Preface

This master thesis is presented to Aalborg University, as partial fulfillment of the requirements for obtaining a Master's Degree in International Technology Management. The thesis has been made in collaboration with Grundfos Manufacturing Serbia under the supervision of Sami Farooq, Assistant Professor at Center for Industrial Production at Aalborg University. The thesis covers the 9th and 10th semester of the educational program, and has been carried out between November 2011 and of January 2013.

I would like to express my sincere gratitude to the people who has contributed to the competition of this thesis.

First of all, I would like to thank the employees of Grundfos Manufacturing Serbia. Through my six month internship at the company they have been open, friendly and helpful, making the time in Serbia unforgettable. A special thanks to the operators who were will to listen to and play along with my crazy ideas, and production supervisor Zorica Trkulja with whom I have had many talk regarding everything from production management to Serbian history.

Secondly, I would like to express my sincere gratitude towards all the members of the Grundfos Shop floor Excellence network, who were willing to dedicate time and effort to this project. Without the cooperation from these people, this thesis could not have been written. They have contributed immensely to my understanding of Lean and Standard Work.

Finally, I would like to thank my supervisor Sami Farooq, who has endured and helped me along the long and challenging road of writing this thesis. And to my sister Julie Krogh, who made it happen and pushed me towards completion.

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The purpose of this Thesis is to investigate and find improvements for the Standard Work implementation process at Grundfos Manufacturing Serbia. First the thesis focuses on the literature in order to gain an overview of the topics and their content. The Literature Review focuses on: Lean Production, Standard Work and Knowledge Management. Based on this review five key elements for implementing Standard Work are found.
Second, a case study of Standard Work implementation at Grundfos Management, Grundfos Manufacturing Denmark and Grundfos Manufacturing Hungary add four key points to each element. The case study is done through five interviews with Lean Agents from each company in order to collect and analyze their experience.
Based on the framework devised through the literature review and case study, an analysis is made of the current implementation process at Grundfos Manufacturing Serbia. The data for this analysis is collected through participatory observation, made during a six month internship at Grundfos Manufacturing Serbia.
Based on the analysis five propositions are made for improvement the implementation process. These range from high level strategic decision, to implementation of daily routine processes.

Number Printed:	5 pieces
Pages:	121
Appendix:	3
Enclosures:	0

The content of this thesis is available at will.

Readers guide

In the Figuree to the right the structure of this thesis is depicted.

The first two chapters are a summary in English and a Resume in Danish, the content of the two chapters are identical.

The first chapter of the thesis is the introduction, in which Grundfos Manufacturing Serbia is shortly introduced and the process leading to initial problem are explained.

In the problem statement the research question, research objectives and research area are put forth, based on the initial problem stated in the introduction.

In the literature Review, the academic foundation for this thesis is explained based on the research objectives.

In the method chapter, the scientific approach to solve the research question and the measure to ensure validity and reliability are explained.

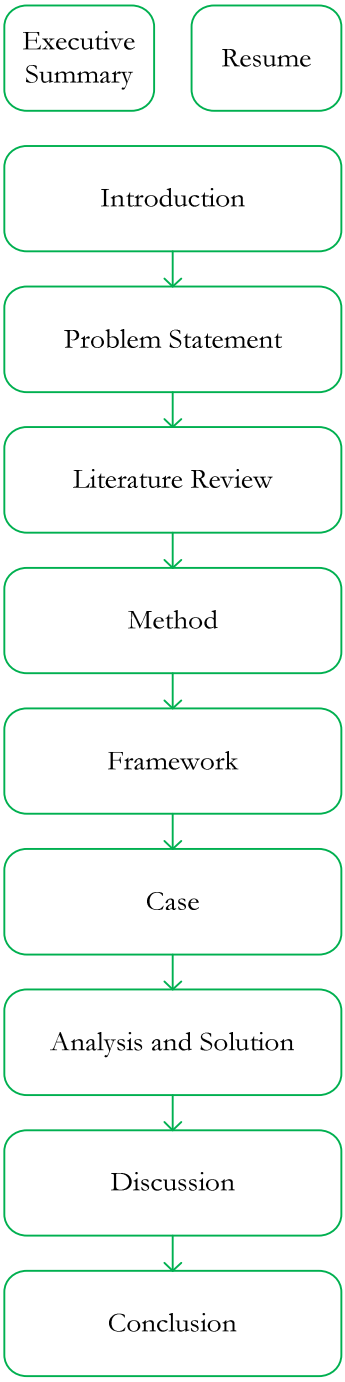
In the framework chapter, a framework for analysis suggested problem is found. Based on the framework, a case study is done in the following chapter. The findings from the case study are then analyzed and five improvement suggestions are made.

In the final two chapters, a discussion of the literature, method and case are made. Leading to the conclusion of this master thesis.

References in this thesis are made using the Harvard Method, thus (author, year of publication), and a full list of the reference can be found in the back of the thesis.

In order to reflect the daily terms used at Grundfos, abbreviation will be used in the text body of the thesis.

- Grundfos Manufacturing Serbia will be refered to as Grundfos Serbia.
- Grundfos Manfacturing Hungary 1, 2, and 3 will be refered to as Grundfos Hungary, unless referencing to a specific factory.
- Grundfos Shop floor Excellence will be refered to as GSE.
- Grundfos Bjerringbro will be refered to as Grundfos Denmark



Executive Summary

This thesis is guided by the following research question: *How can the Standard Work implementation process at Grundfos Manufacturing Serbia be improved?* With focus on the use of Standard Work within Grundfos manufacturing companies.

The main data collection for this thesis has been done as case study and participatory case study. The case study was done of the two Grundfos companies which have the most experience with Standard Work, Grundfos Denmark and Grundfos Hungary. From both these companies two employees who worked with lean implementation participated along with one employee from Grundfos Management, the data collection was done through interviews. The participatory case study was done doing a five month internship at Grundfos Serbia, in which one of task undertaken were the implementation of Standard Work.

In order to answer the research questions, a framework were devised based on a literature review and a case study. The framework consists of five elements, which are derived from a literature review of the three topics: lean production, Standard Work, and knowledge management. For each of these five elements four key points were found through a case study of Standard Work implementation at Grundfos Denmark and Grundfos Hungary, the framework is depicted in Figure 1.

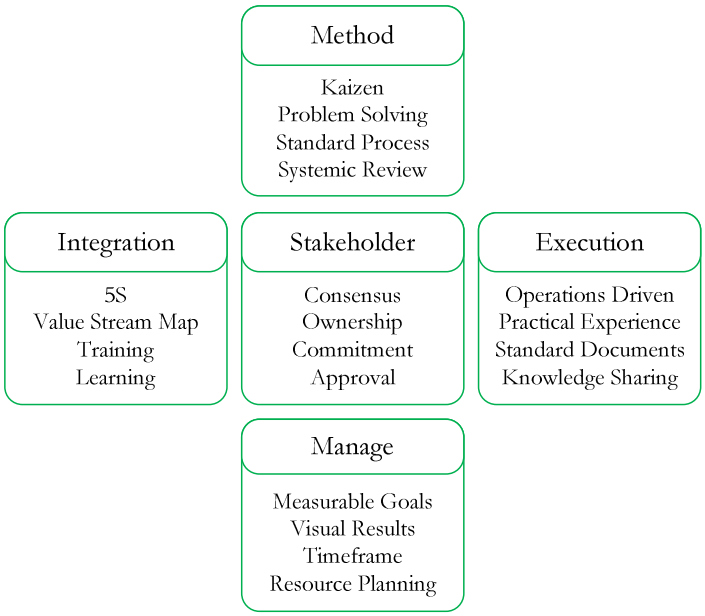


Figure 1: Framework For Implementation of Standard Work

The framework then served as the basis for a participatory case study of Grundfos Serbia, which lead to the following five suggestions. These suggestions are based on an analysis of the current ongoing implementation of Standard Work, using a comprehensive framework.

> Proposition 1: Implement a system for review the use of Standard Work in production.
> Proposition 2: Standard Work description should be made by operators with support from technical department.
> Proposition 3: Involve one or more persons with practical experience with Standard Work in the implementation.
> Proposition 4: Utilize a tactical implementation plan for time and resource planning.
> Proposition 5: Establish Grundfos Serbia as GSE plant

By implementing one or more of the suggestions Grundfos Serbia could improve the implementation process for Standard Work, this is further detailed in the thesis on page 91.

Resume

Denne afhandling er baseret på følgende problemstilling: *Hvordan kan Standard Work implementerings processen ved Grundfos Manufacturing Serbia blive forbedred?* Med et fokus på bruge af Standard Work ved Grundfos produktions selskaber.

Hoveddelen af dataindsamlingen til denne afhandling er lavet gennem et case study og et deltagende case studie. Case studiet blev lavet af de to grundfos selskaber der har mest erfaring med Standard Work, Grundfos Danmark og Grundfos Ungarn. Fra begge disse selskaber deltog to ansatte som med lean implementering sammen med en ansat fra grundfos management, dataindsamlingen var lavet ved brug af interviews. Det deltagende case studie blev lavet igennem et halvår praktikophold ved grundfos manufacturing serbia, hvor en af opgaverne var implementering af Standard Work.

For at svare på problemstillingen blev der udarbejdet et framework baseret på en gennemgang af literaturen og case studiet. Frameworket består af fem elementer, som er udledt på baggrund af en literatur gennemgangen af tre emner: Lean Produktion, Standard Work og Knowledge Management. For hver af disse fem elementer blev der fundet fire hoved pointer gennem et case studie af Standard Work implementeringen ved Grundfos Danmark og Grundfos Ungarn, frameworket er afbilledet i Figure 2.

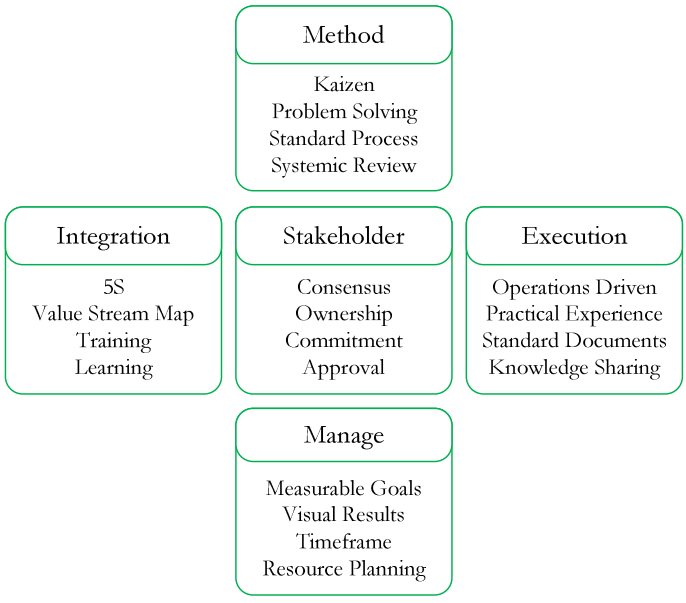


Figure 2: Framework til Standard Work Implementering

Frameworket fungere derefter som basis for et deltagende case studie af Standard Work implementeringens processen ved Grundfos Serbien, hvilket førte til fem forbedrings forslag.

> Forslag 1: Implementer et system review for brugen af Standard Work i produktionen.
> Forslag 2: Standard Work beskrivelserne skal udarbejdes af operatørerne med støtte fra den tekniske afdeling.
> Forslag 3: Involver en eller flere personer med praktiske erfaring med Standard Work i implemenerings processen.
> Forslag 4: Brug en tactical implementation plan til at planlægge tidsforbrug og resoucer.
> Forslag 5: Etabler Grundfos Serbien som GSE fabrik.

Ved at implementer et eller flere af disse forslag kunne Grundfos Serbien forbedre implementerings processen for Standard Work, hvilket er yderligere gennem på side 91.

Table of Content


GRUNDFOS

Introduction

This chapter will contain a short description of Grundfos Serbia and the foundation for the research question for this Master Thesis. The description of Grundfos Serbia will provide basic information about the company, including its history, role in Grundfos A/S, present situation, and future plans. The efforts of implementing Grundfos Shoop floor Excellence (GSE) are described, as this lead to the main topic of this Master Thesis.

Grundfos Serbia was founded in 2008 with the purpose of establishing a production base in Serbia. In 2009 a 25.000 square meter plant was designed and a suitable area located 35 kilometers outside Belgrade was found. However due to the financial turmoil, including global uncertainty regarding consumption and financial stability, Grundfos A/S postponed the project, and instead an alternated plan was made containing a small scale version of the original plan.

History of Grundfos Manufacturing Serbia

In the summer of 2010 the first people were hired by Grundfos Serbia and the company was located in a rented building 25 km outside Belgrade. The management team, engineers, logistics, and administration positions were the first employees which were hired. Some of these employees were sent to Bjerringbro for a six months training course, while the remaining employees made the preparations to be capable of starting production. It was decided in 2010 that a 35 year old circulation pump production line should be transferred to Serbia from Denmark and thereby become the first production line in Grundfos Serbia. In March 2011 the line was disassembled by a team from Grundfos Denmark and loaded into seven trucks heading for Serbia. One month later, the line was completely assembled and the first UPS circulation pump was produced by Grundfos Serbia. Figure 3 depicts a UPS pump.

Figure 3: Grundfos UPS 32-55 Circulation Pump, Similar to the UPS Pumps Produced by GMS (colglopumps.co.uk, 2012)

GMS currently has one production line producing UPS pumps for the central and eastern European market. Once a week a batch is shipped to Grundfos Hungary, which is responsible for any further transportation to customers. In the start of 2012 Grundfos Serbia had 46 employees, making it the smallest production company in Grundfos. 18 of the 46 employees were operators. The plan is that by the end of 2012 the work force should increase to contain 90-10085 employees, including 32 new operators to run the new evening shift and the remaining employees are primary added to the technical and logistics department.

Along with the start-up of Grundfos Serbia in the rented building, the work on establishing a new plant in Serbia continued. In February 2012 the Serbian president, assisted by the chairman of Grundfos Serbia and the Danish ambassador, could break ground on the construction site for the new plant. The new plant wasto be completed in December 2012 and inaugurated in January 2013, where four or five production lines will be transferred to GMS from other Grundfos production companies. When the new plant is up and running in 2014, Grundfos Serbia will occupy around 350 employees. The possibility to expand the factory by additionally 50.000 square meters has been incorporated into the design by adding two extra buildings.

GSE

In the autumn of 2011 Grundfos Serbia started the implementation of GSE, which is Grundfos' version of *lean production* and an important part of the strategy of all Grundfos production companies. GSE has been developed by Grundfos Management in cooperation with Lean Consulting and is based on the lean philosophy. This means that GSEis adjusted to fit the production strategy and values of Grundfos. GSE consists of a number of tools, from values stream mapping to production planning, and lean training. Five of these tools are mandatory, meaning all production companies are obligated to implement these tools in their productions. These five mandatory tools are:

- Value Stream Map – Map of production where tact time, quality, and break downs are recorded.
- Standard Work – Detailed description of the job done by an operator.
- 5S – Production area is kept clean and tools have fixed places.
- Preventive Maintenance – Maintenance plans and schedules for machines.
- Daily Action Meeting – Daily meeting between production supervisor and operators to discuss problems, solutions, and actions.

From the beginning of the production in Serbia the tools; 5S, Preventive Maintenance, and Daily Action Meeting have been regular parts of the daily operations. When the production line was placed in Denmark, 5S manuals, schedules, and tool boards had been developed and these were transferred along with the line to Serbia. During the transfer, operators from Serbia have been trained by Danish operators in the use of 5S and a 5S audit of the whole production area is done

every month. Just like 5S, Preventive Maintenance was used in Denmark and has been copied to be used in Serbia. Preventive Maintenance is mainly controlled by SAP. Every day at 9.40 a Daily Action Meeting is conducted. From April 2011 to March 2012 all employees (operators, engineers, finance, department managers, and general manager) of Grundfos Serbia were present at these meetings. However, in march 2012 a change was made, which meant that only the operators and production supervisor were at these meetings every day, and engineers from the production, logistics, and health and safety were scheduled to be present only once a week or as needed.

Value Stream Mapping

In order to improve the efficiency of the production line and comply with the GSE strategy, the process of mapping the production line began in November 2011. This mapping was done by using a Value Stream Map (VSM), where all processes in the production were mapped and recorded in order to gain a full picture of the line, the flow, tact time, utilization, and bottlenecks. The result from the mapping process, as seen in Figure 4, was placed on a board in the production, and thereby made visible for every employee and visitor in Grundfos Serbia. In Appendix A the entire value stream map can be seen.

Figure 4: Value Stream Map for the production line at GMS

Based on the value stream map a number of observations were made, which formed the basis for different actions to be taken. These observations were:

- In 2012 the customer demand would be 870.000 pumps, with planned capacity of 2389 production hours (excluding time for maintenance and cleaning), and the tact time would be 9,9 seconds per pump.
- None of the machine processes had a tact time above 7 seconds.

- None of the 16 human processes had a tact time above 6 seconds, nine of them had a tact time below 4 seconds.
- Of the 36 processes, none of them had an uptime below 97 per cent. In average the machines downtime were 60 minutes per day.
- Of the 36 processes, none of them a First Time Through rate below 98 per cent. If all pumps that did not meet quality demands were scrapped, it would require 20 minutes per day to produce the needed pumps.

In Table 1 the findings from the VSM are summarized in terms of time and pumps each day and based on a tact time of 6,9 seconds per pump. In the top column the total available production time per day is 480 minutes, which is based on a working day from 6 to 14. In the following columns all activities that deducts from the available time are listed, both in terms of time and loss of pumps. For the activities; daily cleaning, machine breakdown, and loss due to bad quality, it is assumed that the entire production is shut down if one machine breaks down, is cleaned or has quality problems. This is not accurate when compared to the reality of Grundfos Serbia but has been deemed acceptable for the purpose of the initial analysis.

	Time	Pumps
Total available production time	480 minutes	4115
Breaks	45 minutes	391
Daily action meeting	10 minutes	87
Daily cleaning	10 minutes	87
Machine breakdowns	60 minutes	522
Quality	20 minutes	174
Available production time	385 minutes	2854

Table 1: Production Time Available at Grundfos Serbia

The last column in Table 1 shows the available production time per day after breaks, meetings, breakdowns etc. are deducted from the operational hours. This initial analysis, based on the VSM, showed that 385 minutes are available for production each day, which is equal to the production of 2.854 pumps. Based on the experience from the production in Denmark, Grundfos has set a production goal of 2.800 pumps per day. However, two hours are used every week on thoroughly cleaning and in this case the production goal for these days is 2000 pumps. In Figure 5 the actual production and production targets for five weeks in 2012 are shown. For 25 days the plan was to produce 65.700 pumps, but only 53.769 pumps were actually produced. In 8 out of the 25 days the daily production targets were met.

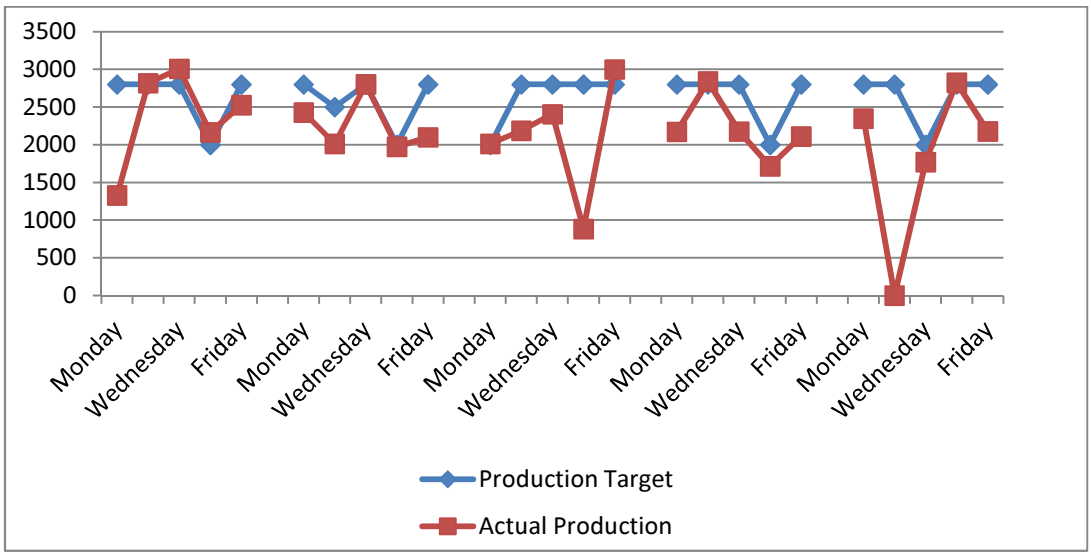


Figure 5: Actual Production and Production Target for Grundfos Serbia.

Based on the findings from the VSM analysis, it was deemed possible to achieve a 10 percent yearly increase in production efficiency, which is the goal for all Grundfos production companies. The VSM showed that the current production line was capable of achieving the daily production target without any improvements. However, the actual production numbers showed that it did not achieve the target. In order to optimize the production line, a better understanding of the operators' tasks during production was needed. In order to obtain this knowledge and improve the production, the tool; Standard Work was chosen from the GSE toolbox. By working with Standard Work, the aim was to gain a greater understanding of:

- The operators' tasks - both assembly task on the line and miscellaneous task in changeovers
- Machine maintenance
- Supplying material to the line.

Problem Statement

This chapter will present the research question, objectives, and area for this master thesis. This is, based on the problem described in the initial analysis in the previous chapter.

In the introduction the process leading to the decision of working with Standard Work at Grundfos Serbia was described. Based on a value stream map analysis of the current production line, it was found that GMS' production line could be optimized by using Standard Work in order to gain a better understanding of the current tasks performed by the line operators. The value stream map analysis also showed that the current machinery in the production line was capable of realizing the targets. However data showed that the production's targets were reached less than 30 per cent of the time.

Research Question

Based on the situation described in the introduction chapter, the following research question can be put forth:

- *How can the Standard Work implementation process at Grundfos Manufacturing Serbia be improved?*

In order to answer this question, a framework for analyzing the implementation process must be used. The literature offers no such, therefore a framework must be made prior to the analysis.

Research Objectives

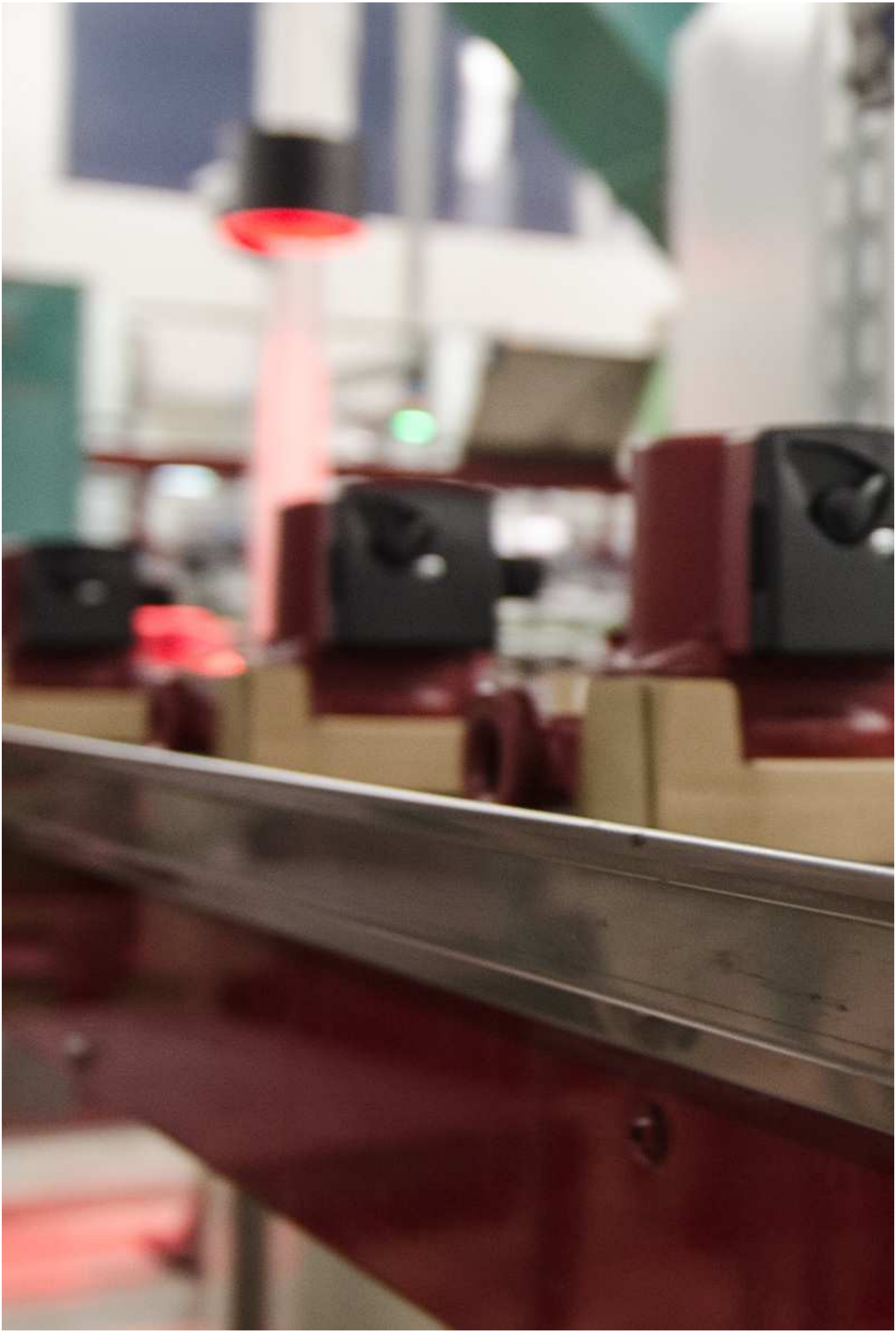
The purpose of the research objectives are to explain what will be investigate in this master thesis in order to answer the research question.

- Review literature: Investigate the literature relevant to answer the research questions, by defining the key concepts and definitions for lean production, Standard Work, and knowledge management.
- Develop framework: Based on the literature and an empirical study of Standard Work in Grundfos a framework for the implementation of Standard Work should be developed.
- Validate framework: Apply the framework to the implementation of Standard Work in Grundfos Serbia, in order to analyze the process, find improvement suggestions, and validate the framework.

Research Area

This master thesis will be constrained to research within the areas of:

- Lean production, Standard Work, and knowledge management: The literature review will be focused these three topics, which each intersect into one and another. This is further explained in the literature review.
- Grundfos Manufacturing Companies in European region: Grundfos Group consist of over 90 companies spread all over the globe, the majority are sales companies with limited or no production. This thesis will focus on the eight manufacturing companies in the European region, as these use the same strategy for implementing GSE.
- Manufacturing: Grundfos manufacturing companies also handles purchasing, logistics, and similar task, however these assignments are not included in GSE and therefore beyond the scope of this thesis.



Literature Review

The purpose of this chapter is to review the relevant literature to solve the research question put forth in the previous chapter. The following three areas will be further examined; Lean Production, Standard Work, and Knowledge Management.

The three topics that will be reviewed in this chapter, Lean Production, Standard Work, and Knowledge Management can be connected to each other. Standard Work is defined as a tool within Lean Production, but it plays an important and significant role for achieving success through lean (Liker, 2004). Basically Standard Work involves finding the best possible way of doing a task. This is achieved by firstly establishing the best known practice and hereafter improve by making incremental changes (Liker, 2004). The task in regards to Standard Work is to transform the knowledge and ideas that workers hold and turn them into standards which can be used by others (Bicheno, 2004). This links to the concept of transforming tacit knowledge to explicit knowledge (Smith, 2001), which is part of the area of Knowledge Management.

The goals of Lean Production are to increase the value that is delivered to the customer (toolbox) and reduce the cost of the product by eliminating production inefficiencies (Monden, 1998). By reducing inventory and workers through continuous improvements the production efficiency can be increased and cost related to production lowered (Monden, 1998). In Lean Production standardization of all tasks are needed before any improvements can be made, as the standardized tasks form the foundation for the further improvements (Liker, 2004). The need for standardization is explained by Liker as (Liker, 2004):

"One must standardize, and thus stabilize the process, before continuous improvements can be made. As an example, if you want to learn golf, the first thing an instructor will teach you is the basic golf swing. Then you need to practice, practice, and practice to stabilize your swing. Until you have the fundamental skills needed to swing the club consistently, there is no hope of improving your golf game" (Liker, 2004)

The need for standardization is a part of 5S, which in most literature is described as a tool for cleaning. Bicheno (Bicheno, 2004) describes 5S as basic housekeeping in lean, but the main reason for working with 5S is Standard Work. Through 5S standards for cleaning are made, items are placed at the workstation where they are needed, and inventory are reduced to the actual need (Bicheno, 2004). These standards are needed in order to implement Standard Work which, when implemented, forms the foundation for continuous improvement (Liker, 2004).

Standard Work is a detailed description of what tasks a worker must perform and in which order, to complete a job (Nicholas, 1998). The Standard Work description details every task in the job, so a complete description of the job can be transferred to other workers without the loss of

information. As stated above, the Standard Work description serves as a foundation for improvements and can be changed if a better way of doing the task is found. In Knowledge Management literature the transition of knowledge from tacit to explicit has been examined and different models and framework have been made to explain the different aspects of this transition (Smith, 2001). Both in terms of Standard Work and Knowledge Management the goals are to create knowledge useful for multiple people and to ensure that knowledge can be shared.

Lean Production

The core principal of Lean Production is to turn waste into value (Womach & Jones, 2003). The philosophy states that it is important to eliminate and prevent waste in the production, to create a fast, balanced, and flexible flow, which allows the customer to pull the product (Bicheno, 2004). Understanding lean involves looking into the five lean principles: value, value stream, flow, pull, and perfection.

First Principle: Value

Porter defines value as *"… the sum, that buyer is willing to pay for what the producer has to offer… "*. (Kotler & Armstrong, 2008) Compared to Porter's definition, the lean philosophy offers a much broader view on the term value. From the lean perspective, value is the customer' subjective opinion about the delivered product, and the sum of different factors: prize, quality, quantity, on-time delivery, and service (Bicheno, 2004). Value is defined by the customer, but made by the producer. Therefore producers have to understand the customers' needs and define value based on these (Womach & Jones, 2003). Value can be define as an equation "*value = benefits – (cost + damage)*". However, contrary to the traditional view in which value is increased by increasing benefits more than cost and damage, lean views an increase in value by increasing value and decreasing cost and damage (toolbox). For this target cost is used, which is a pricing strategy used in Lean Production, by identifying the current waste in the process of producing a product, a target cost can be found by deducting the cost of waste from the prize. This new economic latitude can then be used to increase the product's benefits by adding new features, add or increase service, or lowering the cost, depending on the customers' desires (Womach & Jones, 2003).

Second Principle: Value stream

The value stream covers all processes needed to deliver a product or service to the ultimate customer- Hence, all the processes from concept and product design to information management and making and delivering the product to the customer are taken into consideration (Womach & Jones, 2003). In Lean Production the value stream refers to the processes which transfer the raw material into a product and transport it to the customer. These processes can be divided into three types of categories according to Womack and Jones (Womack, et al., 1990):

- **Value adding:** Processes that adds value to the product and is needed in order to deliver the product to the customer (Womach & Jones, 2003).

- **Non-value adding but still needed:** processes which with the current set-up of machines, product design, and available technology need but does not add value (Womach & Jones, 2003).
- **Non-value adding and not needed:** The third type of processes is those which does not add value and can be avoided immediately (Womach & Jones, 2003).

The principle of value stream requires a change in the mindset of managers. Instead of competing product vs. product, they need to think value stream vs. value stream.And instead of managing functions or departments, managers have to manage value streams including multiple and smaller functions (Liker, 2004).

Third Principle: Flow

Keeping flow is a central part of lean and one of the biggest differences compared to traditional mass-production. Instead of focusing on high efficiency in each department by using batches and large machinery, focus is on high utilization of the product by avoiding rework, transportation, stockpiling, and queuing (Womach & Jones, 2003). With the focus on value streams instead of departments, flow is used to move the product through the value stream quickly without inventory and waste (Tapping, 2010). In Lean Production flow is achieved by creating a continuous one-piece flow with a tact time that matches the customers' demand. Tact time refers to the speed at which one product is produced. By using one-piece flow lean producers can achieve:

- **Reduced inventory** (and thereby the cost of inventory). Inventory is reduced as batches are no longer needed and products therefore can go from one process to the next in the value stream.
- **Higher flexibility** by designing processes to handle one-piece instead of mass producing items.
- **Higher productivity** is obtained as over-production is eliminated and through-put time reduced.
- **Improved safety** as the need for moving batches and large machinery is eliminated due to the elimination of over-production and reduced through-put time.
- **Improved quality** as build-in quality easier can be obtained in a one-piece flow production.

Fourth Principle: Pull

Establishing flow allows the pull principle to be used in a Lean Production. Using pull means that a task is only performed when a demand is indicated by the customer (Womach & Jones, 2003). Pull is the opposite of the traditional way of looking at a supply chain, where raw materials are sent to the producer, hereafter the products are shipped to a store, which creates the possibility for the customers to pick them up. This happens in big batches. In the pull system the customer creates a demand in a store, which then orders the item from the producer. Hereafter the producer orders

the raw materials from its suppliers. By establishing a pull production a lot of the advanced planning and use of forecast are eliminated, in turn reducing waste by decreasing uncertainty (Womach & Jones, 2003). Instead of MRP systems, a simple kanban card system can be implemented. In this case a kanban card is sent to the supplying process when a process needs material (Bicheno, 2004). Together with the value stream and flow principles, pull is the operational foundation for a Lean Production, which is flexible, responsive, productive, and delivers quality.

Fifth Principle: Perfection

Perfection is a principle that applies to the work with a Lean Production, when improving one or more processes. In The Machine That Changed the World, Womack and Jones (Womack, et al., 1990) showed how the Japanese auto industry outperformed both the US and European auto industries by using the lean principles. This was shown by benchmarking the industries in terms of multiple parameters. This lead to that companies began to benchmark, where lean tools were used to improve production in order to reach industry standards (Womach & Jones, 2003)). Womack and Jones (Womach & Jones, 2003) emphasized that the goal should be to obtain perfection by focusing on continuously eliminating waste in an incremental process. Using perfection as a goal should change the mindset needed, where the goal is not to achieve "x" in one year, but to keep eliminating waste towards a perfect Lean Production (Womach & Jones, 2003).

Summary of lean Production Principles

Based on these five principle Womack and Jones (Womack, et al., 1990) described how and why the Japanese auto industry where superior compared to the rest of the world in the eighties. They (Womack, et al., 1990) showed that the Japanese manufactures made cars with higher quality, quicker delivery and better service, but with less inventory, faster throughput time, quicker and cheaper product development, and less atomization. The key to the Japanese success was the commitment to the lean principles, which served as a guiding line through the development of the companies.

Since The Machine That Changed the World (Womack, et al., 1990) was published in 1990, Lean Production has been incorporated in many major corporations in the world and has thereby changed production facilities all over the world. In 1990 Toyota produced half as many car as General Motors and two-thirds of Ford (Womack, et al., 1990). However, In 2010 Toyota was the world's largest car manufacture with 8,55 million cars, 0,1 million more than General motors and 3,5 million more than Ford (Anon., 2012). In the summer of 2012 Toyota produced car number 200.000.000 since its foundation in 1933. It took 78 years to produce the first 100 million, and 11 years to produce the next 100 million (Bilmagasinet, 2012).

Elements of lean

In order to describe the elements of Lean Production the Toyota Production System House (TPS House) is used and seen in Figure 6. The TPS House was developed by Toyota to cover all the

aspects of lean which was used in its daily operations, so it could be explained to the supply base and communicated throughout the organization (Liker, 2004). The TPS house is just one of many models for explaining the different elements of Lean Production. Many scholars and consults have developed models and frameworks for lean which encompass all the elements of Lean Production. However as the TPS house has been developed by Toyota and has become a recognized symbol worldwide in manufacturing (Liker, 2004), it is the foundation of or part of many of the other frameworks. For this literature review, the TPS house is therefore used as a model for explaining the different elements of Lean Production.

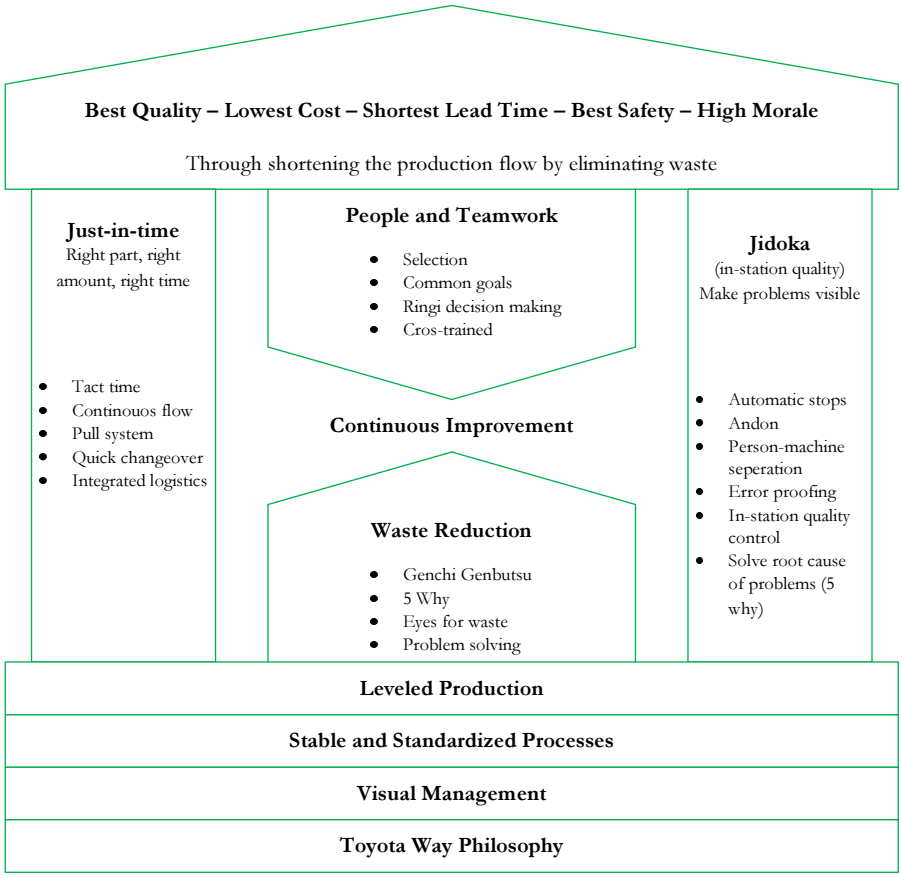


Figure 6: Toyota Production System House (Liker, 2004)

The foundation of the TPS House consists of four elements. Together these elements form the underpinning for the rest of the house. The roof, which represents the goals for the organization, rests on the two outer pillars – Just-In-Time and Jidoka. Continuous Improvement is placed in the center of the house and is a result of the people and teamwork in the organization and waste

reduction. All the elements of the house are needed in order to achieve a lean organization and all the elements support and reinforce each other. (Liker, 2004)

Foundation

The four elements: Level Production, Stable and Standardized Processes, Visual Management, and Toyota Way Philosophy makes up the foundation for the TPS House.

First element: Toyota Way Philosophy

In The Toyota Way Liker (Liker, 2004) identifies 13 different principles which constitute the Toyota Way; these principles are grouped into four categories: (Liker, 2004)

- Long term philosophy
- The right process will produce the right results
- Add value to the organization by developing your people and partners
- Continuously solving root problems drive organizational learning

In the Toyota Way Philosophy all decisions are based on a long term perspective, even if it means that short term financial goals are sacrificed. However, there is also a philosophical sense in the statement, as described in the Toyota way by Liker:

"Have a philosophical sense of purpose that supersedes any short-term decision making. Work, work, and align the whole organization toward a common purpose that is bigger than making money. Understand your place in the history of the company and work to bring the company to the next level. Your philosophical mission is the foundation for all the other principles." (Liker, 2004)

The long term principal can also be seen in the organization of supply chains amongst lean corporations. Lean supply chains are created based on long term relations and commitment to the other partners. In lean supply chains the companies' commit themselves and their resources towards the value chain, as explained above. This is done by using the same supplier for multiple years, only having a few or even a single supplier for one part, taking equity shares in suppliers and customers, and by assisting suppliers in product development in order to keep the suppliers' cost low. (Modarress, 2005)(lean supply chain fra Poul I)

The second category refers to process design. If processes in the production are lean the result will be a Lean Production. This means that all lean tools and techniques should be used in order to create processes that are based on continuous one piece flow and pull principles, are flexible, and deliver high quality. By improving the processes the goal is to create a production where

- Workload is leveled among processes,
- Products are made correctly first time to avoid rework,
- Tasks are standardized to ensure quality, safety, and form the basis for improvements,

- Visual control is implemented in all processes to quickly and efficiently identify and solve problems.
- By using these tools processes can be design and improved which are lean.

(Liker, 2004)

The core component in a lean organization is the employees. The employees have to understand and believe in the overall goals in order for the organization to achieve them. In order for a lean organization to function and improve, the employees have to learn about lean and develop their skills. (Liker, 2004) For many people Lean Production is counter intuitive, big batches and highly advanced processes seems like the most efficient way to produce a product but in reality slows production down (Womach & Jones, 2003). The employees in a Lean Production have to learn how to work together as a team to achieve the company's goal. This is done by having a strong company culture emphasizing team work and the company's philosophy. Leaders in this organization have to understand both the daily tasks in great detail and the company's philosophy in order to be true leaders and role models for other employees. (Liker, 2004) As lean requires a complete value stream mindset, the company's partners – suppliers and customers, plays a significant role for the company's success (toolbox). These partners have to develop, just like the employees, in order to continuously improve (Liker, 2004).

By focusing on identifying and solving root problems, a lean organization is able to learn and evolve. A key element in the Toyota Way Philosophy is to find the source of a problem and identify the problem by observing and verifying data, instead of theorizing based on data from MRP systems and other peoples' observations and interpretations. It is important to investigate all possibilities when making a decision and to surely understand the technical, human, and organizational changes that a decision will require. When a decision is made, it has to be implemented quickly to ensure that the changes are done fast and normal operations can resume. (Liker, 2004)

The Toyota Way Philosophy encompasses all the other parts of the lean house in some form. Understanding the ideas and philosophy behind the tools and techniques is a key aspect in developing and running a Lean Production. (Liker, 2004)

Second Element: Visual Management

The second element of the foundation of the lean house is Visual Management. Visual Management enables operators, engineers, supervisor, and management to quickly identify and act upon irregularities on the shop floor or in the supply chain. It includes a mixture of different lean tools, all supporting each other in order to create a system; 5S forms the basis for other tools such as '*andon*', one piece flow cells, Standard Work, and kanban. 5S is the fundamental housekeeping in Lean Production and consists of five elements, which are explained in Table 2.

Name	Name (English)	Explanation
Seiri	Sort	The goal is to keep only what is needed and dispense the items that are not needed (Bicheno, 2004). Make sure that all items have a fixed place where they are needed (Liker, 2004).
Seiton	Straighten (orderliness)	"A place for everything and everything in its place" (Liker, 2004)
Seiko	Shine (cleanliness)	Create a system for cleaning and inspecting by standardizing clean assignments and schedule cleaning. By cleaning regularly it is possible to identify irregularities and fix them. (Bicheno, 2004)
Seiketsu	Standardize (create rules)	Develop audit systems that control the three first Ss and improve upon them. (Liker, 2004)
Shitsuke	Sustain (self-discipline)	Create and support a culture in which all aspects of 5S are a daily part of the organization. (Liker, 2004)

Table 2: 5S

When 5S has been incorporated in the shop floor, it is possible to use other tools to create a visual management system where operators quickly can see deviations or needs. With a kanban system production cells are visually signaled with a kanban card if some components are needed in another process downstream. This enables the cell to start the production of the needed component. A well-designed one piece flow cell will reveal overproduction or unnecessary work in progress, which will enable operators to identify the cause and solve the problem. Standard Work requires a well-defined process and if operators are not able to do the tasks within the required time, the process has to be optimized. Using andon [andon is Japanese for lantern –Edit] will mean that all operators will know which process has caused the line to stop and experts can quickly rush to the machine or process to fix it. (Liker, 2004)

Third Element: Stable and Standardized Processes

The third block in the foundation is Stable and Standardized Processes. Making every process stable, repeatable, and predictable is the foundation for establishing flow and pull. In Lean Production standardization is finding and applying best practice methods to all processes by empowering operators to continuously developing the standards. (Liker, 2004) By standardizing a process it will become more stable because deviations from the best practice are eliminated. A stable process provides the base for further waste elimination and thereby improvements of the process (Tapping, 2010). Standardization is used in order to secure effective application of machines, work cells, and humans by avoiding waste such as overproduction, rework, and inventory. This is done by ensuring that all operators work according to the established best

practice (Nicholas, 1998). The main tool for standardization is Standard Work. Standard Work is a work sheet specifying the task an operator must perform; thereby it shows how the task is done and what time is needed for completing the task (Tapping, 2010). In contrast to scientific management's top-down approach (taylor), Standard Work in Lean Production is a bottom-up process. Hence, Standard Work is developed and improved by the operators and not engineers and managers (Liker, 2004). The concept of Standard Work is further explained in section Standard Work on page 41.

Fourth Element: Leveled Production

The fourth and last part of the foundation is Leveled Production. This includes both leveling out the production over the year to avoid large spikes in demand and leveling out work between all stations in the production to avoid overburden people and machines. By leveling out production stable processes can be designed. This is the case as demand is more predictable and the needed inventory is minimized. Large buffers to cope with fluctuations in demand have been avoided as uncertainty has been decreased (Toyota way). Heijunka (footnote: Japanese for leveled scheduling) means that the production mix and volume are even over time making every day the same in regards to expected output (Slack, 2007). This means that work in progress inventory is reduced as batches are reduced in size. In addition, finished goods inventory is also reduced as production matches the daily demand and flexibility is increased as the production quickly can be adapted to changes in customer demand (Tapping, 2010). Leveled production is also to level the workload between stations, work cells, and operators in the production and not just over time. For this Yamazumi charts are used. In these charts all processes are mapped according to schedule and time and then compared to the required tact time to identify overload and waste (Tapping, 2010). Together these four components: Toyota Way Philosophy, Visual Management, Stable and Standardized Processes, and Leveled Production form the foundation for the lean house.

Pillars

The two pillars of the lean house are jidoka, which can be described as "automation with a human touch" (toyota-global.com, 2012) and just-in-time, which is teamwork and strategy (Ohno, 1986). These two pillars both support the roof and work together in synergy.

> "… *a production line where just-in-time and automation work together is stronger than other lines. Its power is in the synergy of these two factors*" (just-in-time)

First Pillar: Just-In-Time

The first pillar in the lean house is Just-In-Time which is a system for delivering goods to the market when and in the amount they are needed. Just-In-Time is done by getting information from the market to the production fast, correctly, and easy, so the information flow is ahead of the production flow (Ohno, 1986). The Just-In-Time pillar of the lean house consists of five techniques. These are explained in Table 3.

Technique	Description
Tact time planning	Tact is the rhythm of the production and is based on the expected demand and the time available for producing one item. Based on this the entire production should be synchronized in order to avoid bottleneck and create flow. (Liker, 2004)
Continuous flow	The goal of continuous flow is to create a one-piece flow where a product flows through the production without sitting idle. By creating flow, people and processes are linked together which makes problems more visible. (Liker, 2004)
Pull system	In a pull system, production is postponed until a customer demand requires the production to be initiated. In a Lean Production a kanban card signal is normally used for signaling. (Ohno, 1986)
Quick changeover	By simplifying setup procedures and reducing setup time, quick changeovers can be achieved. This increases flexibility in production, product quality by reducing mistakes in setup, and lowers cost by eliminating inventory and overproduction. (Nicholas, 1998)
Integrated logistics	In order to achieve just-in-time both suppliers and customers must be included. Information and production must flow between the end-customer, producer, and supplier in an integrated solution, hence the value chain perspective. (Liker, 2004) This means that techniques such as flow and pull must be applied to the whole value chain and not only in one plant. (Ohno, 1986)

Table 3: Techniques for Achieving Just-In-Time Production

The techniques, presented in table 3, cover a much broader field of tools for achieving Just-In-Time. These tools include single minute exchange of die, kanban, supermarkets, and work cells. However for the purpose of this thesis, a further explanation of these is beyond the scope.

As stated earlier, just-in-time is focused on teamwork and strategy. In Just-In-Time organizations workers are responsible for assembling parts, running machines, and continuous improving. This means that workers have to participate in teamwork and cross-functional groups for different projects. As a strategy Just-In-Time requires a long-term focus and time commitment to continuously improve instead of short run quick fixes. (Liker, 2004)

Second Pillar: Jidoka

The second pillar is Jidoka which are the implementation of systems that do not allow defects to be passed on to the next station and freeing people from machines (Liker, 2004). The goal is to build machines that have built in quality control. This allows the workers to do other task while the machine is operating, as the machine is shut down and maintenance is alarmed if the machine detects any problems (Monden, 1998). In Table 4 some of the techniques in Jikoda are explained.

Technique	Description
Automatic stops	The production line is stopped if one station stops, thereby making the breakdown visible to the entire production line. The purpose of this is to reduce breakdowns by solving problems when they occur and reduce inventory and improve flow by eliminating the need for buffers. (Monden, 1998)
Andon	A light board which every worker can see. A yellow light will light-up if a worker needs help and assistance can quickly scrabble to the help. The worker can activate a red light if a machine needs adjustments. (Monden, 1998)
Person-machine separation	Workers are freed from the machine, thereby making it possible to separate machine operations and manual operations. Machines have built in a system that ensures that only the needed quantity is produced and if an error occurs the machine stops. This eliminates the need for workers to oversee the machine. (Monden, 1998)
Error-proofing	Tools or procedures put in place to avoid quality problems. (Liker, 2004)
In-station quality control	Every station is responsible for ensuring quality before passing the part on to the next station. This ensures that quality is high as workers will identify problems before shipping the part to the next station. (Monden, 1998)
Solve root cause of problems	Identify the root cause of any problem by thoroughly investigating the problem and possible reasons. Using 5*why the root cause can be found and solved, ensuring that the problem does not reoccur. (Bicheno, 2004)

Table 4: Techniques for Achieving Jidoka (in-station quality)

The goal for Jidoka is to ensure 100 percent quality by detecting any defects before the parts leave the stations. This is done by implementing a system for error-proofing the work done and an automated system that detects faults (Nicholas, 1998). The use of automatic machines can increase the cost of the product if the machines do not reduce the workforce needed but only the manpower needed to do one task (Monden, 1998). As Monden (Monden, 1998) points out automatic machines should only be introduced if there is a strong need and because it is possible in order to ensure that the introduction lowers cost and not introduces new costs.

Center

The center of the lean house consists of three elements: People and Teamwork, Waste Reduction, and Continuous Improvement. These three elements are the most important part of the TPS House because they deal with the people in the organization and how they behave. The foundation provides a stable ground for the house. Just-In-Time and Jidoka force problems to the surface by removing buffers and stopping the product when a problem occurs. This means that the people in the center of the house will have to solve the problems immediately through continuous improvement, teamwork, and waste reduction in order to resume production. (Liker, 2004)

Table 5 describes the elements in People and Teamwork and Table 6 describes the elements in Waste Reduction.

Element	Description
Selection	Develop supervisors and managers from the organization who understand both the daily operations and the company's strategy. These people should function as role models for other in the organization. (Liker, 2004)
Common goals	Create a strong culture with beliefs and values reflecting the company's strategy. Everyone within the organization should understand the principles in Lean Production. (Liker, 2004)
Ringi decision making	Use a consensus decision-making process where lower level employees are involved in the process in order to create commitment throughout the organization. (Ala, 2001)
Cross-trained	Workers are trained in multiple skills in order to increase flexibility and lower cost by reducing support staff in the factory. (Nicholas, 1998)

Table 5: Description of the People and Teamwork Element

Element	Description
Genchi Genbutsu	Problems are solved based on verified and proven information from the source and thereby not data from an ERP system. (Liker, 2004)
5*Why	The root cause of any problem is found through a 5*why analysis. By finding the root cause further problems can be avoided. (Bicheno, 2004)
Eyes for waste	Every employee should be aware of waste in the entire value chain. Systems such as just-in-time and jidoka make waste visible, but employees will have to spot it. (Liker, 2004)
Problem solving	When a problem occurs, a solution for solving the problem and avoiding any repeats has to be found. This is done by identifying the direct physical reason, finding the owner of this, Figureing out the best financial solution, and implementing it. (Bicheno, 2004)

Table 6: Description of the Waste Reduction Elements

Continuous improvement is to improve in incremental steps by identifying the problems and solving their root cause. This is done based on the idea that the optimal solution cannot be found and implemented; instead numerous incremental improvements will change and optimize the organization in order to reach the principals which lean is based on. (Slack, 2007) A part of continuous improvement is to reflect over projects and identify the success and mistakes in order to increase organizational learning, and enable best practices to be standardized and shared in the organization. (Liker, 2004)

Standard Work

The use of standardization and Standard Work in order to create a flexible and creative organization is counterintuitive and a contradiction in itself. However as Spear and Bowen (Spear & Bowen, 1999) showed this is actually the reasoning behind Toyota's success with lean. The rigid specifications and standards are the visual result of an underlying culture where improvements are made in a rigorous problem-solving community based on the scientific method which entails that the standards serve as hypotheses which can be tested. The standards are proposed hypotheses for the best way of doing a task in terms of quality, safety, and efficiency. The hypotheses have failed and must be improved if the products do not meet the requirements. (Spear & Bowen, 1999)

Standard Work has its roots in the American *Training within Industry* (TWI) program, which was established in the 1940's during World War II (WWII) in order to boost the production in American factories. The purpose of the program was to give supervisors the skills and tools they

need in order to train and develop new employees to increase production without increasing manpower. Plant supervisors were trained in instructing and teaching workers on the job and within the industry in order to keep the workers at the plant where they were needed. To assist the training, supervisors were given some tools which included the j-programs, as explained in Table 7. (Huntzinger, 2003) The three J-programs were rolled out in succession and designed to build on each other. Job Instruction provided supervisors with knowledge and skills to train new operators. The Job Method gave the supervisors the skills to increase production without assistance from engineers and Job Relations gave the skills to increase efficiency by a better understanding between supervisor and operator (Huntzinger, 2002).

J-Program Name	Description
Job Instruction	The purpose of this program was to train the supervisor in training new employees. Before new training could begin, some preparations had to be made. The supervisor should make time tables for the training, break down the steps of the job, make sure the workplace was arranged properly, and all equipment present. Training of new employees was made in four steps. First the worker was prepared for the job, then the supervisor showed how the job was done and emphasized key points. After this the new worker was put to work under supervision until he/she knew the job. The final step was to follow up, check in, and help the new worker. (Huntzinger, 2003)
Job Methods	The purpose of this program was to help supervisors to produce greater quantities of quality products by utilizing the available manpower, machines, and material. The supervisors were taught how to break down jobs into constituent operations and improve on those operations by developing new methods for doing the task and by eliminating, combining, rearranging, and simplifying the operations. The job of optimizing the operations was done without help from managers or engineers and therefore had to be done by the supervisor using only the available resources. (Huntzinger, 2002)
Job Relations	The purpose of this program was to increase teamwork and thereby increase efficiency. Supervisors were taught how to work with people and promote teamwork among workers. Supervisors were trained in collecting data, analyzing it in order to make a decision, and take action based on the facts. They were also taught in how to give feedback and credit to workers, and how to

	inform people about changes in advanced. The goal was to prevent problems by improving cooperation, making the best use of the workers' abilities and increase loyalty and teamwork. (Huntzinger, 2002)

Table 7: The three different J-Programs (TWI)

After the end of WWII, *TWI* including J-programs, was exported to Japan in order to help rebuilt the Japanese manufacturing base and infuse democratic principles in the Japanese society. TWI became the foundation for what became known as the Toyota Production System or lean manufacturing, as described by John Shook in 1983: (Huntzinger, 2002)

"To my amazement, the program that Toyota was going to great expense to transfer to NUMMI [NUMMI is a Toyota plant in America -edit] was exactly that which the Americans had taught the Japanese decades before." (Huntzinger, 2002)

When Toyota started developing the Toyota Production System in the 1950s and 1960s the three J-programs became a part of the system. Many of the tools in the Toyota Production System were designed to uncover and visualize problems. The J-programs are used when problems are discovered and solutions have to be found quickly and incorporated into Standard Work. The programs are proven and robust methods for solving problems and create new reliable and repeatable methods. By using the J-programs it was ensured that workers solved problems in collaboration and created a new standard process which replaced the old work process. In addition the J-programs also ensured that workers were trained in using and holding the standard process. By holding the Standard Work the foundation for further improvements was created, as any new improvement was based on the existing work process and not on a random process. Figure 7 illustrates the importance of holding Standard Work and using it as the foundation for the next improvements. (Huntzinger, 2006)

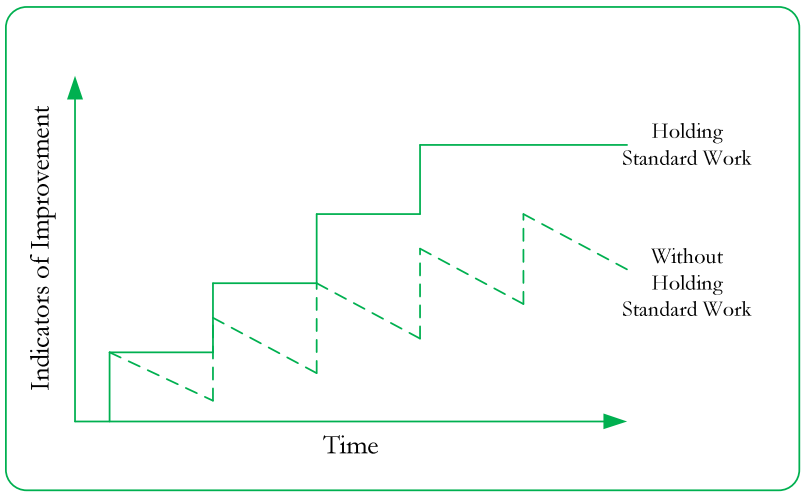


Figure 7: Benefits of having and holding Standard Work (Huntzinger, 2006)

According to Huntzinger (Huntzinger, 2002), Figure 7 shows why so many companies struggle to gain improvements from lean implementation, as they do not implement and hold Standard Work. Developing team leaders and workers to actually standardize improvements and hold them take time and are, according to Toyota, the lengthiest step in a conversion to the Toyota Production System. (Huntzinger, 2006)

In the literature three main reasons for Standard Work are highlighted: product quality, operator safety, and continuous improvement. A Standard Work description contains a detailed list of which tasks an operator has to complete within a given time. The list describes how the task is done, how long time it takes, and the specific order in which the task must be done. For every process a Standard Work description is made. Variability in the production process is diminished by doing the tasks according to the Standard Work descriptions. The standards that the operators must follow ensure that the quality of the product meets the required standards from the customer. It also ensures that the product is delivered on time as the task is designed to be done within a certain time limit. (Bicheno, 2004) The standards also include operator safety by ensuring that the tasks can be done within the given time limit and thereby it is avoided that the operator is overloaded. In addition the job is planned to minimize movements and no-ergonomic actions (Tapping, 2010). As mentioned in the start of the section, Standard Work forms the basis for improvements. Standard Work describes the current way of doing a task and therefore serves as the starting point for any improvements. If the process has a high variability, it will be impossible to identify the areas which need improvements and document the improvement. In fact any suggested improvement will actually increase variability. (Liker, 2004) Standard Work decreases process variability and instability by standardizing the task. This standardization can be improved in a continuous improvement process (Liker, 2004).

Knowledge Management

No single definition of knowledge (Alvesson & Kärreman, 2001) exists in the Knowledge Management literature. Depending on the project, knowledge can either be defined very narrow or very broadly. A very narrow definition of knowledge is: *"that which is objectively known. An intellectual property […] or certified by copyright or some other form of recognition* (McGrath, 2000)." A broader definition is offered by Davenport and Prusak: "*Knowledge is a fluid mix of framed experience, values, contextual information and expert insights […]. In organizations, it often becomes embedded not only in documents or repositories but also in organizational routines, processes, practices and norms.* (Davenport & Prusak, 2000)." In the context of lean manufacturing and Standard Work, knowledge should be defined very broadly, as Standard Work includes all processes needed in order to manufacture a product. The role of management is to plan, organize, co-ordinate, and control work, in order to ensure that the organization reaches its goals (Alvesson & Kärreman, 2001) (Boer, 2012). Management's two main focus objects are worker behavior and employee mindset. Workers' behaviors are managed by designing and supervising work processes in order to minimize the efforts and skills needed to complete the task. Employee mindsets are managed by targeting norms, emotions, beliefs, and values and are intended to affect behavior indirectly.

Knowledge management views a company as a social institution that draws value from the individuals within it and its ability to utilize their knowledge, but the individuals also draw value from the company and their colleagues (Birkenshaw, 2001). According to Birkenshaw (Birkenshaw, 2001) there are two main requirements for knowledge sharing in a company. First, people should be encouraged to interact and share knowledge, work together on projects, and share ideas. Secondly, systems for transforming tacit knowledge into explicit knowledge are needed in order to ensure that knowledge is shared in the organization. (Birkenshaw, 2001)

Knowledge can be either tacit or explicit. Tacit knowledge is practical "know-how" and based on practice and acquired by personal experience, whereas explicit knowledge is "know-what" and described in formal language and based on established work processes (Smith, 2001). In everyday life tacit knowledge does not require much thought or time, but is "automatic" and can be described as knowing more than you can tell. This type of knowledge is correlated with work practices that are improvised, flexible, and responsive to change in an unpredictable environment. The way to acquire tacit knowledge is through one-to-one training with a mentor/teacher who holds all the knowledge and can teach it. As stated earlier tacit knowledge is hard to explain so on-the-job training and experience are needed. Explicit knowledge is systematized in formal language and can easily be communicated, but it requires academic knowledge that is gained through formal education or structured study in order to be understood. Explicit knowledge is used in work processes were the task is organized, routine, and orchestrated. It uses proven methods and logic based on facts and analysis. Explicit knowledge is acquired through studying the stored description

and using format selected by the organization. The skills acquired through the learning process are based on the organizations needs and goals. (Smith, 2001)

In order to transform tacit knowledge into explicit knowledge, the inexpressible must be articulated and codified. This can be done by recording and analyzing the process that is transformed in order to create a manual for doing the task. (Smith, 2001) According to Birkenshaw (Birkenshaw, 2001) there are three focus points in order to get a Knowledge Management system to work and in which tacit knowledge can be transformed to explicit and shared in the organization. First, an information technology system is required to ensure that knowledge can be shared among employees; the system does not capture tacit knowledge. Second, formal and informal structures have to be created in order to capture the tacit knowledge. Formal structures assure that tacit knowledge is stored and informal structures increase the likelihood of knowledge being shared by creating social interaction. Third, specific Knowledge Management tools such as transfer of best practice and centre's of excellence enables knowledge to be shared throughout the organization. (Birkenshaw, 2001)

From a managerial perspective multiple measures can be made to ensure that Knowledge Management is done successfully. One way to promote knowledge sharing is to locate people closely together with the people they normally work with and another is to have meetings and briefings were workers can interact. These two methods for sharing knowledge can prove to be more effective than expensive IT systems (Birkenshaw, 2001) (Smith, 2001). Knowledge Management is as much about recycling old knowledge as it is about creating new knowledge. Hence, ensuring that best practices are shared throughout the organization and knowledge can be reached is just as important as creating new knowledge and making it explicit (Birkenshaw, 2001). In a modern organization with operations in multiple countries and factories, establishing what is best practice is an essential part of managing knowledge. Organizations must create standardized measures in order to ensure that the best practice can be shared and to ensure that the practice is in fact best and not mediocre or worst practice. A study of five multinational companies with intense knowledge sharing activities showed clear lack of understanding where the highest performers were. (Birkenshaw, 2001)


6M PUMP

Method

The purpose of this chapter is to describe the method used for collecting data for this project. This is done by using a case study research framework consisting of five focal points, which ensures that planning, collection, analysis, and reporting of data are taken into consideration when designing the method.

In scientific research a great variety of methods have been developed, ranging from very systematic to the researcher having complete freedom, to cope with different situations. The choice of method must reflect the phenomena that are being studied and must be suitable for the situation in which data are collected, as no-one method can deal with all research questions and interests. The method is chosen based on the research question and objective at hand, were after further reflections regarding the method have to be done both before and during the study to ensure the method fits the purpose. (Gummesson, 2007)

The research question for this thesis was to find improvements for the Standard Work implementation process at Grundfos Serbia, as described in (problem statement). In order to study this, case study research has been chosen as the research method. This is due to the fact that case study research is used for investigating little-known and complex phenomena, with many variables and relationships. (Gummesson, 2007)

Gummesson (Gummesson, 2007) defines case study research as:

"Case study research means that one or several cases from real life are used as empirical data for research, especially when knowledge of an area is sparse or missing, and when complex phenomena are studied" (Gummesson, 2007)

In order to conduct a case study research Gummesson (Gummesson, 2007) presents the following five focal points framework:

- Focus 1: Planning and design
- Focus 2: Empirical data; access to reality through collection of case data
- Focus 3: Analysis and interpretation, including links between empirical data, theory, and conclusions
- Focus 4: Quality assurance
- Focus 5: Reporting and communicating research

These five focal points are not steps but part of an iterative process, where findings or changes in one focus affect the others. (Gummesson, 2007) These focus points are examined in the following five sections.

Planning and design

The purpose of the first focus is to describe what needs to be done, how it should be done, and when it should be done. In order to plan and design the research process, the purpose has to be identified to determine what data is needed and figure out how it can be collected. (Gummesson, 2007) The purpose of this Master Thesis is declared in chapter

Problem Statement on page 24 and based on this the needed data can be determined.

The data needed was:

- **General experience with Standard Work in Grundfos:** All Grundfos manufacturing companies in Europe are obligated to implement GSE in their production line. However, the companies are currently in different states in their implementation processes. This means that some companies have just started the implementation on selected work stations, while others have years of experience and have implemented GSE on multiple production lines. By gathering data about the usage of Standard Work as part of these implementation processes, a better understanding of the requirements and the process can be obtained.
- **Experience with implementation of Standard Work in Grundfos**: The Grundfos companies, which have years of experience in working with Standard Work, can provide detailed knowledge and insights about the implementation process.
- **Implementation of Standard Work in GMS:** By participating in the implementation of Standard Work in GMS, it has been possible to gather first-hand knowledge about the process and the day-to-day development. Gathering data about how the implementation process is organized, planned, and executed will ensure valid information for further analysis.

A research plan, as seen in Figure 8, was made to find the needed data. Figure 8 depicts two courses of data collection. The one named global refers to the data collection from Grundfos Manufacturing companies in Europe and the other named local is the data collection made in Grundfos Serbia. The participatory case study was done during a six month internship from November 2011 to April 2012.

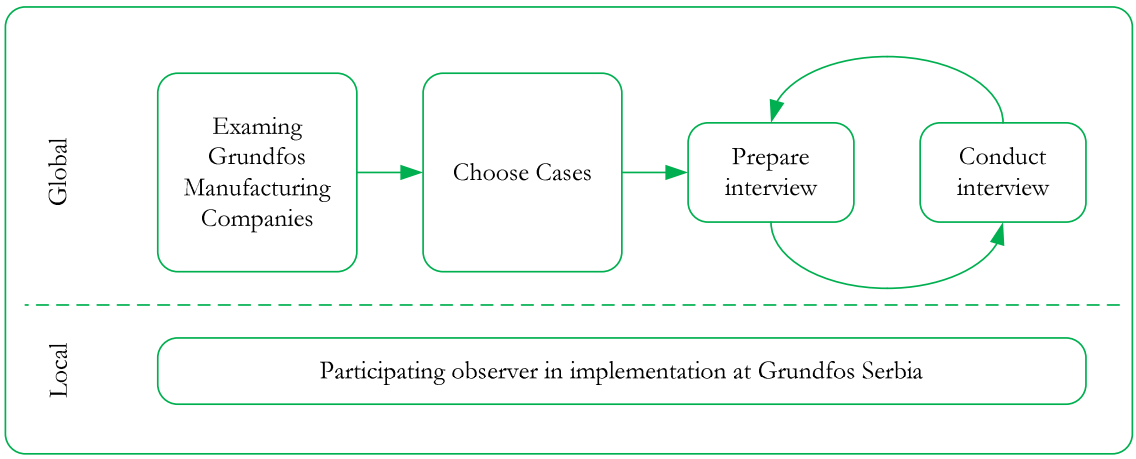


Figure 8: Research Plan

Empirical data

The scope of the second focus is how data is collected and how that data reflects the reality of the phenomenon being studied. Large amount of data can normally be retrieved through statistics, news and scientific articles, studies, and reports. However this type of data is normally collected for other purposes, meaning reliability and validity are unknown and the data may not be complete and up to date. Gummesson (Gummesson, 2007) suggested data generation as a more accurate designation when studying cases, as it provides knowledge about the environment, people, and processes that are the target for the study. (Gummesson, 2007)

An important part of designing a case study research is to address the question of how many and which cases should constitute the research project. Too few cases might provide insufficient data and too many require many resources without providing additional information (Gummesson, 2007). As described in the planning and design section, the cases for this thesis were chosen based on their experience with the implementation of Standard Work. Based on a questionnaire sent to all nine European manufacturing companies; Denmark, Hungary 1, 2, and 3, France, Germany, Finland, Russia, and United Kingdom, four companies were selected for further study based on their answers provided in the questionnaire. Table 8 shows the main findings from the questionnaire.

Company	Time Standard Work has been used in production	Work stations with Standard Work – description made	Gained measurable results from Standard Work
Denmark	More than one year	Between 50 and 100	Yes
Hungary 1	More than two years	More than 100	No
Hungary 2	More than two years	Between 50 and 100	Yes
Hungary 3	More than six months	Between 10 and 50	Yes
France	Less than six months	Less than 10	No
Germany	Less than six months	Less than 10	No
Finland	Less than six months	Less than 10	No
Russia	Less than six months	Less than 10	No
United Kingdom	Less than six months	Less than 10	No

Table 8: Results from Questionnaire

The four companies chosen for further examination were Denmark, Hungary 1, Hungary 2 and Hungary 3. Two internal GSE consultants from Denmark participated and from Hungary 1, 2, and 3 two GSE responsible engineers participated. In addition one manager from Grundfos Management responsible for the implementation of GSE participated. In the remaining part of this thesis Hungary 1, 2, and 3 will be referred to as Grundfos Hungary. In total five interviews were conducted, the interviews are enclosed on CD's in Appendix B.

For this study data was generated through three types of sources; documents, interviews, and participating observations/action research. Information about the formal strategy and goals was collected through documents from Grundfos regarding GES. Through these documents an understanding of how lean terms and tools were translated and used in GSE was gained. As seen in Figure 8, the 'global part' of the data collection was based on interviews. These were conducted using Adobe Connect which is an online conference tool that offers videoconference and a virtual drawing board. The interviews were done individually in an informal format. The interview started with a presentation of the overall project and an outline of the agenda for the interview. Here after a presentation of the work-in-progress Standard Work implementation framework was made.

The framework was used as a guideline for the interviews to ensure all aspects were covered. At the end of the interviews a quick summary was made and the interviewee had the chance to add further considerations etc. During the interviews notes were taken and the interviews were recorded for further study and documentation. All the interviews followed this structure. The other part of the data collection, named local in Figure 8, was done by using participatory observation/action

research. In participating observations the observer is a part of the process, interacts, and gains first-hand experiences when gathering information about the process (Kristiansen & Krogstrup, 1999). In action research the observer is also involved in decision making, thereby affecting the process. Action research is criticized for making the researcher too involved and thereby there is a chance for a lost perspective. However advantages are the ability to get close to data and have a lot of access (Costello, 2003).

Analysis and Interpretation

The scope of the third focus point is the creation of new knowledge and analysis based on the gathered data, where awareness, systemic procedures, and transparency are key points (Gummesson, 2007). As explained earlier the data collection was split in two parts, named global and local in Figure 8, and considerations for analysis and interpretation were made for both parts.

In the global collection where data was collected from Grundfos production companies, data was used to build upon previous gathered data. The basis for the data collection was a review of the literature regarding lean manufacturing, Standard Work, and knowledge management. Based on the literature review the first interview was conducted. This provided the basis for the next interview, as the previous interview had expanded the theoretical knowledge. This meant that a constant shift between 'analysis and interpretation' and data gathering was necessary. By interviewing people from three different parts of Grundfos; Grundfos Denmark, Grundfos Hungary, and Grundfos Management, three different interpretation of the reality in terms of implementing Standard Work were shown. These interpretations are all valid, as they reflect the different cultures, daily operations, and work tasks in the different parts of Grundfos. In the local collection, the analysis and interpretations were based on the results from studying the global cases, thereby providing a framework for data analysis.

Special attention was given to data integrity in the data analysis, as data was collected using qualitative methods and quantitative methods were only used for the initial questionnaire. All interviews were recorded and during the interview notes were taken, the recordings can be found on the attached CD. After the interviews ten to fifteen minutes were used to reflect and take further notes and notice different details.

Quality Assurance

The purpose of the fourth focus is to ensure the quality of the case study, by increasing quality throughout the whole research process. Due to the nature of a case study research, the assessment of the results cannot be reviewed based on the criteria from statistics and hypothesis testing. (Gummesson, 2007) In order to ensure the quality of this thesis, consideration towards the three common quality criteria; validity, generalization, and reliability are made. The validity of the study is ensured by using three different types of data sources for investigating the subject; literature, cases, and practice. These three sources each deals with Standard Work and how to implement it. By

combining these three it is ensure that the thesis investigates and studies the process of implementing Standard Work. The generalizability is narrow as all data are gathered from Grundfos companies, which entails that the data is very specific and reflects the culture, economics, and organization of Grundfos. As the data is gathered from Grundfos companies the results can be generalized and used throughout the Grundfos group, but the cultural difference should be taken into account. In order to ensure the reliability of the study measures were taken in the data collection. Open questions were asked in the interviews to open up the conversation and enable the interviewee to address their subjects of interest, and bring forth ideas and though based on their extensive knowledge and experience. By interviewing multiple people that work with Standard Work in Grundfos, no single source forms the basis for the study. The overall reliability of the thesis is harmed by the fact that the subject is complex, time and resources scarce, and the fact that Grundfos is an organization that evolves and thereby changes over time.

Reporting and Communicating research

The final focus point is the reporting and communication of the research, as the conclusions, contribution, and recommendation of the research should be emphasized and communicated. The report needs to take into account the type of people reading it and the reasoning must make sense to the reader. (Gummesson, 2007) This thesis has been structure with chapters for each major part of the thesis. In the beginning of the thesis a reader's guide presented the structure to the reader. All chapters and sections are numbered in order to make referencing quick and easy. The number of sections is kept to a minimum to minimize breaks and to maintain flow in the chapters. A 'Summary' in English and 'Resume' in Danish provide the reader with the main points of the thesis. Overall, this thesis presents one way for answering the proposed research question, presenting the data, its interpretations, the analysis, and conclusions.

Framework

The purpose of this chapter is to generate a framework for implementing Standard Work. This is done based on the literature review and the case studies of Grundfos Denmark, Grundfos Hungary, and Grundfos Management. The chapter consists of two parts. In the first part five elements are found based on the literature review and further elaborated on and in the second part the case studies are used to detail each of the five elements by adding 'real life' data.

Five elements are needed when implementing Standard Work. These have been generated based on the Literature Review on 29. These elements will be presented in the following sections.

The method for implementing Standard Work needs to be defined. Liker (Liker, 2004) emphasizes that by creating processes that build on the lean manufacturing philosophy results can be achieved, as found in section "lean production" in the literature review. In Liker's (Liker, 2004) study of The Toyota Way one of the key elements is the focus on continuously solving root problems. This requires methods that investigate and find solutions for the root causes of the occurring problems. Spear and Bowen (Spear & Bowen, 1999) have examined these methods and identified strong similarities with the scientific method of hypothesis testing. They identified this as a method embedded in the company culture and could ensure that problems were handled similar. Huntzinger (Huntzinger, 2006) has explored the working methods in Toyota and its roots in training within industry, and has found that the processes are parallel to the scientific method. These findings were further laid out in section Standard Work on page 41. Numerous authors have stressed the importance of kaizen in working with lean. Bicheno (Bicheno, 2004) defined kaizen as a central element of lean which enables the organization to change in all levels according to changes in the environment (customers, suppliers, technology etc.). Womack and Jones (Womach & Jones, 2003) described the endless steps in a kaizen process towards perfection as a fundamental part of lean thinking and the element which sets lean manufactures apart. By striving for perfection the company 'raises the bar' in small incremental steps. Each step exposes more waste while flow, quality, and efficiency are increased (Womach & Jones, 2003). Huntzinger (Huntzinger, 2006) argues that gaining results from kaizen requires a process that effectively gets the progress incorporated into Standard Work. If this is not the case, the next round of improvements cannot be based on a fixed process. In her study of tacit and explicit knowledge in the workplace, Smith (Smith, 2001) explains that transforming tacit knowledge into explicit knowledge requires a process which captures knowledge as argued in section Knowledge Management on page 45. Organizations can create new knowledge, solve problems, and achieve goals by having processes that enables people to transfer and share knowledge (Smith, 2001).

Standard Work cannot stand alone but must be integrated with other processes and lean tools as Womack and Jones (Womach & Jones, 2003) explained in their study of a lean implementation in a

major US manufacturing company. Standard Work is an essential part of the implementation, but without considerations towards improving the value stream, process layout, and organizational learning, the implementation would not have been successful (Womach & Jones, 2003). Bicheno (Bicheno, 2004) asserts that Standard Work is a direct result of 5S activities, as the 5S process of simplifying, cleaning, and standardizing leads to processes that can be preserved. Bicheno's (toolbox) assertation can be linked to Huntzinger's (Huntzinger, 2006) observation regarding the importance of holding Standard Work, as described in section Standard Work on page 41. Bicheno (Bicheno, 2004) further claims that the main cause for using 5S is Standard Work, as 5S without Standard Work does not provide the foundation for improvements. Both Liker (Liker, 2004) and Huntzinger (Huntzinger, 2006) state that Standard Work is fundamental to continuous improvement, because it provides the starting point for improvements. According to Monden (Monden, 1998) Standard Work is closely linked to training of employees, which is based on teaching the employee how to perform an operation according to the standard and explaining the goal of using Standard Work in the operation.

The process of implementing Standard Work requires the involvement of multiple stakeholders including workers, engineers, and different levels of management. In order to successfully implement changes, Nørgaard (Nørgaard, 2009) claims that both management and workers should be committed, as explained in "lean production". Bicheno (Bicheno, 2004) states that in order for Standard Work to take hold and be accepted amongst the stakeholders the process should be bottom-up and driven by shop floor workers and supervisors. By making the workers responsible for creating and using Standard Work, they have to think about their daily work, understand work standards, and know their responsibilities (Bicheno, 2004). Understanding and responsibility is not enough as Shingo (Shingo, 1985) asserts. Stakeholders also have to be convinced in order to swing into action. When stakeholders understand and are convinced by be strength of Standard Work, it can be successfully implemented because people believe in the method (Shingo, 1985). Shingo's assertation fits Liker's (Toyota way) notion that solutions should be made in consensus processes involving those affected in order to reach agreements that are broadly supported and can be implemented quickly. Standards can both be an enabler or barrier to implementing Standard Work, as people generally dislike rigid procedures and the idea of being forced to follow someone's detailed rules (Liker, 2004). As explained in the section Center on page 40, when people are focused on doing a good job, they are normally happy to accept tips and advices which enable them to improve and evolve their own ideas to improve their job (Liker, 2004).

Plans will have to be executed to gain the benefits from Standard Work. However Shingo (Shingo, 1985) claims that the resistance of habit will prevent the implementation of any improvement plans. This fits with Huntzinger's (Huntzinger, 2006) observation about the importance of holding Standard Work, as described in section Standard Work on page 41. Improvement plans have to be translated into practice by ensuring consent and understanding (Shingo, 1985). According to Monden (Monden, 1998) Standard Work is implemented on the individual work stations in a close

collaboration between supervisor and worker. The supervisor should be able to perform and fully understand the operation, then instruct the worker based on the Standard Work description and make sure that the worker understands the standards and the reasoning behind Standard Work (Monden, 1998). Huntzinger (Huntzinger, 2003) explains how a coaching role for supervisors and managers originated from the TWI program and how this easily fitted together with Japanese management philosophy. Huntzinger (Huntzinger, 2003) asserts that the coaching role for supervisors is to build personal relations and skills, instead of solving a problem, in order to create a team where individuals can solve any problem. Monden (Monden, 1998) elaborates further on this process by describing the importance of documentation, studying and determining cycle times, work routines etc. are to little use if the findings are not documented. By documenting the findings the standards will become visual to everyone and serve as a guideline for the operator and help the supervisor to ensure that Standard Work is being followed and improved (Monden, 1998). As mentioned above, Bicheno describes the implementation as a bottom-up driven process, where shop floor workers are responsible for using, holding, and improving Standard Work (toolbox). This claim is supported by Monden (Monden, 1998) and Nørgaard (Nørgaard, 2009) that assert that Standard Work is the responsibility of workers and supervisors and that employees' initiatives and contributions are fundamental elements in continuous improvement.

The process of implementing Standard Work has to be managed in order to contain the improvements and to progress further. Nørgaard (Nørgaard, 2009) maintains that lean implementation should be considered a management discipline where decisions are easily made but hard to get through with. Furthermore management is needed in the implementation process to avoid hurdles and gain the full potential (Nørgaard, 2009). Bicheno (Bicheno, 2004) describes how top management is responsible for the strategy planning and major changes in the production etc. and teams on the shop floor are responsible for closing the gaps defined by top management. Teams consisting of workers and people close to the shop floor are in charge of developing and executing plans which supports the company's strategy (Bicheno, 2004). Bicheno (Bicheno, 2004) emphasizes that measurement is waste and therefore should be kept to at a minimum.

The five elements needed in order to implement Standard Work can be summarized as:

- Method: Methods that ensure systemic processes for solving problems should be designed based on the idea of kaizen.
- Integration: Other processes must be integrated into the implementation of Standard Work, as Standard Work cannot stand alone.
- Stakeholders: The stakeholders must be involved in the implementation in order to create ownership and for the Standard Work to take root.
- Execution: Processes that ensure and help the actual implementation.
- Manage: Processes that aid the management and supervision and support the implementation.

Adding Content to Theory

In the following five sections each of the elements found in the first part of this chapter are detailed based on the case studies of Standard Work implementation in Grundfos Denmark and Grundfos Hungary and the experience from Grundfos Management. Five employees are used as sources for this, in the following section The interviewees are only referenced by the Grundfos appreviation for their company and one initial. The interviewees came from the Grundfos Management (GMA), two from Grundfos Denmark (GBJ), and two from Grundfos Hungary (GMH).

Method

Grundfos Denmark has the goal to use Standard Work to form a shared basis for continuous improvement by ensuring that the current processes are documented and standardized. Standard Work is seen as an evaluation tool if problems occur. The following questions were asked if a problem occurred; was Standard Work followed? If no, why not? How can Standard Work be improved to help overcome the problem? (GMA-P, 2012) Standard Work is considered a self-contained document, which operators continuously update without assistance from engineers – unless changes in machinery are needed. Standard Work is thereby used as the foundation for continuous improvement, kaizen events, or problem solving. The latter is a process where Standard Work is scrutinized if a customer complains about quality issues are filed, by investigating if '*Standard Work allows that type of quality problem?*' and if '*Standard Work has been followed?*'. (GBJ-B, 2012) Grundfos Hungary is incorporating Standard Work into continuous improvement, kaizen processes, and problem solving based on the standard developed by Grundfos Denmark. If a problem occurs on the production line, the operators and supervisor have to use the Standard Work as a part for indentifying and solving the problem. (GMH-T, 2012) If operators from Grundfos Hungary have suggestions for improvements of the current Standard Work, they can fill a report which is then sent to the responsible PT engineer. If the improvement is approved by the line supervisor and PT engineer, the current Standard Work is updated and the supervisor is responsible for teaching the new standard to the operators. (GMH-A, 2012)

At Grundfos Denmark, a daily review of Standard Work is incorporated into the supervisor's assignments with the objective to ensure that Standard Work is being used and followed (GBJ-B, 2012). At every line where Standard Work is used a visual card system is placed. If the line supervisor confirms the correct use of Standard Work at a position, the card is turned from red to green. This allows managers to check the use of Standard Work quickly by looking at the cards and gives the supervisor an overview of the current situation. (GBJ-S, 2012) Every linie in Grundfos Hungary is being audited every week by the responsible manager. This audit includes a review of Standard Work (GMH-T, 2012). A visual card system is also being used in Hungary and the supervisors are responsible for checking the use of Standard Work (GMH-A, 2012). After Standard Work has been implemented on a line, the GSE department has a Standard Work review three months after the implementation to ensure that Standard Work is being used. (GMH-T, 2012)

In Table 9 four key points are deducted.

Element	Description
Kaizen	Standard Work should be improved continuously by operators when ways of improving a task is found.
Problem Solving	Standard Work should be a part of the problem solving process when problems occur.
Standard Process	All processes related to the implementation of Standard Work should be standardized.
Systemic Review	Processes that ensure the use of Standard Work should be put in place.

Table 9: Four Key Points for Method

Integration

The Grundfos Group sees a clear correlation between the goal of 5S and Standard Work and strongly believes that Standard Work should be integrated with other lean tools and processes. 5S is seen as a requisite for working with Standard Work. The standards are a result of the 5S process and without the standards it would be impossible to follow the standards in Standard Work. (GMA-P, 2012) This view is shared by Grundfos Denmark, as 5S is seen as the foundation for many lean tools including Standard Work and 5S is incorporated into Standard Work implementation (GBJ-B, 2012) (GBJ-S, 2012). Grundfos Hungary describes 5S as the environment for Standard Work, which enables Standard Work to be an integrated part of the production (GMH-T, 2012).

Grundfos Hungary uses value stream mapping to form a structure for the Standard Work implementation and development. This means that a new Standard Work implementation starts with the development of a value stream map for the production line. Based on the map critical cycle times and processes can be identified and it provides an overview of the material flow, processes, cycle times, and quality. Combined with the more detailed data from Standard Work, the value stream map forms the basis for line balancing in Grundfos Hungary, as processes can be combined, rearranged, or disintegrated in order to balance the work load on the line. (GMH-T, 2012) (GMH-A, 2012) Grundfos Denmark has no direct link between the use of Standard Work and value stream mapping. However both tools are used as part of Grundfos Shop Floor Excellence, but Standard Work implementation does not require a value stream map analysis. (GBJ-S, 2012)

Standard Work has become useful as training and learning documents when new operators are hired or transferred from other lines in the productions of Grundfos Denmark and Grundfos Hungary. The Standard Work sheets serve as the training guide lines and they describe what the operator must do. The processes of devising Standard Work also served as a knowledge sharing

process, where the operators could share "small tricks" with each other. (GBJ-B, 2012) (GMH-T, 2012)

In Table 10 four key points are deducted.

Element	Description
5S	Using 5S creates a environment for Standard Work
Value Stream Map	Using Value stream mapping creates an overview of processes and highlights areas for improvement.
Training	Standard Work should be integrated with training of operators.
Learning	Standard Work should be used for organizational learning, i.e. document results and experience. (Riis & Mikkelsen, 2004)

Table 10: Four Key Points for Integration

Stakeholders

Grundfos Denmark has experienced that operators should be involved in the implementation, which is considered a democratic process. This means that operators should have the possibility to participate and get their opinions heard. The point of this process is to make decisions on a management level that operators will agree with, as their opinions are reflecting in the choices made. The goal of the process is not to get to a complete consensus on every choice, but to ensure that everybody understands the goals and have the possibility to influence the decisions. (GMA-P, 2012) As the implementation process of Grundfos Denmark is operations driven, meaning that operators are responsible, the need for creating strong ownership amongst operators has been defined. Creating ownership has been done by training supervisors and key employees in Standard Work and the other lean tools, but also by delegating the responsibility of the implementation to these persons. (brian) Creating a common consensus from top to bottom in the organization has been identified as important, as the top has to support the implementation and the bottom has to use Standard Work. In order to ensure a broad consensus in the organization, every Standard Work has to be approved by a PT engineer and an employee from the quality department. Standard Work is made by operators which get the final approval from a PT engineer and a quality engineer. This process ensures that the operators approve of the Standard Work description, since they made it. (GBJ-S, 2012)

The implementation of Standard Work in Grundfos Hungary has been a top-down process. Top and middle management along with the engineers have a lot of commitment (GMH-T, 2012). In Buus's (Buus, 2011) study concerning the implementation of lean in Grundfos Hungary, one of the major changes was the management's involvement. The first attempt of implementing lean had little or no support from the management of Grundfos Hungary and the desired results were not obtained. In terms of the second time the management involvement was increased and its role in

the process had been recognized (Buus, 2011). In the current implementation of Standard Work support from management has been an important factor. This has been obtained through training and explanations of Standard Work. Along with the commitment from management, engineers also recognized the need for Standard Work in order to coordinate current operations and improvements in the future. Operators, supervisors, and shift managers have fully accepted Standard Work, but the use of it in every day operations is partial. (GMH-T, 2012)

In Table 11 four key points are deducted.

Element	Description
Consensus	Stakeholders need to agree on the goals and processes in the implementation.
Ownership	Operators have to take ownership of the development of the Standard Work.
Commitment	Stakeholders need to commit to the implementation.
Approval	Both formal and informal approvals of Standard Work descriptions are needed.

Table 11: Four Key Points for Stakeholders

Execution

Simplicity is a key aspect in order for the operation driven process to work. Grundfos Denmark experienced that if too many engineers and managers are involved it will result in complicated and over detailed Standard Work sheets, with more information than needed. (GMA-P, 2012) In the implementation of Standard Work in the UP production lines in Denmark the process has been driven by operators, without involvement of production technology engineers (GBJ-B, 2012). This was based on the idea that by making the people who should use the sheets develop them would create the most value for the company (GBJ-S, 2012). The responsibilities for making the Standard Work sheets were given to production supervisor and key employees with knowledge about all processes in certain areas. These persons received additional training. The lean department in Grundfos Denmark audits the documents to ensure that they are following group standards when it is reported that Standard Work has been implemented for a process. (GBJ-B, 2012)

Practical knowledge is seen as essential part of the implementation process, as stated in one interview:

Practical experience is alpha and omega. You cannot implement it [Standard Work –Edit] just because you have read some theory; you have to have tried it yourself. (GBJ-B, 2012)

Standardized documents are required in order to implement Standard Work. Without these documents communication is complicated and intelligibility is lowered because the standards would be unknown. (GBJ-B, 2012) Grundfos Hungary acknowledges the need for practical experience as a key component in making Standard Work and therefore the responsibility for creating Standard Work descriptions is assigned to experienced operators with knowledge about the processes and Grundfos shop floor excellence. (GMH-T, 2012)

Standard Work has become a valuable tool for knowledge sharing in Grundfos Hungary. Improvements are implemented through updated Standard Work and ensuring that engineers, line management, and operators understand the standards. Line management has become a central part in the knowledge sharing process. Engineers pass improvements to line management which implements it on the line. Improvement suggestions from operators, from all three shifts, are collected by line management and presented to the engineers at weekly meetings, which form the basis for further improvements. (GMH-T, 2012) Standard Work has proven useful in the transfer of production lines from Grundfos Denmark to Grundfos Hungary, as the standards used in Denmark made the training of new operators easier and ensured that knowledge was shared. (GMH-T, 2012)

In Table 12 four key points are deducted.

Element	Description
Operation Driven	The creation of Standard Work descriptions should be done by people from operations.
Standard Documents	All documents related to the implementation should be standardized.
Practical Experience	Creation of Standard Work requires experience from both operations and making Standard Work descriptions.
Knowledge Sharing	Standard Work should be used as a tool for sharing best practices amongst operators.

Table 12: Four Key Points for Execution

Manage

Grundfos Management has recognized the importance of establishing KPIs that reflect the results gained from lean activities, and are currently in the process of developing these. Grundfos Management's experience is that lean activities create results in terms of reduced inventory and throughput times. However proving the financial impact on Grundfos' bottom line is difficult. (GMA-P, 2012) Both in Grundfos Denmark and Grundfos Hungary establishing KPIs that reflect the financial results from lean and the Standard Work efforts is a key component, as these results

are seen as crucial to ensure top management's support (GMH-T, 2012) (GBJ-S, 2012) (GMA-P, 2012). Grundfos Denmark cannot expand the square footage and therefore increases in production have to be gained through better efficiency, as adding new machinery is difficult. This entails that a focus of Grundfos Denmark is to increase the utilization of the current buildings and machinery by increases in efficiency, redesign of lines and processes, and reducing inventory space. (GBJ-S, 2012)

Grundfos Denmark uses *tactical implementation plans* for planning the timeframe and resources for every lean project. This tool allows Grundfos Denmark to plan the project and assign the needed resources. The tactical implementation plan serves as tool for estimating the resources, the time each project will consume, when results should occur, and the expected benefits. Thereby the tactical implementation plan serves as a tool for assessing projects and finding the balance between input and output. After the decision to initiate a project has been taken, the tactical implementation plan is pursued relentlessly. (GMA-P, 2012) In the implementation of Standard Work on production lines in Grundfos Denmark, the tactical implementation plans are used and followed. The plan is seen as a strong and necessary tool for controlling the implementation process. (GBJ-B, 2012) Grundfos Hungary also uses tactical implementation plans for lean projects and shares the view that planning time and resources are important to achieve a successfully implementation of Standard Work. The tactical implementation plan serves as a step-by-step guide and allows resources to the allocated efficiently between projects. These plans have been a central part of the Standard Work implementation. Making Standard Work for work stations involves engineers, operators, and shift management, therefore the plan ensures that the implementation process has deadlines and that resources are only allocated when needed. (GMH-T, 2012) (GMH-A, 2012)

In Table 13 four key points are deducted.

Element	Description
Measurable Goals	Documents progress and consequences, highlight goals.
Visual Results	Create results that can be seen/felt, i.e. redesign workstation or reduce/eliminate inventory.
Timeframe	Create a timeframe for the implementation – follow up on progress.
Resources	Minimize the utilization of resources through planning.

Table 13: Four Key Points for Manage

Framework

By combing the five key elements and their key points, the following framework for the implementation of Standard Work has been developed. The framework is depicted in Figuree 9 below. The framework shows the five key elements and their key points, which in combination handles the different parts of implementing Standard Work. The framework is not a step-by-step

guide, but a guideline for an iterative process in which the different aspects of Standard Work implementation are handled.

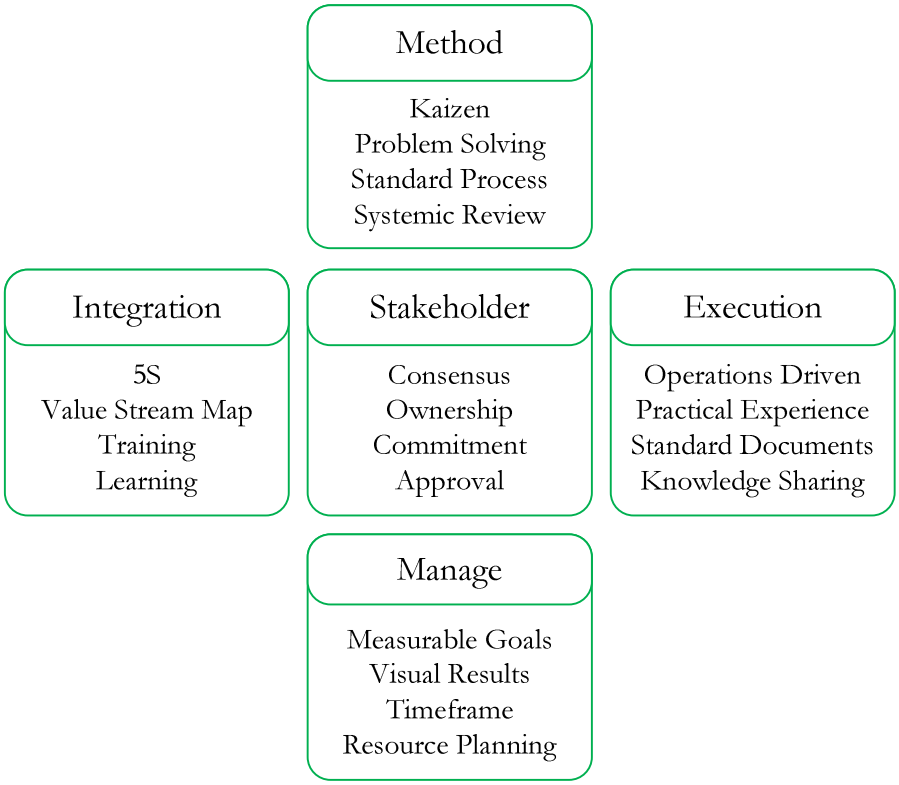


Figure 9: Framework For the Implementation of Standard Work


A2

In this chapter the case study of Grundfos Serbia is presented by using the framework put forth in the previous chapter. The chapter begins with a short introduction to the production in Grundfos Serbia and then the implementation of Standard Work is described based on the five key elements from the framework.

The production line in Grundfos Serbia is an assembly line for UP pumps and all parts are bought from suppliers. The main supplier is Grundfos Denmark which manufactures and supplies the key components. Other components are bought from suppliers located in the rest of Europe and only a few items are bought in Asia. In Figuree 10 the main processes in the production are shown. The flow chart shows 21 of 34 processes and the remaining 13 are fully automated minor processes such as quality assurance, screwing, or moving. The blue processes require human interaction and green processes are fully automated. In Appendix C a full flowchart showing all processes can be seen.

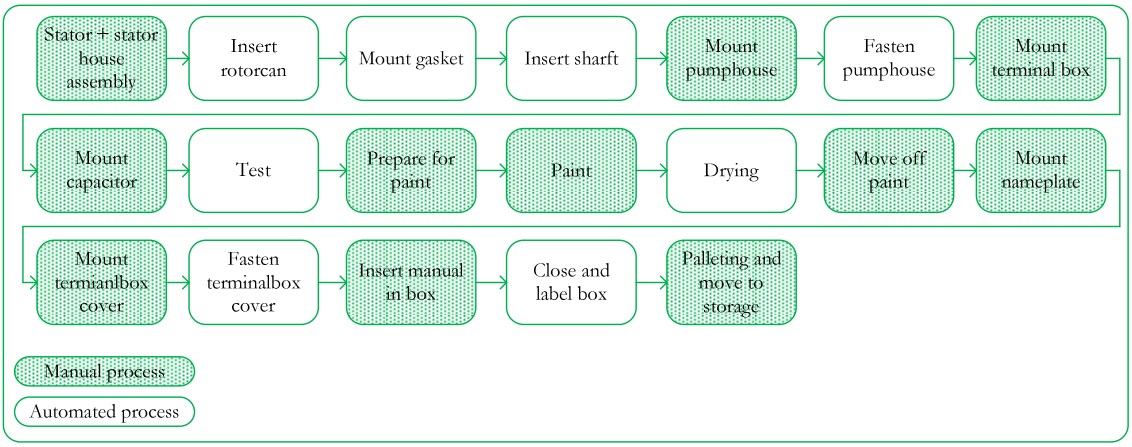


Figure 10: Grundfos Serbia's Main Processes in the Production

In the following five sections each of the elements from the framework are describe based on the case study of the Standard Work implementation in Grundfos Serbia. A summery based on the four elements will be presented in the end of each section.

Method

The implementation of Standard Work at the work stations was done in a three step process, which was represented by the following steps:

- First step: Record the current operation.

- Second step: Based on the collected data a Standard Work description is made.
- Third step: Introduce the new standard to operators and train them.

By recording the current operation, a solid data foundation for making the Standard Work description was made. Two or three different operations were recorded. The recordings were made of normal operations, showing the operator at work with a steady flow of pumps. This was done to provide a recording of the basic situation, but also to expose task done besides direct assembly task the operator undertook. Based on the recordings the Standard Work description was made. For some work stations the recordings showed multiple ways of completing even small task. By documenting all the different approaches and studying the time and movements involved, it was possible to choose one which was time efficient and ergonomically correct. After the Standard Work description was made and put into writing, it was introduced to the operators by a PT engineer during the daily action meeting. The purpose of this introduction was to explain the new standards and ensure that everyone knew what was happening. After the introduction the PT engineer trained the operators in the new standards to make sure that they were fully understood. The Standard Work description was placed at the work station, so it was visible to the operator. After Standard Work had been implemented at a work station, operators could suggest improvements if they had found a smarter way of doing the task. If an improvement was to be suggested, the operator called for the responsible PT engineer who was listed on the Standard Work description. The engineer evaluated the improvement suggestion in regards to time, ergonomics, and quality. If it was needed a small study of the suggested procedure was made. If the suggested meet the criteria, it was approved and adopted as the new standard and introduced the next day at the daily action meeting.

If a customer, internal or external, of Grundfos Serbia, filed a complaint through Grundfos' Customer Complaint System, Grundfos Serbia had developed a procedure for handling the complaint based on Grundfos Shop Floor Excellence. The process is controlled by a quality engineer from the Technical Department who is responsible and a representative for different people involved in the process. Together with the quality engineer, an engineer from logistics and planning, the production supervisor, and operators from the affected work stations a root cause analysis was made. The findings from the root cause analysis could lead to a number of solutions and preventive measures, which were transferred to a A3 report posted in the production. This procedure was developed when the production started in April 2011, but after the implementation of Standard Work it was included into the process. In March 2012 a complaint was filed from Grundfos Hungary regarding a pump with a wrong terminal box mounted. The root cause analysis used and investigated Standard Work. It asked if Standard Work was followed and if it did allow for this type of mistake and if Standard Work could be improved to avoid this type of mistake? The cause of the problem was identified as a mistake in the changeover between orders, when the operators had to shift from one type of terminal box to another. Standard Work was altered, so a confirmation of item number was required in every refill or changeover. Major changes were made

in the storage of the terminal boxes, where visual identification was made easier and two similar looking items were separated.

Element	Summary
Kaizen	A procedure for improving Standard Work was made, which allows operators to make suggestions for improvements.
Problem Solving	Standard Work was incorporated into the existing problem solving procedure.
Standard Processes	A process for implementing Standard Work at work stations were made, which divided the process into three steps. These were followed in each implementation.
Systemic Review	No system for reviewing the use of Standard Work was put in place. The only check would be doing a problem solving process.

Table 14: The Four Key Points of Method

Integration

As described in the introduction to this thesis on page 21, the need for Standard Work was based on the creation of a value stream map for the production line in Grundfos Serbia. The full value stream map can be seen in Appendix A and the initial findings in the Introduction on page 21. The production line in Grundfos Serbia is divided into ten functional areas which each consists of multiple processes. In Tables 15 and 16 the data from the value stream map is showed for each of the ten functional areas. In Tables 15 and 16 the tact, first time through (FTT), up time, and real tact time for each of the functional areas are shown. The real tact time is calculated by adding time for quality and breakdowns to the machine's tact time. For each of the functional areas the main process is mentioned.

Func. Area	1	2	3	4	5
Main process	Stator + statorhouse assembly	Shaft + pumphouse mount	Fasten pumphouse	Mount terminal box	Mount capacitor and test
Tact	6,2	5,7	6,9	5,7	6
FTT	99,95	100	99,88	99,88	99
Up	96,6	100	95,5	99,7	96,2
Real Tact	6,95	5,7	7,61	5,7	6,9

Table 15: Value Stream Map Data Presented by Functional Area. (1 of 2)

Func. Area	6	7	8	9	10
Main Process	Prepare for paint	Paint	Nameplate + cover	boxing	Label + palleting
Tact	5,5	6,4	5,5	5,9	5,4
FTT	100	98,10	100	100	100
Up	100	100	100	100	92,2
Real Tact	5,5	6,5	5,5	5,5	5,6

Table 16: Value Stream Map Data Presented by Functional Area. (2 of 2)

Based on the measurement from the value stream map, it was concluded that Standard Work was needed to create a better flow, as the value stream map showed deviations of one to two seconds. The value stream map served as a guideline and starting point for the implementation of Standard Work, in discussions regarding the next steps the VSM served as data foundation. The phrases "*as we know from the value stream map*" or "*as the value stream map showed*" were commonly used in discussions regarding Standard Work.

Cleaning of machinery was organized through a 5S program in Grundfos Serbia. This was adapted from Grundfos Denmark during the transfer to Serbia and had been further developed. The 5S program was divided into three parts; a daily cleaning, weekly cleaning, and monthly audit. Every day the last ten to fifteen minutes were scheduled for cleaning all the machinery. The main task was to clean hoses and nozzles in the paint cabinet in order to avoid clogging. Once a week two hours were reserved for a thorough cleaning of all machines. For all machines a cleaning description had been made describing the cleaning routine for each piece of machinery. Every month a 5S audit was done by the supervisor and production manager in collaboration. They scored the production in regards to five parts of 5S in a spread sheet. During the audit improvement suggestions were made, i.e. "*this racket could be better organized*", "*Mark the positions for each tool on this work station*", and "*Improve the cleaning routine for this machine*". Based on the spread sheet a 5S score was calculated as a value between one and five. The 5S score influenced the operators' monthly bonuses.

Training of new operators was done by letting them work on a work station with an experienced operator until the operator and supervisor were convinced that the new operator knew how to manage the work station. Managing the work station included knowing the cleaning routines, how to handle machine breakdowns, how to resupply material for the machines, and knowing where to locate documentation for cleaning, maintenance, and Standard Work. During the transfer of the line from Denmark to Serbia, a number of Serbian employees, supervisors and engineers were trained in Denmark by working with Danish operators and engineers. After the machinery was transferred to Serbia, a team of Danish operators stayed one month in Serbia to train the Serbian operators in using the machinery. In June 2012 Grundfos Serbia expanded with a second shift

which entailed the addition of 16 new operators. These new operators were trained by 16 experienced operators. The new operators were divided into two groups of eight people and eight new operators and eight experienced operators were joined together as one new team. Standard Work was not a part of the training, but the new operators had to know where it was located and what it meant.

Element	Summary
5S	A procedure for 5S has been incorporated into the production in Grundfos Serbia, which entails that all work stations are clean and organized.
Value Stream Mapping	The creation of a value stream map served as a starting point and foundation for the implementation of Standard Work. The value stream map was not for line balancing.
Training	Standard Work was a part of the training programs.
Learning	Organizational learning was not documented by updating Standard Work, nor was a process for this put in place.

Table 17: The four Key Points of Integration

Stakeholders

In December 2011 a series of lean training sessions were held at Grundfos Serbia to increase the awareness of GSE and the tools and technique it contained. The sessions were based on a game developed by the Grundfos Group which simulated a lean implementation process in four steps. In the first step a production set-up with no flow and lots of storage and transportation were used. In three iterations the participants could improve the set-up by using the tools and techniques incorporated into GSE. Every employee participated in the game and the work force was divided into four teams in total: Management and support staff, technical and logistics department, and operators and warehouse operatives divided into two teams. The training session for the management and support staff team, and technical and logistics team was four hours in the afternoon with focus on playing the game. Training for operators and warehouse operatives was scheduled to last an entire day where the first four hours were used for explaining the idea behind GSE and what it entailed and the final four hours for playing the game. In Figuree 11 four pictures from the training sessions can be seen.

Figur 11: Four Pictures From Training Sessions

During the four hours the game lasted, every team managed to increase the profit in their company by minimizing inventory and work-in-progress, reduce through put time and reduce the number of employees from seven to three or lower. The results from the game were posted on an information board in the production and a small video from the event was made.

In section "method" the implementation process of Standard Work on one work station was described as a three step process. The operator involvement in this process was in the first step which was the recording phase and in the third step which was the introduction on the line. Before the recording started the operator was advised and helped in finding a timeslot when operations were normal, i.e. flowing production of mass produced pumps and not a smaller order with special parts. During the recording the operators assisted in documenting the purpose and reason for small tasks, which were performed besides the actual assembly tasks on the production line. In the introduction phase the operators were involved in the implementation of Standard Work on the line and after having received training from a PT engineer the operators used the Standard Work on the line and provided feedback. If the operator had any improvement suggestions the PT engineer used them as a basis for a kaizen process, see section "method". In the second step, the engineer responsible for making the Standard Work description had to obtain a formal approval from a senior engineer in order to proceed to the third step.

Element	Summary
Consensus	Through training sessions in GSEa consensus regarding what Standard Work was and how it worked was achieved.
Ownership	By involving the operators in the recording and introduction phases in terms of the implementation, it was attempted to create ownership.
Commitment	Through the training sessions a commitment to GSEwas created.
Approval	Formal approval had to be obtained from a senior engineer and informal approval from operators was obtained through involvement and the possibility to suggest improvements.

Table 18: The Four Key Points of Stakeholders

Execution

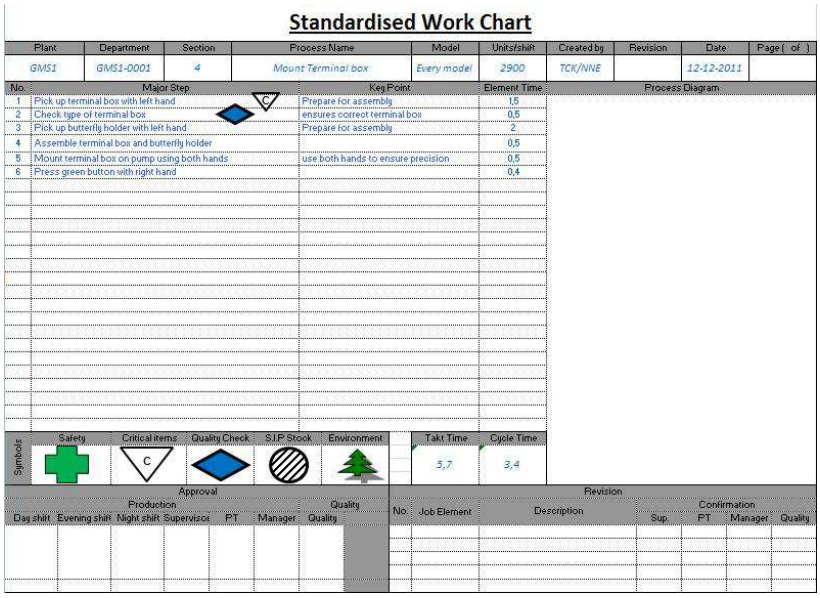
The general responsibility for the Standard Work implementation process was given to the Technical Departments. These have four major areas of responsibility: production, quality, building maintenance, and new product introduction. GSEconsists of 23 different tools. Five of these were mandatory to use: 5S, VSM, Preventive maintenance, daily action meeting, and Standard Work and usage of the others were optional. Grundfos Serbia had decided to use all tools. Every tool was assigned to a person who had the responsibility of implementing it, but was given different goals for the usages and timeframes for the implementation. As described in section "method" and section Stakeholder on page 79, the implementation process was divided into three steps which were managed by the Technical Department with support from operators.

In order to document Standard Work, Grundfos has developed three sheets in collaborating with Lean Consulting. The three documents are used for documenting Standard Work, but on different levels and with different scopes. The three sheets are:

- Standard Work Combination Table: Used to describe the work and processes in multiple work stations.
- Standard Work Chart: Used to describe the work and processes in one work station.
- Standard Work Job Element: A detailed description of one process.

If one operator handled multiple work stations, the combination table would be used to describe the order in which the operator would move between work stations and the amount of time used at each. The Standard Work chart would describe the job at each work station by breaking it down into the individual steps and time usages and the job element sheet would detail each step. After consulting lean agents from Grundfos Denmark, it was determined that the focus for Standard Work in Grundfos Serbia would be to use the Standard Work chart. No operator handled multiple work stations or had such a high amount of processes that the combination table should be used, nor did any step require more detail than what could be described in the Standard Work chart.

Thereby making the job element sheets obsolete. In Figure 12, the Standard Work chart for "terminal box mount" is depicted. In the final version an illustration and formal approval are added.



Standardised Work Chart

Plant	Department	Section	Process Name	Model	Units/shift	Created by	Revision	Date	Page (of)
GMS1	GMS1-0001	4	Mount Terminal box	Every model	2900	TCK/NNE		12-12-2011	

No.	Major Step	Key Point	Element Time	Process Diagram
1	Pick up terminal box with left hand	Prepare for assembly	1,5	
2	Check type of terminal box	ensures correct terminal box	0,5	
3	Pick up butterfly holder with left hand	Prepare for assembly	2	
4	Assemble terminal box and butterfly holder		0,5	
5	Mount terminal box on pump using both hands	use both hands to ensure precision	0,5	
6	Press green button with right hand		0,4	

Symbols	Safety	Critical items	Quality Check	S.I.P. Stock	Environment	Takt Time	Cycle Time
		C				5,7	3,4

Approval								Revision					
Production						Quality					Confirmation		
Day shift	Evening shift	Night shift	Supervisor	PT	Manager	Quality		No.	Job Element	Description	Sup.	PT	Manager	Quality

Figure 12: Standard Work Chart for Terminal Box Mount Process

In the top row all formal information regarding plant, process, creator, and date is presented and in the middle section there is a step-by-step description of the work process, along with key points and times for each step. Symbols can be added to individual steps to visualize the importance of the process. In the bottom of the chart the formal approval and information regarding updates are placed.

The experience with and knowledge about Standard Work in Grundfos Serbia were mainly derived from theoretical knowledge and experiences from training seminars, but no practical experience from Standard Work or lean implementation existed. All members of the Technical Department had acquired knowledge about lean by studying and participating in a work shop, as described in the section Stakeholder on page 79. In February 2012 GSE work shop was held in Grundfos Serbia, where European production companies, lean agents from the European production companies were represented. The main topic of the workshop was Standard Work, as the other of the five mandatory tools had been already been the topics of other workshops. A part of the workshop the participants should develop a Standard Work chart for a work station and the process followed the three step process used in Grundfos Serbia. During this process the experiences that the Danish and Hungarian participants had from the lean implementations in their

respective companies were clear. Based on their experiences, they were able to identify problems and find solutions faster and involve other processes in the solution.

During the recording phase of the implementation, it was found that many different approaches were taken to do task. For any process, three to five operators were trained, the recording showed that almost everyone did the task differently and often one operator could do the same task in multiple ways.

Element	Summary
Operations Driven	The implementation was managed by the Technical Department with support from operators.
Standard Documents	A document developed by Grundfos Denmark and Lean Consulting was used for Standard Work charts.
Practical Experience	The experience and knowledge about Standard Work were based on self study and participation in a lean work shop
Knowledge Sharing	Recordings of operators showed that each task was done in multiple ways.

Table 19: The Four Key Points of Execution

Manage

The implementation of Standard Work was done according to a time schedule, which was based on the goals for GSE. For 2012 Grundfos Serbia had made targets for the implementation of all 23 tools on a scale from one to five, where one means barely used and five is fully implemented. For 2011 the goal for Standard Work was given the number one, meaning that general knowledge about Standard Work was present in the factory and that Standard Work had been made for at least one work station. For 2012 the goal was set to three, meaning that Standard Work was being implemented according to GSE standards and at least 50 percent of all work stations were covered by Standard Work. By the end of 2011 two work stations were covered by Standard Work and a time schedule for covering the rest of the stations by the summer of 2012 was made. A schedule loosely defined the order and deadline for covering the work station, but did not take resource management into account. As mentioned in the introduction Grundfos Serbia was building a new plant in 2012 with a completion deadline in November 2012. This meant that the Technical Department had to handle additional projects regarding transfer of the current production line to Serbia and lines from other factories to the new plant and the building of a completely new production line. By the end of 2012, 10 of 14 work stations had been covered by Standard Work.

The goal for implementing Standard Work was to assist in achieving a ten percent increase in productivity by the end of 2012, which was stated when the value stream map was made.

Productivity was measured on a monthly basis and was based on the man hours used in production, hours of production, and number of pumps actually produced. At the place where the daily action meetings are held, there is a board which has different KPIs related to production posted, as seen Figuree 13. The KPIs include: health and safety, environment, delivery, and production.

Figure 13: KPI Board at Daily Action Meeting Area

At the daily action meeting these KPIs serve as the starting point and form the basis for the agenda. Several of the KPIs affect the operators' monthly and yearly bonuses. The numbers for productivity are no updated frequently, as data has to be collected from finance regarding man hours and production numbers through SAP, since the productivity calculation is not based on the production number posted on the daily action meeting.

Element	Summary
Measurable Goals	Standard Work should contribute to a ten percent increase in productivity, but no KPIs for Standard Work exist.
Visual Results	Some visual changes were made. As described in the section "method" a problem solving process lead to changes in inventory layout.
Timeframe	A loose time schedule was made for the implementation
Resources	No resource plan was made for the implementation.

Table 20: The Four Key Points of Manage


A24

Analysis and Solution

The purpose of this chapter is to analyze the case based on the case study presented in the previous chapter and highlight the strengths and weaknesses in the implementation. Based on this analysis five propositions are made for improving the Standard Work implementation. Finally some considerations regarding implementing the suggested propositions are made.

The case study showed that Grundfos Serbia introduced a standard process for implementing Standard Work on a work station in the production line. Standard Work was introduced through a three step process which was based on analyzing the recordings of the operators. Standard Work was integrated into problem solving activities and a procedure for continuously improvements was made to ensure that Standard Work was used. Besides these three initiatives for introducing and using Standard Work in everyday operations, the study also showed that no method for systematically reviewing the use of Standard Work was put place. The lack of a system for reviewing the use of Standard Work meant that no the usage of Standard Work on the work station were uncertain. This meant that improvements made in the kaizen process for continuous improvement or through problem solving might not be used by all operators and that some of the foundations for the problem solving process might not be valid. As described in the Framework chapter on page 69 Grundfos Denmark and Grundfos Hungary had implemented systems for auditing and reviewing the use of Standard Work to ensure that Standard Work was used by the operators.

Grundfos Serbia has worked with 5S since the production started in 2011 and therefore 5S has become part of the work culture in the operations. As explained in the case study, 5S was being use daily by operators when cleaning machines and the production area. 5S had become an everyday tool as it is used and valued by the operators. In terms of implementing Standard Work, 5S had to be part of production routines as explained in the framework chapter. 5S had provided the foundation for implementing Standard Work in Grundfos Serbia, as the work station was well organized and clean. The reason for starting the Standard Work implementation, as explained in the introduction, was the findings from a value stream map analysis of the production. By using the value stream map, the implementation of Standard Work was based on a solid data foundation upon which improvements and affects could be measured as the starting conditions were known. The findings from the value stream map analysis made it possible to direct efforts towards the work stations in the production which needed improvements in order to increase flow. Grundfos Serbia has started to use Standard Work in the training of operators by ensuring that every operator knows about Standard Work and where to find the standards. However Standard Work has not been incorporated directly into the training and is not used as a tool for teaching operators how to do a job. A process for incorporating Standard Work into organizational learning was not made either. This entailed that new knowledge was not documented by updating standards.

The major part of involving the stakeholders and creating an understanding of lean was the lean workshop in which all employees participated. These workshops assisted in creating a consensus about what GSE consisted of and commitment towards getting it implemented, as people saw the value of GSE. As described in the case study, operators were involved in the introduction of Standard Work to the production by participating in two of the three steps when making Standard Work for a work station. This was done in order to involve the operator and create ownership towards the Standard Work description. The goal of involving the operators in the making was to get them to feel responsible for that standards were done correctly and were updated. In addition informal approvals from operators were sought in order to ensure that the Standard Work description was consistent with reality. This reinforced the feeling of ownership and strengthened the commitment towards Standard Work. As explained above, no system for reviewing the use of Standard Work was adopted, which entailed that there was no valid evidence regarding the actual use of Standard Work. The author of this mater thesis observed during the internship that operators in general followed the standards, but they did not take ownership of Standard Work.

The case showed that the implementation process for Standard Work was managed and driven by the Technical Department. The Technical Department had the full responsibility for making the Standard Work descriptions for all work stations. Even though the department had support from the operators, it was still the department's task to make a Standard Work description based on the collected data. By using a standard document developed by Grundfos, it was assured that the Standard Work descriptions met the standards of Grundfos. This provided a solid starting point for the implementation. Using the Grundfos document also provided a standard for Standard Work descriptions which was acknowledged companywide and made knowledge sharing between companies easier as the same document was used.

Compared to other Grundfos companies with experiences with lean Standard Work, the fact that Grundfos Serbia did not have any practical experience with the implementation of Standard Work made its implementation process slower and much less efficient. The knowledge sharing between operators when making Standard Work descriptions was limited to provding their inputs to the Technical Department. This department used this information in the creation of the Standard Work descriptions. This meant that knowledge sharing was taking place to some extent, but it was still a centralized process managed by the Technical Department.

The implementation of Standard Work was based on a loosely defined time schedule and resource management was not taken into account in the planning. The goal was to have finished making Standard Work descriptions for all fourteen work stations by the summer of 2012. However at the end of 2012 Standard Work descriptions had been made for ten work stations and thereby less than planned, but more than the seven which were expected by management. Grundfos Serbia's major task in 2012 was the construction of the new plant and all the preparations needed for this. Since no resource plan existed for the Standard Work implementation resources were diverted to the

construction project. Grundfos Serbia did not have any KPIs related to the lean or Standard Work results. A number of KPIs measured the performance of the production line both in terms of actual production and efficiency, but also health and safety, and environmental impact. Changes in these KPIs could be a result of the benefits gained from Standard Work or other lean projects, but could as well be the result of planning, changes in the organization, or logistics. Through the implementation of Standard Work a few visual changes were made, which enhanced the feeling of "*something is happening*" and thereby increased the commitment to implementing Standard Work.

Solution

Based on the analysis in the previous section, this section will present five propositions for improving the implementation of Standard Work.

Proposition 1: Implement a System for Reviewing the Use of Standard Work in the Production.

Figure 14: Proposition 1.

In the case study it was found that Grundfos Serbia did not have a system for reviewing the use of Standard Work done by the operators. This meant that data regarding the actual usage of Standard Work was unreliable as established in the analysis. Furthermore the missing review system hardens the implementation process, as it could have prevented operators from falling back to old habits. Control systems in a lean production should be kept at a minimum, as they do not add value and as such is not necessary in culture where the use of Standard Work has been established (Liker, 2004). However in a change situation where Standard Work is being implemented, the review system would keep operators from falling back to old habits (Cameron & Green, 2009). As found in the Framework on page 69 both Grundfos Denmark and Grundfos Hungary have established a review system in order to ensure that operators use Standard Work and obtain the results from using Standard Work. The Standard Work implementation world be supported by implementing a review system where either a supervisor or production manager is responsible for checking that operators follow the work instructions from Standard Work. The review system could also lead to a KPI or other indicator, such as a t-card system, for monitoring and supporting the use of Standard Work.

Proposition 2: Standard Work descriptions should be made by operators with support from the Technical Department.

Figure 15: Proposition 2.

In the case study it was found that the implementation of Standard Work was managed and controlled by the Technical Department with support from operations. This was due to the fact that the Technical Department was responsible for all three steps in the process of making a Standard Work description and also the formal goal for using Standard Work was linked to the department. As mentioned in the literature review, both Liker (Liker, 2004) and Bicheno (Bicheno, 2004) point out that the implementation of Standard Work should be driven by operators in a bottom-up process. In such a process each operator is responsible for making and maintaining Standard Work in terms of their own work place. The implementation processes of Grundfos Denmark and Grundfos Hungary are driven by operators. For each line one experienced operator is given the task of making the Standard Work description for the work station and is assisted by the operator of the work station. In the current situation many new operators have been hired and changes in the organization take place. In 2012 32 new operators were hired to handle evening and night shifts and 2 new operators with '*special needs*' were hired in accordance with Grundfos CSR profile. In addition six new operators were hired to replace six operators who moved to new positions in the organization. In the beginning of 2012 there were 16 operators. Using the process proposed by the literature might not be feasible in the case of Grundfos Serbia, as new operators do not have experience with GSE or lean production. By using the approach from Grundfos Denmark and Grundfos Hungary, one or two experienced operators could be trained to make the Standard Work descriptions and teach new operators how to use them. Thereby operators at the work stations will have the responsibilities of updating and improving the standards when needed.

Proposition 3: Involve One or More Persons With Practical Experience About Standard Work in the Implementation.

Figure 16: Proposition 3.

Grundfos Serbia did not have any employees with prior experience in working with Standard Work before the implementation began. This lead to a less efficient implementation and was properly not the best solution. As explained in the case study, the employees, from Grundfos Denmark and Grundfos Hungary with experience in terms of Standard Work, solved problems faster and came up with better solutions when faced with implementing Standard Work at Grundfos Serbia. Grundfos Serbia has two options for brining in people with practical experience; consultants can be hired from an external company or the internal resource from other parts of the Grundfos organization can be used. Both Grundfos Denmark and Grundfos Hungary use lean consultants from Lean Consulting in their implementation processes of GSE. The consultants serve as coaches for the lean agents and operators involved in the implementation. Another option could be to utilize the knowledge and experiences Grundfos already has by repositioning an employee. In the training of PT engineers for the first production line in Serbia, the engineers spent half a year in

Denmark where they worked with and were trained by the Danish PT engineers. The same approach could be used for gaining experience with Standard Work and lean by relocating an engineer from Serbia to Denmark in order to gain experience in working with Grundfos Shop Floor Excellence. The weakness of this approach is that the process of Grundfos Serbia would be put on hold during the training. Thereby the opportunity for creating a GSE culture in the new plant will be missed, see proposition 5 below. Another minor weakness would be that the experience would be gained within a Danish culture working with lean, which has been built in the last three years. A strong point for the approach is that Grundfos Denmark has a number of employees with experience, lean consultants attached, and many ongoing lean projects. Another option would be to relocate a Danish or Hungarian employee to Serbia to help the implementation and serve as a coach during the process. A drawback to this approach is that the implementation is limited to ongoing lean projects at Grundfos Serbia and that the Serbian employee would not be involved in major projects as these are taking place in Denmark and Hungary. In support of the option of using the experienced employee's knowledge in the projects of Grundfos Serbia, thereby training more people and develop the knowledge within a Serbian mindset. In both cases, a mentor/coaching program should be set up to further enhance training and knowledge sharing.

Proposition 4: Utilize a Tactical Implementation Plan for Time and Resource Planning.

Figure 17: Proposition 5

As the case study showed the implementation was only guided by a loose time schedule and no resource planning existed. This entailed that the implementation did not reach the goals put forth as resources were diverted to other projects. By utilizing a tactical implementation plan it would be possible to both plan time and resources for the implementation of Standard Work. This plan was used by both Grundfos Denmark and Grundfos Hungary. Figuree 18 depicts a raw tactical implementation plan used by Grundfos Denmark and Grundfos Hungary.

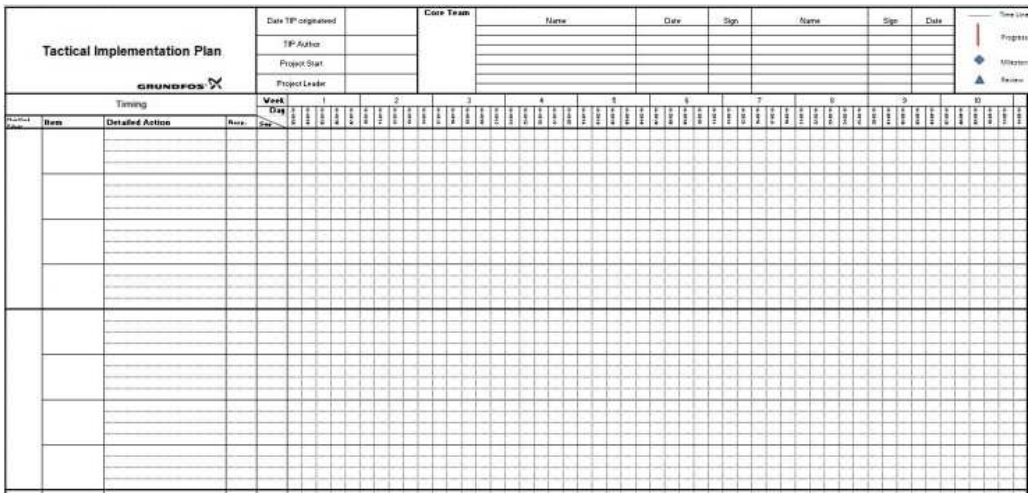


Figure 18: Tactical implementation plan

In the left columns the different tasks and the resources assigned to them are listed and their completion dates are marked under the date. Every day a red line is drawn from the date to the bottom of the plan. If a deadline has not been reached the red line makes an arrow towards the missed deadline, as illustrated in Figuree 19.

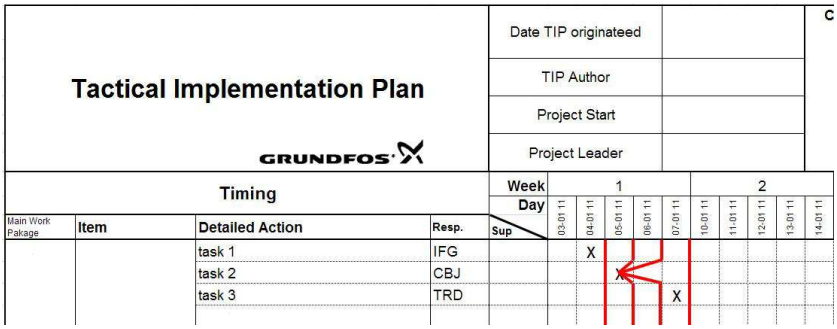


Figure 19: Example of Tactical Implementation Plan With Missed Deadline

By utilizing the tactical implementation plan, Grundfos Serbia could improve the planning of resources and time for the implementation of Standard Work.

Proposition 5: Establish Grundfos Serbia as a GSE plant.

Figure 20: Proposition 5

A major theme in the Lean literature is to make lean a part of the organizational culture and corner stone in the production (Liker, 2004). Grundfos Serbia in the start of 2013 moves to an entirely new plant and will increase the work force throughout 2013 and 2014. This could be used as an opportunity to create this culture on the production floor. Grundfos Serbia's new plant could be established as a GSE factory, where every new production line uses Standard Work from the beginning. This would entail that all new operators were trained in using Standard Work and acquired knowledge about lean production and the ideas in the lean philosophy. Before a new production line could start, Standard Work descriptions would have to be made for all work stations and other tasks related to supplying and maintaining the line. Making Grundfos Serbia a GSE plant would require investment, commitment, and a genuine believe in the concept from Grundfos Management. The result could be a factory where GSE was the standard and not something that had to be implemented and required changes in people's habits and routines.

Implementation

The first thing that Grundfos Serbia needs to do is to make a decision regarding proposition five, which suggests that Grundfos Serbia should become a GSE factory, as this decision will affect all other projects. If Grundfos Serbia chooses to follow this strategy, it will affect the already ongoing projects of transferring the line from the current plant to the new and the installation and start-up of an entirely new production line which will be installed in the beginning of 2013. It will also entail that the decision concerning the relocation of an employee for training and knowledge sharing regarding GSE should be made quickly. To support the process it should involve adding a resource to Grundfos Serbia or relocating an employee. If Grundfos Serbia chooses not to accept the proposition the time frame becomes a little wider.

Secondly, a decision regarding how to train a Grundfos Serbia employee in GSEshould be made. As explained above there are three possibilities with different implications. If Grundfos Serbia chooses to hire external consultants or an employee from another company is relocated, the implementation could continue. If an employee from Grundfos Serbia is relocated to Denmark to receive training, the implementation should be postponed while the training is done, as the knowledge and experience from the training are important parts of the implementation.

After the two major strategic decisions have the made, a tactical implementation plan should be made for the implementation process and a process for reviewing the use of Standard Work should

be put in place. The tactical implementation plan will create a time frame and allocate the needed resources for the implementation of Standard Work, thereby making a clear and visual presentation of the process. It should be posted in the production area where the production line is placed to show and clarify the next steps and deadlines to the involved employees. By making a process for reviewing the use of Standard Work, it is ensured that more reliable data regarding the results will be available and it is ensured that operators actually use Standard Work. The responsibility for making the reviews should be handed to someone who is daily present in the production area and know the different processes. This could most likely be a supervisor or production manager. The review should be linked with an indicator or visual chart posted in the production area, which showed which processes that have been checked that day. The review should not be to time consuming and should be seen as an activity that does not add value. If the supervisor knows the standard for all processes the review could be done doing the normal workday.

Shifting from an implementation process driven by the Technical Department to one that is driven by operations, with support from the Technical Department, is an important change. Both Grundfos Denmark and Grundfos Hungary have had success with a set-up where one operator is removed from the line and made responsible for making the Standard Work descriptions for work station. Grundfos Serbia could copy this set-up which should be included in the tactical implementation plan. By having this set-up the implementation would be done by operations with support from experienced engineers from the Technical Department. The operator has the understanding from working on the line and the engineer has the experience to help the operator with finding good and reliable solutions to problems.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Discussion

This chapter will contain a review of the theory, method, and case study used in this master thesis. The chapter further discusses the academic and practical contributions of the research, its generalizability, and its weaknesses. At the end of the chapter some suggestions for further research are put forth.

The academic foundations for this thesis were lean production, Standard Work, and knowledge management. These areas of theory were investigated and explained in the literature review. These areas were chosen based on the problem statement put forth, which concerned how Grundfos Serbia could implement Standard Work. By reviewing the literature about lean production, the principles of lean production were found along with the different elements of lean, where the Toyota Production System House was used as a basis. This approach provided a broad understanding of what lean production entailed and what it consisted of, which was used to develop the framework. Standard Work was reviewed by looking at the historical origin, where the American training within industry was transferred to Japan after WWII. This provided a deeper understanding of elements and benefits of Standard Work. Knowledge management was the last topic investigated in the literature review and focus was concerned with the transformation of tacit knowledge into explicit knowledge. In combination these three subjects presented a well rounded foundation for understanding the theory behind Standard Work implementation. Other subjects which could have been included are organizational theory and change management. These could have added some additional perspectives and points to the thesis. Considerations regarding people behavior and management of organizations could have been included from organizational theory. Change management could have provided considerations about how to manage a change process. However these were not included as it would have been beyond the scope of this thesis.

The methods used for studying the phenomena were both case study and participatory observation. These were considered to be appropriate in terms of collecting data. Both case studies were based on qualitative methods for data collection. In the study of Grundfos Serbia interviews with five employees and participatory observations of the company were the sole data sources. In both cases quantitative methods could have been used to collect a broader data foundation. In the case study of Standard Work in Grundfos Denmark and Grundfos Hungary, a questionnaire could have focused on the results gained from Standard Work by collecting data from operators. Productivity and efficiency data could also have been collected, reflecting the production before, during, and after the implementation of Standard Work. For the participatory case story of Grundfos Serbia, formal interviews with operators and management could have added validity and more nuances regarding the implementation. Actual production and efficiency data could have exposed the results from implementing Standard Work. During the internship some data was gathered about actual production. However as the implementation process was not complete at the end of the internship

and took place over several months, this data does not reflect the results from the implementation, but rather other factors such as planning, breakdowns, vacation etc.

The overall data collection was structured as a three step process. Based on the literature review five elements for implementing Standard Work were found. Case studies of Grundfos Denmark and Grundfos Hungary made it possible to add four key points to each of the five elements. Lastly the created framework was used to study the implementation process in Grundfos Serbia. The case studies of Grundfos Denmark and Grundfos Hungary were based on five interviews with engineers or managers directly related to the implementation process in the factories. As mentioned above additional data could have been collected either by conducting extra interviews or collecting actual data from the production. More interviews might have added extra information and nuances to the case study, especially if the interviewee was an operator. During the process of making the five interviews, it was clear that the margin value of each additional interview was declining. The first interview provided a lot of information and perspectives, the next two with employees from Denmark and Hungary changed some of the initial perspectives, and the last two added some minor details and confirmed some prior observations. This entails that the margin value of additional data might not correspond with the needed investment in terms of the time both interviewer and interviewee should use, preparation, and resource requirements i.e. meeting room and computer logged with access to the conference system. For the study of Grundfos Serbia, additional data would have contributed with more value as the data collection was based on observations and informal talks during the work days.

One of the three research objectives for this thesis was the development of a framework for the implementation of Standard Work. On page 70 a framework based on literature reviews of lean production, Standard Work, and knowledge management and experience from Grundfos Denmark and Grundfos Hungary were presented. The framework provided the basis for the study of the Standard Work implementation in Grundfos Serbia and lead to five propositions for improving the implementation process based on the findings. The study confirmed the relevance of the five elements presented in the framework. However this does not mean that the framework covers all elements needed in implementing Standard Work. The work of this thesis could have had some unintentionally biased observations, meaning the interviews and study could be influenced by the author's own experience. The observation bias is sought to be minimized by using multiple sources in regards to literature and different Grundfos companies.

No framework for implementing Standard Work was found through the literature review. Therefore this thesis offers a comprehensive framework which includes elements from lean production, Standard Work and knowledge management, and empirical findings from Grundfos. The framework does not have a high degree of generalizability as the empirical findings are limited to three Grundfos companies. Thereby it is difficult to generalize it to other organizations. The case study provided further insight into the implementation of Standard Work and highlighted the need

for practical experience which the literature does not cover. This observation was further backed by the analysis of Standard Work in Grundfos Serbia, where limited experience with Standard Work affected the implementation.

The practical contribution of this thesis for Grundfos is a guiding framework for Standard Work implementation, as the framework highlights all the important elements that should be considered in the implementation process. The framework should be used as a guideline for the implementation in an incremental process as described in the Framework chapter on page 61. Since the process is iterative, all elements must be used continuously and not be considered done with after one iteration.

The major weaknesses of this thesis are the narrow scope which is limited to only study Grundfos, and the inability to test the usefulness of the framework in practice. For further research the framework should be tested by using it in an actual implementation and thereby obtain data and knowledge about its usefulness and robustness. The framework should be tested both in a Grundfos company, but also in other companies thereby expanding the scope of usability. Furthermore, additional research is needed in terms of how to measure the success of Standard Work implementation, as it is proved that a causal link between Standard Work and improvements in efficiency and productivity is impossible with the current measuring tools. Finally, more research about how to efficiently allocate resources and plan the implementation should be made, as these are major areas of the actual implementation but hardly covered in the literature.

Conclusion

Through a value stream map analysis of the production line in Grundfos Manufacturing Serbia it is found that the efficiency of the line could be improved. In addition, it is found that the implementation of Standard Work could assist in increasing the efficiency. This leads to the following research question: *How can the Standard Work implementation process in Grundfos Manufacturing Serbia be improved?*

To analyze the implementation process and improve it, a framework is made. Five elements are identified, to be crucial for the implementation process, based on a literature review. Case studies of Standard Work implementations in other Grundfos manufacturing companies are made in order to elaborate on the five elements. The result is that each of the five elements, found through the literature review, are expanded with four key points. This leads to a framework for Standard Work implementation and can be seen in Figure 9 on page 70.

To test the framework and analyze the implementation of Standard Work in Grundfos Serbia, a case study of this process in the company is conduced. This case study finds evidence to support the relevance of the elements presented in the framework. In regards to element named method the case study confirms the need for standardized processes in which Standard Work can be implemented and improved. In addition Standard Work can also be used as a tool for problem solving. The need for incorporating other processes into Standard Work and integrate Standard Work in training and learning processes are confirmed when investigating the integration element. The case study supports that stakeholders need to be involved in the process and a bottom-up process for implementing Standard Work should be used. The empirical evidence also supports the need for processes and knowledge to support the implementation. Finally, the case confirms the need for processes that can aid management and people involved, but creating processes for managing the implementation.

Five propositions for improving the implementation process are found based on the analysis using the framework. The five propositions range from high level strategic decision to the use of daily reviews. The wide span in both improvement propositions and elements in the framework suggest that the Standard Work implementation is a complex task, which requires a comprehensive framework and approach. Implementing Standard Work is not a straight forwards task and success requires a framework which includes all the different aspects. This thesis offers such a framework.

Appendix A

FTT and Uptime data are not available.

	Process		Inventory	
	cycle time	takt time	min time	max time
Assembly of stator and stator house	166,6	6		
FIFO			76	
Move to lower conveyor1	6,7	4,3		
FIFO			10,3	
Mount small gasket	4,7	4,7		
FIFO			5,2	
QC small gasket	4,2	4,2		
FIFO			7,6	
mount rotorcan	5,8	5,8		
FIFO			22,7	
mount big gasket	5,8	5,8		
FIFO			6,4	
qc rotorcan + big gasket	4	4		
FIFO			31,2	
assemble rotor and sharft	96	6		
mount rotor and sharft	16,2	5,7		
FIFO			13,6	
mount pumphouse	2,5	2,5		
FIFO			10,7	
fasten pumphouse1	12,6	6,2		
fasten pumphouse2	13,6	6,2		
FIFO			33	50,8

qc of screws	4,9	4,9		
FIFO			9,3	
move to upper conveyor	9	6,9		
fifo			219,8	575,7
Move to lower conveyor2	5,7	5,7		
FIFO			14	
Mount terminalbox	3	3		
FIFO			13,7	
fasten terminal box	3,3	3,3		
FIFO			20,1	
fasten groundscrew	3,3	3,3		
FIFO			14,6	
mount capacitor	3	3		
FIFO			12	
fasten capacitor	1,9	1,9		
FIFO			14	
tester 1, 2, 3, and 4	24	6		
queue			36,4	52,6
mount dummy cover	2	2		
unlock pallet	5,3	5,3		
Buffer				
move to paint gondola	5	2,5		
paint	39,2	6,4	6,4	
drying	2711	6,4		
remove from gondola + QC	3,7	3,7		
queue				
Montage	12	4		
FIFO			160	

add manual + bolts	3,6	3,6	
FIFO			4,2
boxing	9,8	5,5	
FIFO			14,5
labelling	5,4	5,4	
FIFO			24,4
palleting	6,2	6,2	

Appendix B

Appendix C

Process number	Process Name
1	Assembly of stator and stator house
2	FIFO
3	Move to lower conveyor1
4	FIFO
5	Mount small gasket
6	FIFO
7	QC small gasket
8	FIFO
9	mount rotorcan
10	FIFO
11	mount big gasket
12	FIFO
13	qc rotorcan + big gasket
14	FIFO
15	assemble rotor and sharft
16	mount rotor and sharft
17	FIFO
18	mount pumphouse
19	FIFO
20	fasten pumphouse1
21	fasten pumphouse2
22	FIFO
23	qc of screws
24	FIFO
25	move to upper conveyor

26	fifo
27	Move to lower conveyor2
28	FIFO
29	Mount terminalbox
30	FIFO
31	fasten terminal box
32	FIFO
33	fasten groundscrew
34	FIFO
35	mount capacitor
36	FIFO
37	fasten capacitor
38	FIFO
39	tester 1, 2, 3, and 4
40	queue
41	mount dummy cover
42	unlock pallet
43	Buffer
44	move to paint gondola
45	paint
46	drying
47	remove from gondola + QC
48	queue
49	Montage
50	FIFO
51	add manual + bolts
52	FIFO
53	boxing

54	FIFO
55	labelling
56	FIFO
57	palleting

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