second step are welded together to a finished product, the tube outer (the house) (*Figure 36*).

*Figure 33 The tube*

*Figure 34 First welding*
The components are placed in pallets within the production cell, behind the operator when facing the robot. Since there is no room for five pallets, which corresponds to the number of components, two pallets are placed on each other, overlapping, to enable easy access. The fifth component is manually brought, in small batches, possible to carry by hand, from a pallet standing outside the cell, to be placed in one of the pallets together with other components. The fixture that is used to hold the welded product when the plastic covers which protect the threads at the painting are attached, is located outside the cell, as an attachment to a pallet rim. Also the finished goods pallet is located outside the cell.

During the observations it became apparent that the testing station, where the angles are being measured to assure the quality level, is located away from the robot cell. This means that the operator cannot make the measurements while the robot works; the robot stays idle while the quality is controlled.
At some occasions during the observations the operator had to wait for the robot to finish its work. This implies that in the normal case the robot is the bottleneck and that the operator should have time to perform the manual tasks within the time span it takes for the robot to do the welding.

At a couple of occasions it happened that the operators did not finish the components of the pallet in the inventory with the least amount of parts in. Since the production at this stage is run by kanban cards, that means that more than one card moves upstream at the same time. This leads to scheduling problems upstream. The products are moved, by the operator, from the welding station to a WIP inventory next to the painting.

At several occasions during the observations, the operator was interrupted by colleagues. Some interruptions must be allowed, and they cannot completely be eliminated since the operators must have the possibility to ask each other for advices and help. However, it should never be allowed to interrupt an operator while he is setting up the machine. This time is always idle, and a clear waste, therefore every personnel has to be aware of the increase in waste it implicates when this time is prolonged.

In the evenings the operators of the welding machines are also responsible for the edging press robot. This means that the operator responsible for both needs to move through the plant to that robot, hence, leave his own welding robot idle.

When the product has gone through the three welding steps, and before the plastic covers are attached, the operator moves the product away from the fixture. This movement and the positioning of the product differ between all the observed operators. Some move the product directly from the fixture out of the cell to the plastic covering fixture, hence, take many extra steps. Others move the fixture an additional step and place it either in one of the pallets where the components are placed, or place it on the pole that holds the welding fixture. All positioning of the product are un-ergonomic and add extra waste to the procedures since it is moved in sequences. Further, due to the temperature of the product at this stage, the distance that it has to be moved should be kept as short as possible.

When talking to the operators about their work, most of them witness about a decrease in energy level throughout the day. The shifts are long and the work procedures very monotonous. Therefore, the operators say that they try to speed up their work as much as possible in the beginning of the shift, since they expect themselves to get tired and slower later during the shift. This information can be interpreted in two ways, either it is true that the tempo of the work decrease throughout the shift and then the way the operators reason is understandable, or, since the operators expect to get tired and slower, and since they work extra fast in the beginning, this results in a decrease in speed later on.
As with the computers at ROL Ergo, also at this welding station, the operator stays idle due to waiting time when registering orders. Further, due to the poor layout of the cell, every time the operator needs to refill material for one of the components, all the pallets have to be moved. This work is done by a help of a forklift, and there is always waiting time associated with locating and using these forklifts. Often the forklifts are not to be found within the welding area, but have to be collected elsewhere. This implies long times while the machine stays idle.

**An one day study**

Due to the information from the first observations, and after discussions with the Production Manager and the Managing Director of ROL Production International AB, it was decided to perform a one day study of the welding station. This study was conducted on April 20, from 8 am to 5 pm, with breaks of about 45 minutes in total. The results from these observations were added to the cycle time calculations already made.

It can be concluded after these observations that there are no standardized work procedures at the welding cell. Both the loading of material to the robot fixture and the movement of products, as previously described, differ significantly between the operators.

During the one day observations, the packing material (boards) needed to build new layers on the finished goods pallet was positioned relatively close to the cell; closer than during the previous observations. However, the quality control place, where the angles are controlled, was still positioned at some distance from the cell.

The quality control performed by the operators at the station differs; especially the control of the welding seams. For the operators that control very thoroughly, it is sometimes problematic to work as fast as the robot; hence, there is a risk that the operator becomes the bottleneck.

During these observations it was found that the robot has to be cleaned at every 50th product, which had been missed in the previous observations. This cleaning takes between one and three minutes and leaves the operator idle.

**5.3.3 Edging press**

At the Edging press both the plate and the cover base are being processed. The procedures look similar for both products; the materials that come from the punching station are placed to the left of the operator and the finished product pallet to the right. The press is programmed for the specific product and the operator needs to move the product towards the tool in a predefined sequence to get the angles at the right positions.

The operator picks up the products at the WIP inventory located between the edging press and the excenter press, and that is also where the operator places it back after it has been processed.
Due to the short processing time of each product, it is not useful to produce entirely in one-piece flow; bringing one product from the left pallet, processing it and place it in the right pallet, the movements would take too large part of the entire cycle time. Therefore, the operators create batches within the batch; bringing a small amount of material to be placed at the bench on the machine, processing, and placing the products back on the bench, before moving the small batch to the finished goods pallet. By doing so, the cycle time can be kept shorter, and the movements are decreased, saving time and energy.

The work is quite monotonous and could bring stress on the shoulders and back if performed during long hours. The most stressful task for the operator’s body is to fill the pallets when they are close to getting full. They are from the beginning standing on a wagon which is not adjustable in height. This is good when the first couple of layers are placed; it prevents the operator from having to bend down to floor level. However, when the pallet is two and three pallets rims high it becomes un-ergonomically high for the operator to work in that position.

5.3.4 Excenter press – pounding

At the Excenter press workstation, two different tasks are performed, the pounding and the stamping.

At the excenter press punching hank clinch nuts are pounded into the holes created at the punching station and in the laser cutter. The products associated with these procedures are the cover front and the cover base.

In the same way as at the edging press, the products are handled in small batches, to decrease the cycle time. Further, in the same way, the products are picked up at the same WIP inventory and placed back there after being processed.

The hank clinch nuts are not positioned close to the machine, but have to be collected in a pallet rack quite far away from the machine, this increase the waste at the station.

5.3.5 Excenter press – stamping

The stamping is performed on the cover front and marks it with the EFG logo.

In the same way as the other stations with short processing times, the work is done in small batches, which are placed on the small flat area on the machine. The inventory has the same location as the previous stations.

5.3.6 Drill

In the same work area of the factory as the excenter presses are located, the drill is placed. At this station the plate is processed to create threads in the four holes already produced at the punching station.

As for the edging press and excenter press, the packing and refilling of materials to the machine are done in small batches, and the inventory has the same location and is handled in the same manners.
5.3.7 Laser cutter

At the Laser cutter the cover front and the cover back are being produced.

The machine is automated and the only manual work is to start the work from the computer, inspect a product from the first sheet, and load the products in the finished goods pallet.

The machine gets the metal sheet from the STOPA inventory automatically; the sheet is fed into the cutting area, the laser cuts the products, and the entire sheet is moved out of the machine to the table where the products are collected by the operator.

The procedure of emptying the sheet of all the products and place them in the finished goods pallets is called to plunder. It is a heavy job, where the sheets are shook to release the products, and then the products are collected manually and placed in a pallet at floor height. This task is performed because the part of the machine that is supposed to do the same task does not work properly with small pieces.

After the plundering is finished, and while the machine cuts new parts, the operator transports the product to the WIP inventory between the excenter presses and the edging presses.

There are many problems with the laser cutter, even though not occurring during the observations, it has to be brought up that the machine often stops due to problems. Since the grid which the sheet is placed on has large spaces, it happens that the parts that have been cut falls down half way and becomes a hinder when the laser head moves over the sheet.

5.3.8 Punching

The Punching is conducted in an automated Salvagnini machine. Metal sheets are picked up by an Automated Guided Vehicle (AGV) in the automated STOPA inventory and placed in position in the storage place inside the machine. When the previous work order is finished (and if no tools need to be changed) the machine takes one sheet at a time, feeding it into the punching position and fixes it there. The machine tool consists of 66 dies and cushions. The plate and the cover base are produced here. The finished products fall down in a gap under the tool and are transported on a conveyor to fall down in the finished goods pallet. The pallet is transported by the operator to the WIP inventory between the edging press and the excenter press.

The problems of emptying one kanban batch at the time at the welding station become evident here. During one of the operations two kanban batches had to be produced at the same time to fulfill the needs downstream.
There are some problems at the welding station that are not directly related to the
machine but to the AGV and STOPA. The automated inventory is programmed
in such a way that it always picks up the pallet with the least amount of sheets
first, independent of the size of the order. This implies that a pallet with only one
sheet on it can be collected even if five are needed for the order. This is a good
system in that sense that it prevents the inventory positions to be full of small
amount of sheet, however, in this case, dependent on the AGV, it is a large
problem.

The AGV is very slow in its movement, it has to to ensure that the sheets are not
sliding of in the corners, therefore it takes long time to go and get the material
from the STOPA and bring it back to the machine. This adds to the waste,
especially if this movement has to be performed several times during the same
order due to small amount of sheets on each pallet.

As the situation was during the observations, waste is further added to the
process, since the AGV does not move to refill the materials until the previous
order is finished. This means that the machine stays idle while the materials are
collected, something that, depending on the queue of the STOPA and the
movement of the AGV, can take very long time.

In the machine, under the tool, the products fall down on a conveyor, this
conveyor is not the original one, but a temporary solution constructed on sight.
Since the conveyor do not have any edges some products always fall off and land
under. Therefore, at least in the end of every order, the operator has to turn of the
machine and crawl in and under to pick up those products. Further, when small
parts are being produced, they are mistaken for waste and end up in the waste bin.
This means that in addition to crawling under the machine to find parts, the
operator also has to go to the other side of the machine and locate the good parts
in the waste bin.

During one of the observations problems occurred that revealed information
about the tool organization. The idea was to measure the cycle time, but the result
was a study in what happens when the machine breaks down. After locating the
problem the operator had to search at two locations at the work station, and one
location next to the offices, before finding the right tool. The tools were found to
be much unorganized and not marked in a correct way, wherefore the search took
much longer time then necessary. The search took at least one hour, something
that adds a lot of waste to the process.

**5.3.9 Value Stream Mapping – ROL Production Sweden**

As mentioned in chapter 3; where sufficient information is lacking in the map it is
marked with a question mark.

At ROL Production Sweden (Figure 37) the planner receives a forecast from ROL
Ergo, based on the forecast ROL Ergo has from EFG. This forecast does not
trigger any production, but the production can only be triggered by a customer
order. Normally ROL Production Sweden receives customer orders from ROL
Ergo two times per week.
When the order is received the planner withdraws the quantity from the kanban inventory located right before the Painting. The Painting can never start before a customer order is received; hence, there are no downstream inventories from this point. In this kanban inventory there can be a maximum of 1040 unpainted products, and the order point is 560 products. This means that when the level goes below 560 products, a kanban card triggers the production at the welding station.

To schedule the Painting of this specific product, the Tube with house, the planner fits it into the Master plan. This has to be done since the Painting is a shared resource and not all the products produced are run by kanban.

When the welding operator finishes one kanban batch of any of the components he gives the kanban card to the supervisor of the Punching and Laser cutter. At ROL Production the stations in between these are seen as one closed system, a line with internal buffers in-between. Therefore the kanban card does not go from the Welding back to the immediate upstream operation, but to the starting operation from where it is pushed back to the Welding.

In the same way as the planner for the Painting needs to fit the kanban quantity into the Master plan, so do the supervisor of Punching and Laser cutter. This means, due to long set-up times, that when a kanban card arrives to the station, it can happen that it has to wait for some days before that part can be produced.

When the Punching or Laser cutter uses material, sheet metal, from the STOPA inventory, an order is placed to the supplier, the same goes for the Hank Clinch Nuts used at the Excenter press and for the Tubes at the Welding station.
Figure 37 Value stream map – ROL Production Sweden
In the same manner as with the Value Stream Mapping of ROL Ergo, the production lead time and the processing time were calculated according to the longest time in those cases were several steps could occur simultaneously. Due to the increased complexity in mapping the production at ROL Production Sweden, the map is also more complicated to understand. The process steps before the Welding, the Punching, the Laser cutter, the Excenter press, the Drill, and the Edging press, are divided into the different components they produce, hence giving four horizontal lines. Each horizontal line represents a product and each vertical line represents a work station, for example, both the Cover Back and the Cover Front are processed in the Laser cutter, but only the Plate goes through the Drill. The product with the longest processing time is the Cover front, and therefore that processing time is included in the summary at the bottom right corner.

For each of these four products the inventory seems empty at the map until they reach the last supermarket location right before the Welding. This is not true in reality, but since ROL considers all the production steps before the Welding to be one cell and do therefore not keep track on the inventory levels between each of these steps, the inventory that on the map looks like it is located before the welding might just as well just have come out of the punching machine.

The Painting is difficult to grasp in the map, and the reason it looks like it does is because what was considered essential during the observations was to measure the manual time; the time when the workers handled the product. The conveyor has a predefined cycle time, 9.5 seconds, hence; that time is just included in the map based on secondary data. Therefore, to be able to capture the manual handling, it became necessary to divide the Painting station into three sequences.
6 Analysis

This chapter presents a general analysis of the current situation at ROL’s Swedish production facilities; it summarizes the analysis from the work stations at the two factories and the value stream mapping, but also takes a broader perspective on the organization and its communication.

6.1 The value stream maps

As can be seen in the value stream maps in sections 5.2.5 and 5.3.9 the production at both ROL Ergo and ROL Production Sweden has quite complex production processes, even though, as also can be seen by analyzing the maps, the flow at ROL Ergo is much easier to follow and keep track of. What makes the situation even more complex when looking at these specific value streams is that a majority of the resources used are shared with other products and production families, where a majority of them do not use kanban system but more traditional production planning. Therefore, even if the capacity is enough at the moment for the product looked at in this research, there is nothing that says that there will not be a lack of capacity due to an increase in sales of other product groups. Further, dealing with the shared resources in this case make it very complicated to create value stream maps that can be seen as good grounds for analysis and creation of future state maps. No one at the company, in a planning or operational position, knows what the actual capacity is, neither do they know how large percentage of that capacity that is dedicated for the IZI table leg. This leads to a very problematic planning that would be easier to handle if there was a true kanban flow of all products.

What can be concluded, based on the somewhat unfinished value stream maps, is that a very small fraction of the production lead time is put on the actual processing of the product. If the production at both facilities is summarized, it takes 16.7 days for the customer to receive a product that takes less than 18.5 minutes to produce. Hence, there are very good chances for improvements of this value stream.

What also can be seen at the maps is that there is no balancing of the production; the different stations are using between 5.1 and 361.1 seconds to complete one production step. To be able to create flow, it is essential to create balance between the different steps; there is no need for such rapid steps as 5.1 seconds if those work tasks cannot be combined with others. It only means that while packing one product more than 70 products can be stamped. If the resources were not shared, so that the operator performing the stamping had other products to work with, there would be a massive inventory created, and that is the reason why kanban cards are used in the current state; to control overproduction.
6.2 The lean implementation

It can be concluded from the current state observations and the current state value stream maps that ROL is doing many things right in their lean implementation. They have introduced some lean tools and are on the way towards the transformation into lean; they use kanban cards, they use scoreboards and have work teams which meet at every shift change to go through the happenings of that day.

6.2.1 The kanban system

However, based on the findings, there is a risk that ROL will become one of those companies that implement the tools but do not get the big picture, like both Womack & Jones (1996) and Tapping et al. (2002) are talking about. There is evidence that the operators, neither at ROL Ergo, nor at ROL Production Sweden, understand where the tools they are using come from or what their purpose is; the operators at ROL Ergo do not have a visualization of the kanban system since they only hand the cards over to the supervisor and get the material fed back by the same person. In the same way the operators at ROL Production Sweden have difficulties in seeing the big picture; if they fully understood the logic behind the kanban system they would never attempt to empty several kanban batches at the same time, something that brings the entire system out of balance.

6.2.2 The layout

One clear hindrance to the flow within, and between the factories, is the current functional layout. As can be seen from the description of the work stations, significant amount of time is put in transferring materials, organizing materials, and keeping track of materials, time that now is pure waste and which could be used to create value instead. Not only does the current layout make the material handling more problematic, it also divides the workers into functional groups instead of groups that belong to a product family. This makes it more difficult for the individual worker to see the value that the operator creates in its context, something that makes it more difficult to feel pride in the work performed and also to be able to see the causes and effects of the own actions.

6.2.3 The registration system

Some of the tools that ROL has implemented to make the processes better; for example the computerized combined inventory and working hour system where each worker is responsible for registering the order he or she is working on, registering when material is moved from inventory to work station, and also to registering what tasks are performed when, sometimes complicates the work and put stops to the flow. The system of registering everything is good for the purpose of keeping track on specific products and to get a clear picture of what tasks are performed and in addition, whether or not those tasks are value adding, but when the system that is supposed to register this in itself, due to the process of registering, create waste, there is a need to look into how to simplify and improve the system.
6.2.4 Transparency and communication

Further problems with the companies’ way of implementing lean are related to the transparency. As the situation looked during the observations it was impossible for the workers to understand whether or not the management was following any specific predefined sequence in the transformation work. If there is a sequence of implementation steps, it is on the top management level, and there is no transparency downwards in the hierarchy. Transparency, a clear structure, and following of predefined steps are some of the core aspects that need to be in place to make a successful implementation. There are indicators that ROL does not have these core aspects.

The communication in the organization is, even though this is a relatively small medium-sized company, somewhat hierarchical. The workers have good ideas, many of them which became apparent during the observations, and possess great knowledge in the separate production steps. Also the management, as it has been perceived during the time spent at the company, possess deep knowledge, especially on the strategic level, but in some way there is a gap between these two levels. It could be that there are boundaries that are difficult to realize when not being part of the organization, but it can also be that there is not really any forum for discussions and exchange of knowledge. Even though the different teams meet at least once per day, both at the functional level and at management level, the knowledge transfer between them seems to stop somewhere. It could be related to the effects of the financial crisis, occurring prior to the studied period, and whose aftermaths were still present; many people had been laid off and people could be having a feeling of hopelessness.

Furthermore, there is a clear deviation in the work procedures and mentality between ROL Ergo and ROL Production Sweden. It cannot be said that one of them is better than the other, but in order to create a smooth flow that goes all the way from the Austrian supplier to the end customer of EFG, it is a critical first step to make the transference between the two internal companies as smooth as possible. There is a need for a coherent system in communicating with the workers, and in work organization.
The transfer to a single piece flow and dedicated work teams with a high degree of transparency is far away for ROL. Not so much because the organization will be difficult to change; with the right people at the right positions it can be done, but more importantly because the right-sizing of the tools will be very problematic. During the past years ROL has invested heavily in automated systems, where several of them have a questionable performance level according to the observations made in this research, to shorten the production time for large batches of products. However, due to long set-up times and complex material feeding these machines are not flexible enough to provide the right quantity for a smooth flow of product families. This means that in order to completely transform to a lean production environment the tools need to be changed to more dedicated, smaller, tools that are able to be located in sequence with the other production steps of the products within a product family. This is a transformation that will take a lot of time, and to justify it financially there is a need to come up with an alternative solution for the large automated machines that are already in place.
7 Improvement suggestions

In this chapter the improvement suggestions for the researched company are presented. They cover both very detailed suggestions as well as suggestions on a more general level.

7.1 Structuring the transformation

The first suggestion can be seen as a global suggestion for both factories, and maybe also for the entire ROL Group, and is related to the structuring of improvement efforts. Based on the studied literature and on the current situation in the observed locations there is a need for a clear transformation structure. In order to succeed with the change management and stay competitive in the global market it is important to decide what approach to have. It is recommended to follow the proved sequences of steps presented in the theoretical background, but most importantly is to follow a structure, stick to that structure, and communicate it clearly to the workers. It is essential to appoint one person responsible for this change management; a change agent. The best thing would be to choose a person from within the company that already has insight in the processes and the work procedures, but in doing so it is crucial to give that person the management support and the sufficient time to be able to perform these transformation tasks.

When implementing lean, it is important to have everyone on board, therefore it is not only the workers associated with production that need the education and training but also all other employees within the organization. In order to go lean, everyone must understand the principles and what the organization is striving for; understand the common goal to eliminate waste in every step of every process.

7.2 The work stations

This section presents the specific improvement suggestions related to the work stations.

7.2.1 ROL Ergo

When it comes to the observed work stations there are some improvements that can be made right away to ease the work and eliminate the first most obvious waste while the transformation is taking place. Related to the Packing station at ROL Ergo is the problem with the operator being interrupted by colleagues. This can be improved by moving the packing station to a location which is not so frequently trafficked or to put up some sort of shields. The shields will complicate the easy access to the packing operator. Important to keep in mind is to make the shielding as transparent as possible to prevent that the operator feels shut out from the rest of the factory floor and also to enhance the transparency throughout the value stream. Further problems in this station are related to the ergonomics. Even though there is a vacuum lifter to use for the heavy lifts of the boxes, not all operators use it. Further, the packing height is too high for many of the operators, even though the height has been decreased as a consequence of too heavy pallets. Working over shoulder height as frequently as at this station is un-ergonomic and will in the long run cause work-related injuries.
Improvement suggestions

Concerning the work station with the Milling cutter, valuable time, that now is pure waste, would be saved if the conveyor bringing the product out of the machine could start moving based on a sensor, instead of a press of a button. In addition, it would be beneficial for this station if the operations could be more balanced. As the situation is now, station 2 stays idle while waiting for the operator to finish the manual tasks at station 3, and the operator has to wait for both station 1 and for the conveyor.

The station where the screwed spindle is being produced needs to be addressed; to create flow and increase the value-added part of the production time, the layout needs to be changed. During the thesis period this work was done; the cell was rebalanced in theory and some of the changes were implemented in practice. Most likely, a full implementation of a balanced cell would lead to the elimination of one operator, or to the possibility of increasing production volume.

In general, at ROL Ergo, it would be beneficial for the workers, as well as for the organization to introduce work rotation. Many of the tasks are monotonous and in order to stay healthy it would be valuable to change tasks often. If separate production lines were created for each product family, the workers could be given the opportunity to change between tasks several times per day. This would not only increase the work satisfaction for the workers, in making them feel more involved and knowledgeable, it would decrease the risks for the organization, in case of workers resigning, getting ill, going on parental leave, or any other issue that can occur that make them incapable of performing their work tasks, there is a built in flexibility in the work rotation system that makes the process much less vulnerable.

Further, and not only at ROL Ergo, but also at ROL Production Sweden, there is a need to change the registration system. To decrease the time waste it implies when every operator registers every action it could be useful to implement an easier way of doing this. For example, a good way would be to have a scanning system when inventories are relocated and to monitor the workers’ times by systems with easier access.

7.2.2 ROL Production Sweden

One of the most labor intensive and un-ergonomic work stations at ROL Production Sweden is the Painting; hence, here is room for many improvements, where most of them can be done by very easy means. Since the operators at the hanging station move a lot back and forth along the conveyor there is a need for a carpet that is longer than the current one and which follows the turns of the conveyor, to enhance that the workers always are able to stand on it. Further, it would be preferable to move the packing station to the long side of the conveyor where there is more space for the operators to move and where the two stations, hanging and packing can be next to each other, increasing the flexibility and possibly decrease the number of people needed. Moreover, a change of the pallet set-up would be valuable for the workers, to enable for the pallets to be lowered down and raised up would keep a constant work height; hence, decreasing the risk for work related back injuries. It would be preferred to be able to lower the pallet fixture down into the floor to enable the passage of the forklifts in the same area.
**Improvement suggestions**

During the observations made at the Painting station, it was found that the two shifts observed work with very different pace. If this is a stable state, and not only present during the relatively short time that the observations were executed, it could be beneficial to mix the workers on the two shifts to reach a more even productivity level.

Related to the technical specifications of the conveyor, there are several improvements to be made. For example, if the speed of the conveyor was decreased, it would be possible, with special hooks, to at least hang two products on the same hook, since the product only is 566 millimeters long and the available hanging height is 1800 millimeters. Also, if the products were turned so that the short side, 131 millimeters, instead of the long side, 296 millimeters, was facing the painting outlet, it would be possible to fit two products at the same conveyor length as one in the current set-up. Combining the two improvements, hanging the products on the short side and two on each hook, would increase the hanging possibility to 452 percent. Even if the conveyor was slowed down to half the speed this would increase the productivity to 226 percent, an increase by 126 percent if the current approach is seen as 100 percent.

At the Welding station, several improvements can be suggested. If the pallets holding the components could be changed to smaller bins, the operator would have easier access to the material and the freed-up floor space could be used so that the fixture for attaching plastic covers could be moved within the cell, along with the finished goods pallet. This would enhance the workability within the cell; increase the productivity, and many un-ergonomic, un-necessary, movements would be eliminated.

Throughout the plant at ROL Production Sweden, but also applicable for ROL Ergo, it would be useful to implement a kanban system for empty pallets. This would increase the productivity primarily at the welding robot cell since these operators are the one that spend the most amount of time on searching for empty pallets to place the finished goods on, but it would also give the workers at the other station easy access to empty pallets and the time spent in total on searching for them throughout the plant would decrease significantly. Further, this would decrease the usage of forklifts, and make the forklifts accessible for the workers that really need them to transport heavy loaded pallets.

The accessibility of the forklifts throughout the plant is a problem; the amount seems to be right-sized, but the forklifts are often used in situations where they are not really needed and then not returned to the area where they were first collected. One solution to this problem would be to have a predefined parking place for the forklifts; the operators pick it up there when they need it and immediately put it back at the same place after usage. Furthermore, the usage of forklifts could be decreased if the bins of components where smaller and placed closer together, with a layout with easier access.

During the observations of the Welding station it was found that the workers believed themselves that they try to work faster in the beginning of the shift, since they feel that they get more tired and slower later during the shift, both for morning shifts and afternoon shifts. Even though this behavior only was
confirmed by the workers at this station, it is likely that it works in the same way at other locations. No matter what the actual reason for this behavior is, if it is the workers own perceptions or if it is based on incentives from management, it is important, both for the quality of the product and the health of the operators, to try to keep as even speed as possible throughout the day. This can be enhanced by dividing the large orders into smaller batches so that the operator easier realize if he produce according to the predefined hourly amount or not. Further, it could be useful to use some sort of load-leveling system, for example a Heijunka-box, to keep track on the production rate.

At some occasions during the observations, the operators at the Welding station had problems with programming the robot. There seems to be a need for more thorough education of all the operators. Making sure that all operators keep a high knowledge level on every aspect of the operations they perform increase the flexibility and productivity; if the operator himself can solve the problems without involving other people, these people can keep working with their own tasks. To solve these types of problems, ROL adopt a system with supervisors at every work station, but during the observations it was more frequently occurring that the fellow colleagues were helping out than that the supervisor was; hence if this system is to be successful there has to be a clear definition of roles and responsibilities and the best thing would be if it could be possible to implement an andon system where the supervisor has the role of helping out at any time.

At the Punching station the most urgent problems are related to the AGV, and its work procedures. In the current situation a lot of time, pure waste, is spent on moving the material from the main inventory, the STOPA, to the loading station at the machine. As long as the inventory is set up in this way this movement needs to take place, however, to decrease the waste the sequence of the movement needs to take place in such a way that the AGV is refilling materials for the subsequent order while the present order is still processed. As it works in the current state, the machine stays idle for long periods of time while waiting for the AGV.

### 7.3 Suggestions on a general level

As has been mentioned in chapter 6, the kanban system needs to be communicated to the workers. The change agent, along with lean experts, should teach the workers not only about the specific tools, but also about the theories behind them and how it all fits together into a lean production system.

Since ROL already has started its transformation towards lean, the need in this stage is for structure of that work. It is done by appointing the change agent and the team and by educating the entire staff on what changes that will come. Based on findings it is essential to start working with 5S, some of the improvement suggestions in this chapter can be seen as first steps of such an implementation. 5S is important to clarify the work structure, and to make the waste more apparent for the workers at the shop floor. Further, when working in a clean and organized environment, the productivity increases and the tasks become easier to perform.
It is important to communicate what the overall long-term plan for the company is, and how it relates to each individual worker. Even though the workers do not need to have detailed understanding in all aspects of the transformation work, they need to have a general idea of what is happening and approximately when it is to happen.

As a next step for ROL, it is advisable to perform an AVIX analysis of the welding and the painting, the two operations with the most man intense work. AVIX is a computerized tool that helps to perform method- and time studies (AVIX, 2010). This would give a clear visualization of the value-adding time, and identify the waste in the operations. This analysis could also be adapted to the operations of pressing and drilling. Further, it is suggested to start with the future state maps and make sure to not get stuck in planning procedures, but actual focus on execution.

As a long-term improvement suggestion, the production, at least of the table leg, would benefit from a strict one-piece flow, or a flow with small batches, preferable with a layout where all the steps are visible for all the workers working on the product, and where the legs are produced separated from the other product families. This would mean that the factory has to be rebuilt and that the production at ROL Ergo should be co-located with the production at ROL Production Sweden; the machines need to be changed from large automated producers of large batches, to more product-specific, dedicated machines that are located on the line.
8 Discussion and conclusions

This section ties together the thesis work; it brings together the research questions with the findings and analysis, it discusses the chosen methodology and the results, and concludes the work.

8.1 Discussion of method

8.1.1 Reliability

Williamson (2002, p. 128) defines reliability as "the stability, consistency and dependability of measures". This means that the same result shall be given, if the analysis is conducted in the same way again (Williamson, 2002).

High reliability in quantitative work is almost always easier to achieve than in qualitative work. Since this thesis can be seen as a combination of both, it should be possible to keep the reliability relatively high.

When it comes to the measurements of cycle times they are believed to have a high reliability and if measured again similar results can be expected. However, since the measurements were conducted, the production layout has been changed to such a great extent that the same measurements cannot be performed.

Related to the qualitative work, which basically are the discussions with the workers during the operations and the continuous dialogues with management, the reliability is more complicated. It cannot be assured, or even expected, that people will say the same things or perceive the situation in the same way as they once did. Also with regards to the qualitative work, it can be assumed that the major changes to the processes and their layout have had a great impact on people's perception of the situation.

8.1.2 Validity

Williamson (2002, p. 128) describes validity as “the capacity of a measuring instrument to measure what it purports to measure, or to predict what it was designed to predict; or, the accuracy of observations”. This is related to whether or not the result is showing what it is supposed to show and if the right parameters have been analyzed. There is a difference between internal and external validity; internal is related to whether or not the result is a result based on chosen variables or if it has become influenced by unknown factors while external is related to if the result gives a possibility to generalize, that is, to apply the same result to other populations (Williamson, 2002).

The validity of this thesis work can be seen as moderate. Due to the complexity of the value streams and the difficulties in gathering and analyzing information, it cannot be said that the value stream mapping completely shows what it was supposed to show; there is some information lacking. However, from a general point of view, the overall result from the analysis of these complex streams can be seen as satisfactory.

Related to internal validity, it is inevitable that the result has been affected by other factors. The cycle time, for example, has been measured at the actual location where the tasks are performed and is therefore to a great extent influenced by outer circumstances.
The results of this research does, as mentioned earlier, give a limited possibility to generalize; hence a relatively low external validity. The possibility of generalization is larger for other populations within the same organization; other product families, than it is for populations outside this specific company.

8.2 Discussion of findings

The purpose of this thesis work has been, as identified in 1.3:

- To map the predefined value stream.
- To identify improvement areas.
- To find out how this knowledge can be used at other companies.

The first task, to map the value stream, which was already defined by the company, has been accomplished, and the work of that can been seen in the analysis. The improvement areas have been identified and presented thoroughly. However, due to complexity and difficulties in information gathering, the mapping is not as extended as it was supposed to be from the beginning and therefore the improvement suggestions that are presented are to a larger extent than what was the original idea based on the qualitative data instead of the quantitative derived from the maps. It does not mean that the result is of less value, but it is of a different character and therefore more subjective than intended.

When it comes to the applicability to other companies, this is described in the last chapter. However, it needs to be emphasized that a work with such a specific focus as this thesis work never can be completely applicable to any other organization. What can be used is the conclusions drawn from the procedures with which this work was performed and, as with any thesis work, suggestions made here, can often be modified, and rebuilt to fit other companies.

It is believed, that reading this report can be an initial step for other organizations to go further in their own transformation process. The literature review, along with the methodology can be a hint of what approaches that work and what can be done in another way, further; the conclusions made here can be a trigger to start the work of change.

8.2.1 What could have been done differently?

First and foremost it is important to stress the need of a team when mapping value streams. If the work was to be done again, it is highly advisable to not do it as a one person job. Partly because there are massive amounts of data to gather and keep track of, but more importantly because the level of the analysis and the possibility to capture different dimensions of the same problem clearly rises when more people are involved. Further, it is advisable to let people with a thorough understanding of the organization to perform similar tasks. In this research, significant amount of valuable time was spent on understanding not only the structures and procedures, but also the social codes and corporate culture.
8.3 Conclusions

ROL Ergo and ROL Production Sweden are in the transformation phase towards becoming lean. Many of the improvements that are in place are functioning well and are improving the company’s capability of keeping its position in the global market. However, based on the findings from extensive observations it can be concluded that the company has a lot of work left before becoming lean.

The largest problem has to do with the communication between management and lower hierarchical levels; including both how management communicate their long-term change plans and the strategies behind these changes, and how workers communicate improvement suggestions and reflections back to management.

Even though, at the current state, the company is working with kanban, it is only implemented for certain product families and therefore makes it difficult to get a clear picture of the entire production and its planning. The kanban system would benefit from being implemented throughout the entire production and also from being applied to a future production system where the workers, who have the immediate contact with the products, are responsible for every aspect of the kanban system and have deep knowledge and skills in how this system works. Further, it would be beneficial for every aspect of the production if it could be brought together in one location where it has the cell layout with smaller, more dedicated machinery and multi-skilled workers.

8.3.1 Suggestions on further research

For further research in the area two different dimensions are interesting. The first one is internal and related to this specific company, while the second one is one a general level.

Suggestion on further research within ROL is to analyze the production system, which was implemented shortly after this research period, in a similar manner to the research presented in this report and to compare the differences. Even though this study is not comprehensive there are parameters that can be compared and evaluated. Also, it would be interesting to perform similar measurements on different value streams that go through the same facilities.

On a general level it is advisable for further research to focus on lean implementations in SMEs. Does this specific research object represent a particular complicated set-up, or is it so that the tools identified by the literature are more suitable for larger companies. If that is the case, can changes to the tools, or even new tools, be developed based on further findings?
Applicability for others

The findings in this thesis work are highly related to one specific company and its specific conditions and situation. However, many of the issues brought up, both in the analysis and in the improvement suggestions, can be recognized by many companies in different sectors.

In general, performing a value stream analysis, mapping the current state, and based on that, transform the organization into a lean enterprise, is something that many companies, especially in a high-cost country as Sweden, have to pursue within a not too distant future to maintain competitiveness on the global market. This means that the steps performed and described in this report can be copied and applied to nearly any type of production system.

What can be concluded from this specific research is that the value stream mapping often is much more complicated and difficult to perform than what it appears to be at first. It is very important to follow the suggestions by literature to be a team to perform the observations and also to do it rapidly, even if it seems like impossible to perform it in one day.

Further, the most important lesson that can be learned from this work is that communication is as important as literature says; when management do not communicate what is intended to happen and what the plan looks like, they do not only get a work force that is anxious and worried; hence perform poorer, but also they create a business climate that is the opposite of what is needed to make the transformation successful. There is a need for an open, joyful atmosphere where people feel included and are happy to come with suggestions of improvements; since they feel respected and listened to.
10 References


Vink, P.; Stahre, J. (2004) Human factors research to increase manufacturing productivity and innovation


11 Appendices

Appendix 1  Value stream mapping symbols,
            retrieved from Rother & Shook (2003, book cover)
Appendix 2  Excel sheet from the Welding station
Appendix 1

MATERIAL FLOW Icons

- **ASSEMBLY**
  - Manufacturing Process

- **XYZ Corporation**
  - Outside Sources

- **Data Box**
  - Inventory

- **Mon. + Wed.**
  - Truck Shipment

- **PUSH Arrow**
  - Finished Goods to Customer

- **FIFO**
  - First-In-First-Out Sequence Flow

- **300 pieces 1 Day**

GENERAL ICONS

- **Kaizen Lightning Burst**
- **Buffer or Safety Stock**
- **Operator**

INFORMATION FLOW Icons

- **Manual Information Flow**
- **Electronic Information Flow**

- **Withdrawal Kanban**
- **Production Kanban**

- **Signal Kanban**
- **Kanban Post**

- **Weekly Schedule**
- **Load Leveling**

- **Kanban Arriving in Batches**

- **Sequenced-Pull Ball**
- **“Go See” Scheduling**
### Appendix 2

#### Time measurements on March 23

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<td>21</td>
<td>172.1 new board on pallet, pick up plastic covers</td>
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<td>22</td>
<td>126.2 moves components between pallets to get easier access</td>
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#### Time measurements on March 25

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