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autumn 2010, Lund

Making HES more Lean

- Identification and reduction of waste

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Preface

Alfa Laval Lund AB in Ronneby had identified the need of balancing the production flow at Heat Exchanger Systems (HES) for making their production of district heating systems more efficient. As a response to that we performed, in collaboration with the Institute of technology in Lund, our Master Thesis at HES as the final part of our Master of Science in Industrial Engineering and Management during the autumn of 2010. In this 20 week project we have applied many of the things we have learned during our education profiling in logistics and production management.

We would like to thank our supervisor Stefan Nilsson at Alfa Laval in Ronneby for all the support during the project. We also would like to thank our supervisor at the department of production management Bertil I Nilsson for all the feedback and guidance during the project. Finally we want to thank all the personnel at HES in Ronneby for all the provided information, patience and good response to this project.

Lund, December 2010

Johan Bergskans & Marcus Svensson

Abstract

Title: Making HES more Lean – Identification and reduction of waste

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Research questions: Where are the largest gaps between how HES (Heat Exchanger System) are working today and how they could be working according to lean philosophies? How could these gaps be reduced and what effect will it have to HES and their customers?

Deliverables: The project contains a gap analysis which is the foundation to a new suggested work pattern. The new work pattern was implemented, evaluated and revised. Finally further recommendations are presented.

Methodology: Quantitative data as well as qualitative data was gathered from interviews, observations and internal documentations. In parallel to the empiric study, literature on lean philosophies, material supply and assembly systems was studied. After the data was gathered a gap analysis was performed to see where HES could be improved and an identification of where an implementation of a new work pattern would be of most value for Alfa Laval and their customers was made. The implementation was performed according to PDCA (Plan-Do-Check-Act), and was continuously evaluated and revised. The implementation was performed together with the employees who had a key role with their experienced input.

Delimitations: The project was performed at Alfa Laval in Ronneby and it only includes the internal flow from customer order to order dispatch at HES in Ronneby.

Conclusions: The largest gaps where identified as poor flexibility and visualization in the production, an unstable material supply process and warehousing- and purchasing policies that need to be reviewed. The internal downtime at a changeover has been reduced from varying 15-60 minutes down to four minutes by changing the material supply process for the assembly line. The new standardized way to supply material is visual and all the material are secured, prepared and everyone know where to find it. The changes have made the production more flexible and aligned with the sales company strive to satisfy the customers' demand for a wider product range.

Keywords: Lean, gap analysis, waste reduction, material supply, visualization, standardization, flexibility, changeover time reduction, assembly line, kitting, work organization

Contents

1 Introduction

The purpose with this chapter is to give the reader an understanding for the project and state what the writers wants to achieve with it. The background for the project is described to explain why the project has been performed and were the problem areas were. Through this the problem formulation is declared and the delimitations for the project are set as well as the target group. The introduction also gives the reader a chapter overview and guidance for reading the report.

1.1 Background

For four years there has been an assembly line within the Heat Exchanger Systems at Alfa Laval in Ronneby. Six different models of Heat Exchanger System for single family houses are assembled on the line. A Heat Exchanger System is the link between a building and the district heating and it contains among other things a heat exchanger, a temperature controller and a control unit. Both production of standard products to stock and production to customer orders are assembled. In addition to this several other heat exchanger systems, which is different in working tasks and materials, are assembled at separate workplaces within HES. The line was created with the purpose to reach an efficient high volume production with a well defined takt. Workstations and the different roles on the assembly lines was carefully balanced and dimensioned to achieve high effectiveness. During the years the product portfolio and thereby also the working tasks has changed, but there has not been made any new studies for these products to balance the line and its material supply. Therefore the productivity has decreased. The production line and its warehouse have also been moved in the beginning of the year 2010 and at that time the layout of the line was changed but it still needs to be improved in order to be effective.

1.2 Problem description

HES are today struggling to keep up a high output from the assembly line and at the same time stay flexible to meet the customer demands. There are efficiency problems that need to be investigated so that Alfa Laval could be better prepared for future higher volumes. Understanding these problems is a key to change due to its effect on flexibility, work in process, stock balance and lead time for the customer. Answering the following questions will structure the work towards a more balanced and efficient flow at HES.

- Where are the largest gap between the current flow and the desired flow according to lean philosophy?
- What can be done to eliminate or at least decrease these gaps?
- What effect will these changes have for HES and their customers?

1.3 Target group

The target group for this master thesis is the company Alfa Laval and its personnel. That includes the mangers and production staff at HES, but the project can also be seen as best practice for other parts of the company.

The target group is also other students at Faculty of Engineering and the master thesis can be relevant for other manufacturing companies as well.

1.4 Purpose

The purpose with the project is to develop the structure and set-up for HES in Ronneby, by mapping the internal value stream, in order to improve the production. The project will tie theoretical knowledge to practical experience in a real company case and give us valuable experience for our future engineering careers. This will be done by studying and applying lean philosophies in order to develop and balance HES production flow, from customer order to finished goods. By mapping the internal flow and compare it with theory the authors will identify the gap between HES current production and a lean production. Then some of the most valuable improvement opportunities will be chosen and analyzed to see which improvements can be made by Alfa Laval. Some of these improvements will be implemented and evaluated during the project and others will be left in form of suggestions, and together it will lead to recommendations to the company.

1.5 Delimitations

The project will only include the flow, from customer order to finished products, of HES at Alfa Laval in Ronneby. Other parts of the Alfa Laval production are studied only with the purpose of understanding and to see opportunities for potential improvements for HES.

1.6 Project deliverables

The project will be presented in a detailed report with a description of the chosen methodology, a theoretical framework, a gap analysis of the current state and the desired state of the HES production flow according to lean philosophy. A proposal of changes will be presented and the authors will start to implement some of them. After the implementation the proposals will be evaluated and revised. Finally further recommendations for the company will be made and a company presentation will be held. A scientific article will also be written and an oral presentation at the university will be made. An opposition on another project is also included in the project.

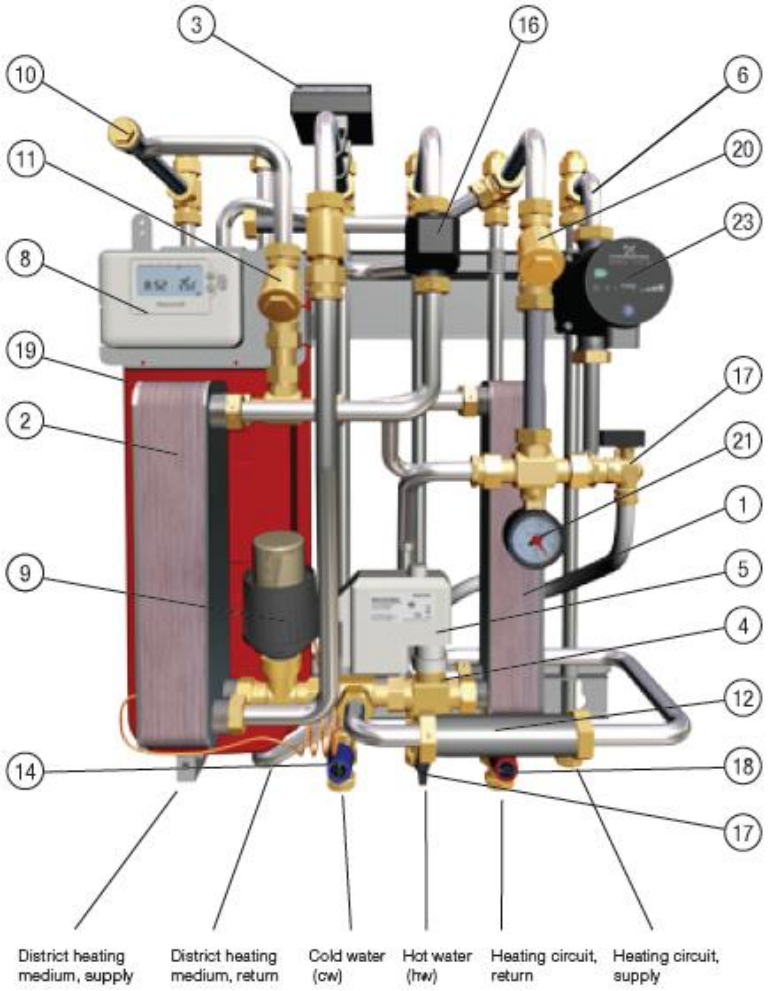
1.7 Alfa Laval Lund AB

Alfa Laval is a leading global provider of solutions to a large number of industries and their core technologies are heat transfer, separation and fluid handling. The corporate mission is to optimize the performance of their customers' processes, time and time again. The company has approximately 12 000 employees worldwide and a large number of employees work in Sweden, Denmark, India, France and the US. In 2008 they had a turnover of SEK 27 464 million and they has a broad geographic coverage, selling product in about 100 countries. Alfa Laval has 27 large and medium sized manufacturing units: 15 in Europe, 7 in Asia, 4 in the US and 1 in Brazil.[1]

1.7.1 Alfa Laval in Ronneby

The site in Ronneby has worked with heat transfer products under different companies since 1964. It was in 1987, when Alfa Laval acquired Euroheat AB, the site became a part of the Alfa Laval group. At that time they produced welded heat exchangers, heat exchanger systems and water heaters. In 1988 the production of brazed heat exchangers started and in 2005 the production of fused heat exchangers started. Today Ronneby is the main supplier for comfort and heat pump customers. [2]

[1] http://www.alfalaval.com
[2] Internal documents from Alfa Laval



Components

1. Heat exchanger for heating
2. Heat exchanger for hot water
3. Connection box for electric power and sensors, heating circuit
4. Control valve, heating circuit
5. Actuator, heating circuit
6. Supply temperature sensor, heating circuit
7. Outdoor temperature sensor
8. Room thermostat/control panel
9. Temperature regulator, hot water
10. Temperature sensor connection, district heating supply
11. Filter for district heating supply
12. Adapter for energy meter
13. Non. return valve for cold water
14. Safety valve, domestic hot water
15. Flow switch for tap water priority (option)
16. Safety temperature limiter, domestic hot water (option)
17. Valve to top up the heating circuit
18. Safety valve, heating circuit
19. Expansion vessel, heating circuit, 12 litres
20. Filter for heating circuit
21. Pressure gauge, heating circuit
22. Floor heating thermostat (option)
23. Circulation pump, heating circuit
24. Shut. off valves (6 pcs)

Figure 1: A Mini ECO, which is a district heating substation for single-family houses and a typical product for HES.[3]

1.8 Chapter overview and guidance for the reader

This report is presented in eight main chapters. They can be read separately, but to get the overall picture they are best read from the beginning to the end. After the main chapters the references are presented followed by appendix and a survey made with the personnel at the end of the project. A short description of the chapters is given below.

1. Introduction

The purpose with this chapter is to give the reader an understanding for the project and state what the writers wants to achieve with it.

[3] http://www.alfalaval.com

2. Methodology

This chapter gives an overview of how a scientific study can be made and how this project is performed.

3. Frame of reference

In this chapter the theoretical framework used in this project is presented. This forms the foundation for the later analysis of the current state.

4. Current state

This chapter describes the current state of HES in Ronneby. The chapter starts with presenting and explaining the layout and is followed by an explanation of the main functions and how they communicate with each other.

5. Current state analysis

The current state at HES is analyzed in this chapter. The analysis identifies gaps, which generate waste and inefficiencies, between how HES currently are working and how they could work according to the theoretical framework.

6. A new work pattern

In this chapter the authors' suggestion will be explained followed by a description of how an implementation was made using PDCA.

7. Conclusions

In this chapter we summarize the outcome of the project and present the conclusions. Important things for HES to do next and to make the improvements last are also presented here.

8. Reflections

In this chapter the authors' makes recommendations for further studies and what HES should focus on after this project is finished. This chapter also includes the authors' personal reflections about the project and the used methodology.

2 Methodology

This chapter gives an overview of how a scientific study can be made and how this project is performed. It starts with a description of the work process and the different available strategies and methods followed by the authors' choices. Different ways of how to collect data and how to make sure that the project is valid, reliable and objective will then be presented. This chapter will also secure the quality in this research paper.

2.1 The work process in the project

This project will be performed during a 20 week period and in figure 2 an explanation on how the project will be executed is illustrated. The objective and the problem formulation are set at an early stage in a project specification. Then a pre-study will take place in order to understand the value chain and the organization at HES. Information of available methods to use are chosen and studied simultaneously to secure the credibility. When the authors have an understanding of the value chain it is time to study different theories and more in depth how they are working at HES which will be analyzed against the theories. When the gap has been analyzed it is time to start implement and follow up changes that will reduce these gaps and the final step will be to summarize the project and present the conclusions.

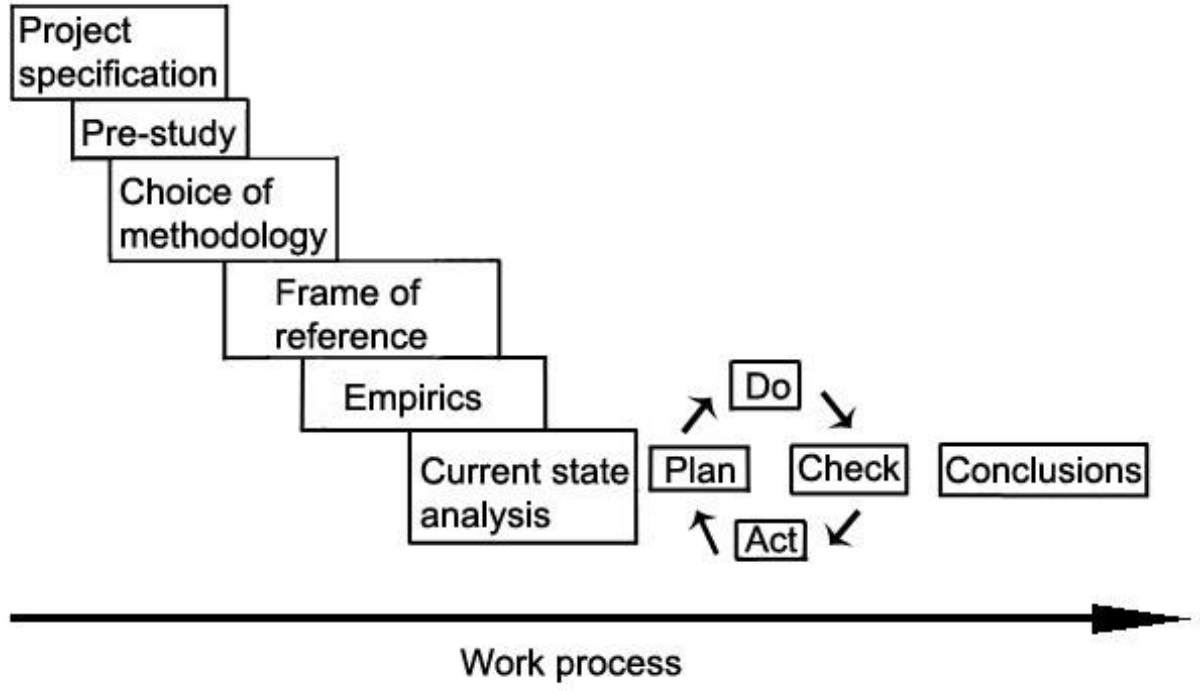


Figure 2: The authors work process

2.2 Different scientific strategies

Which scientific strategy to use depends on the characteristics and the aim of the research. An overview of the different strategies will below be given, followed by the chosen strategy for this thesis.

Exploratory study is used when there is little knowledge available and the main purpose is to gain as much knowledge as possible. The studies can be used to form a problem and later used as a base for further studies which emphasizes the importance that it is performed thoroughly and illustrates the problem from different angles.[4]

When there already is some knowledge about the environment and the problem is determined this method is used to describe rather than explain existing relations. The method tries to map the facts, relationships and consequences of different phenomenon.[5]

Explanatory studies are used for further more in depth studies. The purpose is to find the cause and the effect between different parameters. The relationships will be investigated and explained in the study.[6]

Normative studies are used when you have a problem to solve. The purpose for the researcher is to clarify his or her perspective with a clear recommendation and state the impact an implementation of the recommendation would have. Normative studies are the most common method used at Technology Institutes.[7]

2.2.1 Strategy in this project

In the beginning of this project the exploratory strategy will be used to map the internal value stream and to see where the problems are for the company. The exploratory study will form the foundation for the normative studies, where the authors will try to solve the problems with the most valuable potential. The solutions will then be evaluated and revised.

2.3 Research methods

Within the scientific research area there are different methods for gathering data. The most common methods in this kind of projects will be described more in detail below.

- **Survey -** Survey is used when the objective is to describe or explain an extensive question. It is an investigation of random samples from a population. For example how many people in a group are using a certain computer program etc.[8] The purpose is often to update the knowledge of certain things and to get an overview of the area at a specific

[4] Höst et al., 2009
[5] Ibid
[6] Ibid
[7] Ibid
[8] Ibid

time. [9] The survey can be performed in different ways for example written or online questionnaires, observations and interviews by telephone or face to face.[10]

- **Case study -** Case study is a more intensive study of one or several objects where the investigator tries to have as little influence on the object as possible. No generalizations of the received result are made for other cases, because the study is very specific with a specific purpose. For example how a specific organization is working.[11]

- **Experiment -** Experiment is an empirical investigation and it is the fundamental principle within the scientific research area. An experiment is designed to investigate specific properties and relationships of an element under controlled circumstances. [12]

- **Action research -** If the purpose is to improve something or solve a problem while you study it, action research can be used as a valuable support. Denscombe says that there are four characteristics of the action research:

  - **Practical approach -** The project has the purpose to solve real cases, often at a company or in an organizational environment.

  - **Change -** Change is one approach to comprehend practical issues and a mean to acquire more knowledge of a phenomenon.

  - **Cyclic process -** It is a cyclical process where the initial result is evaluated and gives feedback and opportunities to new changes to implement.

  - **Participation -** The key persons for the research process are actively participating.

  The action research starts with observations of the situation or phenomenon, in order to identify the problems needed to be solved. Here it is possible to use surveys or case studies. After the problems are identified the next steps are to develop solutions and implement them followed by evaluation of the results. During the evaluation the researcher analyzes the changes made and reflects over the results. If the problem stays the researcher starts over again.[13]

- **Clinical research -** Clinical research resembles action research, and the difference lies in who initiates and defines the problem. In clinical studies the company defines the problem

[9] Denscombe, 2009
[10] Ibid
[11] Höst et al., 2009
[12] Denscombe, 2009
[13] Höst et al., 2009

and the research is in action rather than about action. In the case of action research the company gets involved as a result of a research initiative.[14]

2.3.1 Research methods in this project

This project will include a combination of the methods of case study, action research and clinical research. Case study because the project takes place in a specific organization and the result will not be generalized. Both clinical and action research will be used due to characteristics of the project and the combination of problems initiated by Alfa Laval and the authors.

2.4 Techniques for gathering data

There are several techniques that can be used for data gathering. Below follows a description of the most common techniques which leads to choice of technique for this project.

2.4.1 Interview

An interview might seem simple to perform due to its similarity to a conversation, but it is not a simple option and it needs a lot of preparations for being successful. The potential of an interview is best used when complex phenomena are studied and when the researcher needs to get an understanding of peoples' opinions, emotions and experiences. There are different kinds of interview techniques, which will be described below.[15]

- **Structured interview -** A structured interview gives the researcher control over the interview by using a list of question and the respondent is just given a limited amount of answering alternatives. This makes the following analyze relative simple and is often used where there is a lot of data to be analyzed.[16]

- **Semi-structured interview -** In a semi-structured interview the researcher also has a prepared list with questions but is trying to be more flexible with the sequence of the questions and the respondent are allowed to elaborate the answers.[17]

- **Unstructured interview -** An unstructured interview is where the researcher intervenes as little as possible in order to let the respondent to elaborate his/hers thoughts. The researchers therefore only choose the issues to talk about.[18]

2.4.2 Observations

Observation means that the researcher studies a course of events and makes notes of what happens. He can choose not to participate and just observe, or the observer can participate and

[14] Skiöld, 2007
[15] Höst et al., 2009
[16] Ibid
[17] Ibid
[18] Ibid

have a role in the event while he observes. The advantage of participation is that the observer gets trust from the persons he studies, and the disadvantage is that the observer risks losing the distance to the object of study. The risk of being passive is that the observer may not be admitted into the event properly. [19]

2.4.3 Techniques used in this project

This research will include semi-structured and unstructured interviews as well as observations, in order to see the problems from different perspectives and to utilize the experience of the workers in the organization.

2.5 Qualitative and quantitative studies

Data can be gathered with a quantitative and a qualitative approach. A combination of the two is often used to get a comprehensive picture and to validate results.[20]

2.5.1 Quantitative

Quantitative studies are designed to collect data in form of numbers that can be statistically generalized.[21] The data can be gathered with standardized surveys that enable the researcher to only investigate a selection of a population.[22] Data in form of numbers can be used to make statistical calculations such as mean value, median value, and modal value and to confirm or reject hypothesis.[23] The advantages with quantitative studies are for example; reliance through statistical calculations, easy to analyze lots of data and it could be presented in a concise and effective way in forms of tables and graphs. Some of the negative aspects with quantitative studies can be if the researcher takes to many variables in consideration and the analysis therefore gets difficult to comprehend and then deviations might be discarded from the calculations.[24]

2.5.2 Qualitative

Qualitative data is gathered and presented as words instead of numbers. To develop knowledge in these studies the relation between researcher and the survey unit are essential, as the unit's situation needs to be faced face to face.[25] Qualitative methods are often used when the researcher chose one of the strategies ethnography, phenomenology or grounded theory. Methods such as interviews and observation are associated with qualitative studies but there are several other methods that can be used to produce qualitative data.[26] The advantage with qualitative studies is that data is formed from social conditions and it considers the entire situation, which gives a holistic view and a better understanding. It is very important that the researcher is objective to the

[19] Höst et al., 2009
[20] Ibid
[21] Denscombe, 2009
[22] Ibid
[23] Ibid
[24] Ibid
[25] Holme & Solvang, 1997
[26] Denscombe, 2009

study when he gathers and interprets data. Deviating results and alternative explanations could and should be investigated in qualitative studies. There are some negative aspects with qualitative studies for instance; difficult to generalize, affected by the researcher's personality and prejudices and time consuming to analyze.[27]

2.5.3 Chosen approach in this project

Due to the fact that lean is a qualitative philosophy and a holistic view is necessary in this research, the project will mainly use a qualitative approach. To get a comprehensive picture and validate the results some quantitative measures will also be used.

2.6 How argumentation are built

There are three sets of logic: deduction, induction and abduction. Grounded theory and triangulation can be used as a complement to them. The following part will describe them more in detail.

2.6.1 Deduction

The deductive approach means to draw conclusions about real problems based on theories and logical thinking.[28] This approach is used by experimental researchers and they apply general principles which are well known to explain specific events and phenomenon. The researcher verifies and show consequences of something already accepted as truth.[29]

2.6.2 Induction

Induction is often called the explorer's way and is when the researcher develops theories based on empirical studies.[30] This approach is mainly used by qualitative researchers and means that general rules evolve from specific cases or observations of phenomena. A holistic view is used.[31] The weakness with inductive research is that it is rarely based on all possible observations.[32]

2.6.3 Abduction

Abduction is a mixture of deduction and induction and an approach for making conclusions about causes for an observation. Here the researcher often have an effect and tries to figure out what the most common factors are without having the possibility to manipulate them. The relations are not unambiguous and the researcher looks at probable relations and makes conclusions based on elimination of different factors supplemented by tests. An abductive approach can be used for instance in an investigation of a crime scene or diagnosis of a disease.

[27] Denscombe, 2009
[28] Holme & Solvang, 1997
[29] DePoy & Gitlin, 1999
[30] Holme & Solvang, 1997
[31] DePoy & Gitlin, 1999
[32] Eriksson et al., 2001

2.6.4 Grounded theory

Grounded theory is used in small projects, when qualitative data is used for studying human interaction and when the research is exploratory and concentrated to certain environments. It is a procedure to generate theories and emphasizes empirical work on the field and the need to connect every theory with the practical reality. The empirical research is the foundation from where the theories gradually are evolved from analyzing the data. As the theories evolve they are tested with empirical data for the specific purpose.[33]

2.6.5 Triangulation

It is possible to get a more comprehensive view of the object of the studies by using several methods, types of data and persons who study the object. Then the things are seen from different perspectives and this is called triangulation. [34]

2.6.6 Approach in this project

This project will require both an inductive and deductive approach. An inductive approached is used to create an idea on how they are working and then a deduction approach will be used to identify gaps between theory and empirics. To complement this and due to the certain environments, grounded theory will be used in this research. Triangulation will be utilized to see complex problems from different perspectives.

2.7 Information sources

There are different kinds of information sources available when gathering data for research, for example books, brochures and journals. Lester says that the library, where the best books and journals are, should be the center of your research whether you access it electronically or in person. The reason is that the articles you access through libraries are in main written by scholars and thereby carefully reviewed by a board of scholars before publishing. [35] Data can be either primary or secondary data and below the difference between them will be explained.

Primary data is data collected by the researcher for the purpose to be used in the research.[36] For example: methods and tools, experiments, observations, discoveries and findings from tests. [37]

Secondary data are data which has been developed with another purpose than the current research such as general literature of the subject. Thereby it is important to know that the secondary data can be angled, not complete or written for another target group.[38]

[33] Denscombe, 2009
[34] Höst et al., 2009
[35] Lester & Lester, 2005
[36] Björklund & Paulsson, 2003
[37] Lester & Lester, 2005
[38] Björklund & Paulsson, 2003

2.7.1 Information sources in this project

Both primary and secondary data will be required in this research. Primary data will be used to develop our own opinion and not just accept everything received from the company. Secondary data will be used to collect knowledge about the general theories and how best practice companies work with similar problems.

2.8 Credibility

To make sure that a study is credible it has to be approached from different aspects. The study needs to be reliable, valid, and performed objectively.[39]

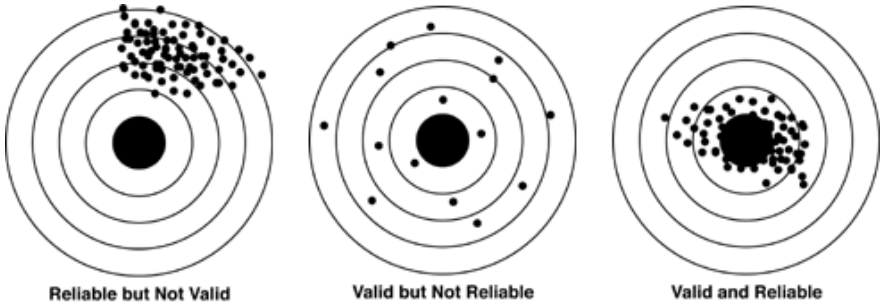


Figure 3: An illustration of valid and reliable[40]

2.8.1 Reliability

Reliability is the preciseness of the measuring tool. A precise tool attains the same results when measuring the same process at different times given the same circumstances. The reader can easily make a judgment on the used methods if they are well described and presented.[41] The researcher can do several things to make sure that the study is reliable. When qualitative data is gathered a compiled version of an interview can be presented for the interviewed person to eliminate the risk of any misunderstandings. The qualitative data should be analyzed with statistical methods to be reliable. It is also important that a group are randomly selected in case of a selection of a population is used to represent a whole population.[42]

2.8.1.1 Reliability in this project

To make sure that the gathered data in this project is accurate the data will be documented together with all assumptions. The documentation will be presented to the interviewed persons to eliminate the risk of misunderstandings. Quantitative data will be measured several times to make sure that we get a reliable result. Given the sort of project it will be difficult to get the same results again, if other researchers are doing the same study again at a later stage, due to changes in work pattern and change in mindset among the personal after the implementations.

[39] Höst et al., 2009
[40] http://ccnmtl.columbia.edu
[41] Denscombe, 2009
[42] Höst et al., 2009

2.8.2 Validity

There are two types of validity, internal and external. Internal validity is the measure of to which degree the study measures what it is supposed to measure. External validity is the way interviewed people answers a question, did they remember the situation wrong, did they misinterpret the question or did they lie? The researcher can use triangulation and study the object from different perspectives to validate the study.[43]

2.8.2.1 Validity in this project

Quantitative data in this project, for instance numerical measures will measure a well defined process to reduce the risk of having significant measuring errors. Interviews will use triangulation by containing questions in various forms to make sure that the interviewed person understands the question without any room for misinterpretation.

2.8.3 Objectivity

Objectivity is the measure of to which extent the authors affect the result. It is important that no personal values affect the study and that chosen methods are well described and motivated. An objective research is impartial and presents honest results.[44]

2.8.3.1 Objectivity in this project

The authors´ documentation will be coordinated with members from several functions at Alfa Laval so that decisions are based on facts and not affected by the authors´ valuations.

2.9 Critique of sources

The number of sources the researcher can comprehend is limited when a study is made. It is therefore important that the researcher review the available sources to find the best suited and most reliable sources for his work. Holme and Solvang divide the review in four phases:

- **Observation** - The first stage is to overview the available sources to find the most suited for the study.

- **Origin** - Identification of whom or what is the root of the source and the difference between the source and what it describes. Investigate the date of the study and when the source is published.

- **Interpretation** - The researcher needs to interpret the source to understand what the author wants to mediate.

[43] Denscombe, 2009
[44] Ibid

- **Usability -** Finally the usability of the source must be determined to make sure that the information is aligned with the researcher's purpose with the study.

These steps help to find suitable and reliable sources. Holme and Solvang also want the researcher to keep in mind that a source is a historical document that reflects the opinion and knowledge at a given time.[45]

2.9.1 Sources used in this project

Information from Alfa Laval will be collected by viewing and comparing different internal documents together with compiled answers from interviews with several persons within Alfa Laval to make sure that we have the whole picture instead of just one person's opinion. There is a lot of literature written about the subjects that concerns this project and the authors will look at several independent sources to validate the information. Where there have been difficult to find several sources the limitation of the project simply forced the authors to rely on the publishers´ data.

2.10 Summary of chosen research strategies and methods

First exploratory studies will be made to map the value stream and to form the foundation for the normative studies where the detected problems will be solved. A combination of the methods of case study, action research and clinical research will be used due to the characteristics of the project. The research will include semi-structured interviews as well as unstructured interviews and both an inductive and deductive argumentation will be used. As a complement grounded theory and triangulation will be used to utilize the experience of the blue collars/workers to see the complex problems from different perspectives. As the lean philosophy is very qualitative the authors' analysis will be more of a qualitative nature, but complemented with some quantitative measures.

Regarding information sources both primary and secondary data will be used in this project. Secondary data in order to collect knowledge about the general theories and how best practice companies work with similar problems. Primary data will be used to develop our own opinion and to analyze problems mentioned by the personnel. Several sources will be studied and the described methodology will be used to make sure that the project is credible.

[45] Holme & Solvang, 1997

3 Frame of reference

In this chapter the theoretical framework used in this project is presented. First process choice and assembly systems are described, followed by different kinds of material supply. Also the lean philosophy is presented here as well as work organization theories. Finally tools and techniques related to this project are described. Together this forms the foundation for the later analysis of the current state.

3.1 Process choice

When choosing which process is best suited for a product one must consider that a product has both a technical and a business dimension. The former relates to aspects such as design and material, while the latter defines the business aspects for example what characteristics qualify your product as an alternative for the customer and what characteristics wins the order.

Below is a description of the five generic types of manufacturing:[46]

- **Project -** Project process is used when the product cannot be physically moved when completed. Instead the required resources are brought to the site where the product is built and are allocated for the duration of the project.

- **Jobbing -** Jobbing is used when a product can be moved and companies choose to make it in house for later dispatch to the customer. A characteristic of jobbing is that it is used for unique products that are not thought to be repeated. The process is often performed by a small group of skilled people.

- **Batch -** Products that are of high and repeat volumes that move from step to step until complete are suited for a batch process. Another characteristic is that different products use the same process simply by setting and resetting them each time.

- **Line -** Processes can be dedicated to needs of a given range of products due to their high volumes. In a line the processes are designed to work without resetting each time a new product is to be made.

- **Continuous processing -** This process is just like a line designed to make mass products without being stopped and reset. A characteristic of the product is that they need to be transferable through piping or in liquid form and the processes are designed to run continuously.

[46] Hill, 2009

It is not always easy to choose a process that fit between the business requirements and the process characteristics. When encountering this issue a company can choose to have Hybrid processes, a mix of two generic types, as the best way.[47]

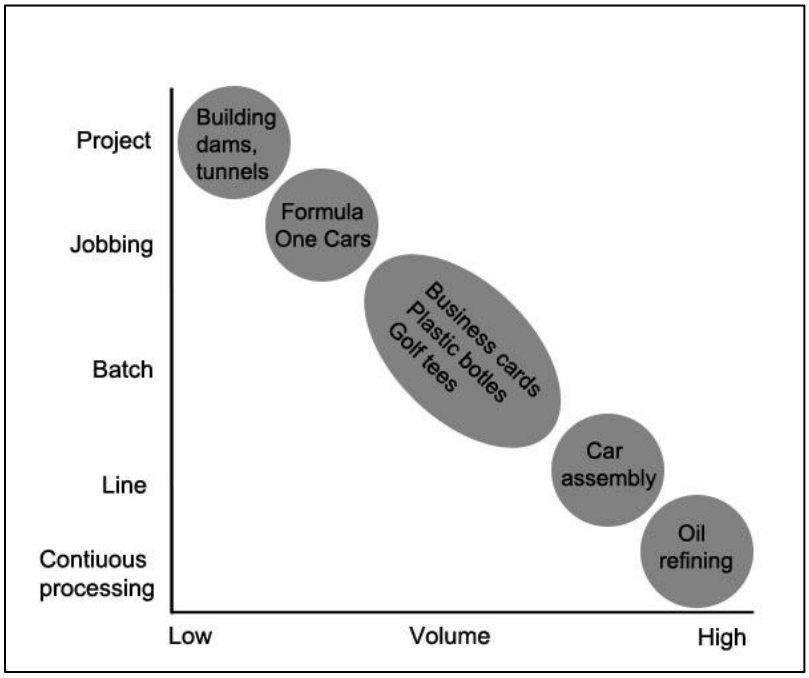


Figure 4: An illustration of Hills model of process choice

3.2 Assembly system

When designing an assembly system it is important to maximize the value adding time of the operator and by having compact work stations it is possible to reduce non value adding time such as unnecessary movements and transports.[48] When it comes to the efficiency of the assembly system, two important criteria is: high capacity utilization and low degree of tied up capital. However, it is important to complement these with criteria related to the people working in the production system for example: stability in the production, attractive work tasks and good production environment.[49] Below some of the most common production layouts will be described.

3.2.1 Product oriented layout

In a product oriented layout the assembly occurs in one place due to that the product often is big, heavy or hard to move. This layout is common when having long production times and small

[47] Hill, 2009
[48] Wänström & Medbo, 2009
[49] Axsäter, 1998/99

series or one piece production for example airplanes or ships. The final manufacture is often characterized by a lot of manual work.[50]

3.2.2 Functional oriented layout

In the functional layout all machines are sorted by kind of machining operation, which allows a large amount of product varieties because the processing sequences can be changed if necessary. The disadvantages are complex material handling, long internal transports and often queues in front of the machines. This layout is common when producing according to batches.[51]

3.2.3 Flow oriented layout

Here the machines are lined up according to how a specific product is processed. This is done in a way that creates a visual production flow through the factory. This layout enables a higher production pace, but more fixed installations are necessary such as material handling equipment and therefore the layout is more suitable for long series and mass production.[52]

3.2.3.1 Line organization

The benefit of a line organization is the well defined material flow, which easily can be mechanized. The different assembly operations are performed at different stations, which mean that the components only have one material address. This makes the material supply easier.[53]Other benefits are short lead times and by having short work cycles it is easy to teach new employees. High utilization of resources, easy managing and visualization of the work are other benefits with a line organization.

Some of the disadvantages are monotone work tasks, which have a negative impact on the work environment, and the workers might feel very replaceable. The system also risks being sensitive for disturbances and inflexible.[54] In a line organization an extensive balancing between the different work stations is necessary to reduce losses, and a fully balanced line is difficult to achieve.

3.2.3.2 Parallel production flow

One way to increase the flexibility and capacity of the assembly system, and at the same time reduce the sensitivity for disturbances, is to utilize parallel production flows.[55] Then it is possible to reduce time losses, operation safety and increase the possibility to have a good work environment compared to the line organization.[56] When using parallel production flows it is

[50] Ståhl, 2009
[51] Ibid
[52] Ibid
[53] Agervald, *1981*
[54] Bellgran & Säfsten, 2005
[55] Agervald, *1981*
[56] Ibid

beneficial to use lean principles, where real demands manage the production instead of estimated demands which is common in traditional mass production. [57]

3.3 Material supply

The material supply design has an important impact on the flexibility and performance of the assembly system.[58] The material supply shall provide the assembly operators with correct material, and the material should be obtainable in a way that makes the operators work easier. The operator should not have to walk long distances or reach for components.[59]

The way of buying material and its packages have a big influence on how the material supply is organized in Sweden. The consequence of this is having large packages that need a lot of space in the production and unnecessary handling and movement of material at the workstations occurs. This can also cause ergonomic problems connected to the heavy lifting.[60] According to Vollman et al. the goal in lean production is to use small container sizes to minimize the hidden inventory costs and increase the adaption to changes in demand. [61]

The general idea of an effective material supply is to minimize the amount of handling of material, because it is a big part of the overall cost and lead time of the material supply. An efficient way of reducing the number of steps included in the handling is to integrate the material supply with other functions and to merge different handling operations into a handling process. Another thing to consider is that the material supply, production and work organization should be synchronized with each other. More common thou, the production is developed first and the material supply just have to adapt to the situation. [62]

An effective material flow into and within a factory is crucial to any productivity improvements. In a production plant where the shop floor is tight or there might be congestions an optimization of the internal flow can radically improve the capacity of the production, without expansion.[63]

3.3.1 Continuous material supply

Continuous material supply, also called line stocking, is the traditional way of supplying material for an assembly line. All articles are available at the line and the material supply personnel refills when one type of material is consumed. No coordination between switches of the different articles exists. Which material is to be used for a specific product is often declared in some more

[57] Engström et al., 2005
[58] Wänström & Medbo, 2009
[59] Engström et al., *2005*
[60] Ibid
[61] Vollmann, 2005
[62] Kurslitteratur kompendium, 2000
[63] Hillis, *2006*

or less cryptic code or article number. The material is then picked from packages according to the codes.[64]

The continuous material supply requires a lot of space in the production as the level of customization and amount of products increase. It is not uncommon that the length of the assembly line is dimensioned by the required area for the material. [65] When using continuous material supply it is hard to guarantee that right components are used for the products as the operators can be confused which material to use.[66]

By using only one bin of articles at the time, a good delivery performance from the material supply personnel is required to avoid material shortages. A two-bin system does not require as high delivery performance, but require more space on the other hand.[67]

3.3.2 Batch supply

This requires that there are well defined batches. Every batch is then supplied either in the exact amount of material, or by roughly refilling the material and then having a return flow when the order is assembled. Here it is common that every pallet only contains one sort of article.[68]

3.3.3 Kitting

Growing diversity of product varieties and parallelization of the assembly systems are trends making it more difficult to supply material in a traditional way. As a result of this other principles of material supply has been developed, called kitting. This involves order picking and the characteristics of the components picked differ between systems, but the basic objectives and main activities are common i.e. picking and sorting a number of components in one stage of the production flow in order to satisfy a demand in a later stage.[69] When having parallel assembly systems one solution for the material supply can be to place the kitted material on a "material square", where the assembly personnel picks the material themselves. This increases the independence of the work group.[70] The main reasons for using kitting is to ensure that the product consists of the right components, so that the operators does not get confused which component to use, and to utilize the kitted material as a pedagogic support. This means that the operator uses the material as a physical work instruction.[71] Kitting also ensures that the right components are at the work station at the right time, as the accuracy is increased and the number of stock keeping units is reduced. It also saves space at the work stations and reduces the overall material handling time in parallel flows.[72]

[64] Engström et al., *2005*
[65] Kurslitteratur kompendium, 2000
[66] Engström et al., *2005*
[67] Kurslitteratur kompendium, 2000
[68] Ibid
[69] Brynzér et al, 1994
[70] Axsäter, 1998/99
[71] Engström et al., *2005*
[72] Medbo, 2003

By extensive use of manual material handling it is possible to reduce the requirement that the operator shall be provided with the right material at the exact right time in independent work groups. For example if one operator in the group has some time to spare, he can get the material for himself and to other members of the group at the material square instead of waiting for the warehousing personnel to come. By doing this the company also reduces the need of advanced technology. Instead it is more beneficial to use several simple transport equipments such as manual trolleys, due to the possibility to adjust the trolleys to different production systems and products. They are also easier to modify and develop compared to automated equipment, and this result in having a more flexible material supply. It is also possible to ease the learning of the assembly work, by first picking the material and gradually learn how to assembly it.[73]

According to Brynzér et al. the picking efficiency is often expressed in terms of a single variable such as transportation time, but it is also important to see the efficiency of the whole picking process. If a change in one problem area affect others it is important to see this and state the effect.[74]

3.4 Lean Production

The ideas of lean production are mostly picked from the car manufacturer Toyota and are also known as The Toyota Production System[75]. The hallmarks of lean production are communication, teamwork and efficient use of resources.[76] Almost every company has started to use the philosophy in their own company during the last decades, and worldwide companies are requesting Toyota employees for their knowledge. The company is seen as world leading in terms of quality, efficiency, production speed and flexibility.[77] By using lean remarkable results have been achieved, like cars with one third of the defects, build in half the factory using half of the time.[78] But the success surely does not only come from the layout of the production system, but also from the management culture and the leadership principles which are applied at Toyota. Liker describes 14 principles, which has many similarities with Deming's famous 14 key principles for management.[79] Toyota´s 14 principles can be divided into four groups:

- **Long term philosophy** - The company should think and act based on a long-term perspective, even if it goes against short term financial results. It is all about creating value for the customers, society and the economy and every department should be evaluated against their capability to achieve this. [80]

[73] Engström et al., *2005*
[74] Brynzér et al, 1994
[75] Bergman & Klefsjö, 2008
[76] Womack et al., 1991
[77] Liker, 2009
[78] Womack et al., 1991
[79] Deming, 1986
[80] Bergman & Klefsjö, 2008

- **The right process will produce the right results -** The value-streams should be designed for continuous flow without waste, where the products are pulled from the internal and external customers. Aim at doing right from the beginning, standardize, visualize and make the processes transparent for detecting problems easily and being predictable.[81] Build a culture of stopping the production to fix problems to get the right quality and use only reliable, throughout tested technology that serves the organization. [82]

- **Add value to the organization by developing the people -** In order to develop exceptional people and teams who live the company culture, it is necessary to have a management who understands and teaches the company's philosophy and nature of work. It is also important to respect and develop the suppliers and partners in the same way and help them to improve.[83]

- **Continuously solving root problems drives organizational learning -** Walk the organization and go to the source of the problems to fully understand the situation. Make decisions slowly by consensus and consider all options before implementation, which is done rapidly when the decision is made. Finally become a learning organization through relentless reflection and continuous improvement. [84]

3.4.1 Eliminate waste

It is important to understand what creates value, but it is also crucial to understand what generates waste in order to eliminate it.[85] Continuously eliminating waste is the heart of Toyota Production System. Toyota have identified seven kinds of waste in business and manufacturing processes: [86]

1. **Overproduction**
   Producing items before the item is needed or without any customer orders does not create value.[87] Overproduction is often considered as the worst kind of waste, because it generates all the other kinds of waste. [88]

2. **Waiting**
   For example waiting for the next processing step, waiting because of stock outs or capacity bottlenecks.

[81] Bergman & Klefsjö, 2008
[82] Liker, 2009
[83] Bergman & Klefsjö, 2008
[84] Ibid
[85] Ibid
[86] Liker, 2009
[87] Bergman & Klefsjö, 2008
[88] Petersson et al., 2008

3. **Unnecessary transport or conveyance**
   Carrying things for long distances, inefficient transports and moving materials into or out of storage or from one process to another does not create any value.[89]

4. **Over processing or incorrect processing**
   When unnecessary process steps are taking place or when the process is inefficient due to poor tool and product design, unneeded motion and defects are made.

5. **Excess inventory**
   Excess inventory hides problems such as late deliveries, long setup times and defects and makes the problem solving more difficult. Extra raw material, work in process or finished goods are also contributing to longer lead times, higher grade of obsolescence and more tied up capital.

6. **Unnecessary movement**
   Things like walking, stacking products, reaching or looking for products that are included in the daily work are waste.

7. **Defects**
   All kinds of rework or repair, scrap, inspection or production of defective parts are waste.[90]

3.4.2 The principle of one-piece-flow

One-piece-flow is when the products are manufactured one by one throughout the supply chain according to customer orders. The ultimate goal of lean production is to achieve a one-piece-flow in all business operations, from product design to physical distribution.[91]. All over the world companies has made huge gains such as increased productivity and quality and reduced inventory and lead times, by introducing one-piece-flow. The results are always the same and it always seems miraculous when things that once took weeks to produce now can be done in hours. One-piece-flow eliminates most of Toyota´s seven wastes.[92]

3.4.3 Just-In-Time

Just-In-Time (JIT) is a set of tools, techniques and principles to deliver the right products, in the right amounts, at the right time. It enables the company to produce in small quantities with short lead times in order to be responsive for specific customer needs. JIT also reduces the inventory level and thereby the total cost of inventory. [93]

[89] Bergman & Klefsjö, 2008
[90] Liker, 2009
[91] Ibid
[92] Ibid
[93] Ibid

3.4.4 Pull system

A pull system means that the entire flow is managed by actual customer orders and not by any forecast or plan. The production order is given to the last stage of the supply chain. That stage in turn gets the components, which shall be processed or assembled, from the previous stage of the supply chain.[94]

The main reason for using a pull system is to avoid overproduction, which is by Toyota considered to be the worst kind of waste. A pull system also provides less work in process compared to a push system and thereby earlier detection of quality problems. It also provides shorter lead times, which is leading to an increased responsiveness to the customers and less dependency on the forecasts. A pull system may cause that some of the operations in the production system are not fully utilized, because sometimes there might not be any demand from the next operation.[95]

3.4.5 Takt

Takt is originally a German word for rhythm and it is a measure of the demand rate. A takt system is used to synchronize the production with the customer demand and the takt time is defined by:

$$\text{Takt time} = \frac{Available\ working\ time}{Customer\ need\ during\ the\ working\ time}$$ **Equation 1: Takt time**

and sets the pace in the entire supply chain.[96] In other words the takt time is the pace at which products move forward in the flow. The takt time is telling people how much personnel and capacity they need as well as how fast they need to work in order to keep up with the rest of the chain.[97]

The goal is to eliminate waste when you are working with lean manufacturing and by using takt instead of number produced per hour it is easier to find waste and the source of the waste.[98] The takt could be visualized with a takt board and markings on the floor that shows the takt and what are supposed to be done on the product when it passes a marking. Every station should have a clear work method and if the operator cannot keep the pace he either does not follow the work method or there is something wrong with it. The takt is for this reasons a good way for the managers to find areas where they can improve the production.[99]

[94] Bellgran & Säfsten, 2005
[95] Ibid
[96] Pascal, 2002
[97] Liker, 2009
[98] Petersson et al., 2008
[99] Ibid

To mitigate the risk that you will not be able to keep up with the given takt you could use checkpoints. If you know that you are supposed to produce one unit every second day you could have a checkpoint after one day and see if you are on track with the takt, and if not you could ask for support.[100]

3.4.6 Changes in Customer demand

When solving the problem how to respond to changing customer demands there are three options:

- Absorb demand changes with a stock of finished goods
- Run overtime or similar capacity increase over calendar time
- Adjust the takt time and change the number of operators

The first two options can be used on a daily basis without any bigger problems, but changing takt is a little bit more difficult. The reason is that in order to change takt one often needs to change standardized work charts and redeploy people. Veteran lean companies are used to such changes, but a company new to lean production may have some problems initially.[101]

Most people would probably say that all form of stock is a waste of resources, but if a company has a small inventory of finished goods this will be well compensated by the ability to maintain the production pace in most cases. In this way you protect the company against a temporary increase in demand and you maintain the company's ability to produce to orders and the total waste is decreased. [102]

3.4.7 Production leveling

Production leveling is a method for reducing waste and it is important in the development of an efficient production according to the Toyota Production System and Lean Manufacturing.[103] When production leveling is used a company does not produce according to the actual demand exactly, because the demand could vary a lot over time. Instead you take the total number of orders during a certain time period and balance the production so the same amount and mix of products is produced every day. In this way the production is predictable and you do not have to work overtime one day and sending people home the other day.[104] In order to level the production, the company has to study the demand and try to see trends and different patterns for the volume and the product mix.[105]

[100] Pascal, 2002
[101] Ibid
[102] Liker, 2009
[103] Ibid
[104] Ibid
[105] Pascal, 2002

The benefits with production leveling is the flexibility to produce what customers want and when they want it and thereby decrease your stock on hand and problems linked to that such as tied-up capital and obsolescence.[106]

Another big benefit with the use of leveling is the ability to balance the workload for the employees and the machines. In this way it gets easier to standardize the work, secure the quality and be more efficient. A standardized work is easier, cheaper and faster, but also better for revealing waste like missing components and obsolescence. Production leveling will also lead to a more stable demand for the suppliers and the possibility to use Just-In-Time. In the end this will lead to savings for the suppliers which can be shared with the company so that the whole supply chain benefits from it.[107]

3.5 Work organization

In an assembly system the work load is often quite high for the assembly personnel and therefore they have a significant impact on the system. This makes the work organization very important besides the technical requirements of the system. The work organization deals with how the work is performed and divided among the employees and both the human aspects and the efficiency aspects are considered here.[108] It is important that the personnel understand that they together are responsible for the outcome of the group and agrees to get feedback on what they have performed as a team.[109] In order to be successful with an improvement project the attitude of the workers are important and it is significant to establish the ideas among the workers at an early stage and create participation.[110]

Lean production has received some critique related to the work environment. An overview of studies of lean production factories, mainly in North America, shows on high stress levels due to high production pace, a lot of repetitive work and few breaks. Older people and physically weaker people are then more vulnerable. [111]

Proponents of lean production say that lean results in competence improvements of the workers and that lean companies soon will have the repetitive work automated. In this way the workers will become more of skilled problem-solvers, whose job will be to think of new methods making the system even more smooth and productive.[112]

The direct work at Toyota is repetitive and has short cycle time (approximately 1 minute). The workers have to be able to carry out a lot of different standardized work tasks, in order to achieve

[106] Pascal, 2002
[107] Liker, 2009
[108] Bellgran, 1998
[109] Hackman & Oldham, 1980
[110] Sörqvist, 2004
[111] Börnfelt, 2009
[112] Ibid

a flexible organization. They also have responsibility for indirect work tasks as, reparations, quality controls, maintain order and purchase material. This is considered as enrichment of the work. [113]

The workers at Toyota are organized into quality control circles and participation is compulsory. The purpose is to create a feeling for responsibility, cut costs, make technical competence improvements and to create conditions for the workers to be accepted and respected. At Toyota the suggestions from the workers are rated by a committee and rewards are often given to the whole group with the purpose to be used for group activities. Every year a reward is also given to the person, which has come up with the most suggestions. Very valuable suggestions are also rewarded by the company.[114]

At Toyota a very important part of the culture is *"genchi genbutsu",* which means that you should go to the source of the problem and look for yourself. Even top managers need to do this and understand how the work on the shop floor is done, so they can live the company culture and teach their employees. The philosophies of Toyota emphasize practical work and trial and error, instead of theoretical knowledge. In lean the human elements are the most important resource and to give the employees trust, feedback and respect is crucial.[115]

3.5.1 Ergonomics

According to Axelsson people in the industry believe in a strong relationship between ergonomics and quality and they speak out of experience. Employee development and job satisfaction is considered to be a pre-requisite of quality. Axelsson says that both qualitative and quantitative data demonstrates that human errors resulting in quality deficiencies happen more often when the ergonomic situation is poor. Failure rates are substantially increased when working in adverse work postures and with high physical loading and he states that ergonomic improvements can reduce quality deficiencies with 30-50%. He also shows that a feasible and often necessary strategy to create lasting improvements is to integrate the perspectives of employers, employees and customers i.e. efficiency, work conditions and quality.[116]

Adverse work postures can cause musculoskeletal disorders which not only affect the individual but also the company if the disorders results in sick leaves and rehabilitation training.[117]

[113] Börnfelt, 2009
[114] Ibid
[115] Liker, 2009
[116] Axelsson, 2000
[117] Neumann, 2004

3.6 Production development tools and techniques

This section will present important things to consider when performing production development according to lean philosophy. Success factors are described and what to think about when choosing project. A set of tools connected to improvement work will also be described here.

3.6.1 Important success factors for improvement work

In order to be successful in the implementation of an improvements program it is of great importance that the top managers are involved and act in a convinced and visual way. Also important is that the necessary resources are given for making the implementation possible. Without this kind of involvement from the top managers it is hard to be successful in the implementation.[118]

Another important prerequisite for a successful improvement project is that the project utilizes the collective knowledge and experience of the employees, as Nilsson says. He means that the difference between widespread distrust for a threatening change and a more accepted attitude often lies in to what extent the personnel participate in the project.[119]

According to Sörqvist the initially prioritized projects should be chosen tactically, in order to quickly and safely achieve success to demonstrate the improvements initiative with. Choosing to big projects is a common mistake and the resistance to change should not be underestimated. Follow up of ongoing project and verifications of results should also be highly prioritized. Another very important thing is that the improvements projects are aligned with the company's strategies and goals.[120]

3.6.2 Value-stream mapping

Value-stream mapping is a tool or a technique that helps people understand how the value-stream of a product works in an organization and shows both the information, material and product flow.[121] It helps the steering committee to visualize and communicate how the organization works today and how they should act in the future to improve the cost, service and quality on the products.[122] This technique can create a high level look at the total efficiency of the company and not just independent efficiencies of departments or individuals.[123] A value-stream map is a basic tool for both leading already existing value-streams and to continue and implement new value-streams. It is the first and most important step to get focus and control over a transformation to lean.[124] The practices of companies' that successfully implemented lean production shows that value-stream mapping can eliminate 50% waste per process/step and reduce the cycle time by

[118] Sörqvist, 2004
[119] Nilsson, 1999
[120] Sörqvist, 2004
[121] Chen & Meng, 2010
[122] Keyte & Locher, 2008
[123] Chen & Meng, 2010
[124] Keyte & Locher, 2008

30%. They also prove that it is possible to reduce variation from 30% to 5% and improve quality.[125] The steps in the value-stream map process are:

1. Choose product family and make delimitations
2. Map the current state
3. Map the future state
4. Develop an action plan on how to reach the future state

3.6.3 Kanban

There was a lot of waste in form of overproduction and buffers at Toyota that could be eliminated if every process knew when the next replenishment was needed. Taiichi Ohno realized this and wanted to create a system that would control these issues by creating a pull system through the flow.[126] Kanban is the Japanese word for card and a Kanban card conveys information regarding what amount and when the next process will start. When a need is generated at the last process it sends a card to the previous process which in turn sends a card further up the stream creating a pull system.[127]

3.6.4 Pareto principle

Pareto principle is also known as the 80-20 rule or the rule of the vital few. The principle was suggested by Josef M Juran who stated that 80% of the effects come from 20% of the causes. This principle can be used by illustrating all the causes and how big impact they have on the effect in a chart, which can be used to determine what cause is most important to solve.[128]

3.6.5 5S

5S is a concept that creates order and visualizes waste. It is originated from Japan and the reactions from the Americans that visited Japanese factories in the 1970s were that everything was so clean that you could eat from the floor. But the 5S program in Japan was responsible for much more than just a good looking factory, their measures was also made to eliminate waste that contributed to errors, defects and injuries at the workplace. The concept has gained popularity because it creates an environment that is clean, well organized and efficient. The philosophies of 5S are now widely used as a starting point for continuous improvement efforts. The 5S is five steps that you continually have to go through to eliminate waste, create structure, sustain the order and find new improvements. Below is a short description of the five steps.[129]

1. **Sort** (Japanese translation, Seiri) – The concept starts by identifying what items are necessary to get the job done efficiently and effectively. The essential items for the job are tagged and the rest are removed.[130]

[125] Chen & Meng, 2010
[126] Liker, 2009
[127] Ståhl, 2009
[128] Bergman & Klefsjö, 2008
[129] Liker, 2009
[130] Ibid

2. **Set in order** (Seiton) – In this step all the tagged items needs to be determined where they should be placed for easy access. Every item needed for the job needs a home where they always could be found when needed. A common reason for long downtimes in many industries is due to searching for items that are not in its place.

3. **Shine** (Seiso) – The first two steps have organized the required tools and equipment efficiently and eliminated what is not needed. It is now necessary to keep everything that is used to make the product clean to reduce the risk that dirt in the production processes cause deviations in the product.

4. **Standardize** (Seiketsu) – The fourth step is to standardize processes so they can be used to maintain the first three steps. Visual management is very important for visual identification of abnormalities in the surroundings. Color-coding and standard colors is one way to visualize these abnormalities so they can be detected and corrected immediately.[131]

5. **Sustain** (Shitsuke) – The final step is the most challenging one. It is all about defining a new status quo with a mindset that thinks lean. Everyone must be willing to maintain order and cleanliness and feel that the standard procedures are a normal way of life instead of just a response to a 5S audit.[132]

Without 5S many waste accumulates and hides problems, often in form of buffers, and becomes an accepted dysfunctional way of doing business. Using all five S´s creates a continuously improving environment that becomes more efficient and eliminates waste. Most of the companies that have succeeded with their 5S program have regularly audits of the program. These audits are performed randomly and they use checklists to see how well the program is followed and what they need to change and how to become a more mature organization.[133]

3.6.6 5 Why

There are some difficulties that need to be considered when trying to eliminate waste. First the waste has to be identified and analyzed, then the right measures has to be done so that the waste does not occur again.[134] 5 Why is a method that finds the root cause of a deviation. By asking the question "Why?" at least five times, starting with a simple question and then going deeper in to the cause, the root cause of the problem should come up. Most of the time it is the process rather than the operator who is the root to a deviation. The managers have to believe that the operator is

[131] Howell, 2009
[132] Ibid
[133] Liker, 2009
[134] Ståhl, 2009

doing his job and realize that the problem could be on a process level. This creates a good climate for change and the operator will note deviations that they encounter. [135]

3.6.7 Single Minute Exchange of Die

Single Minute Exchange of Die (SMED) is a concept for reducing manufacturing changeover times to less than 10 minutes, in other words single-digit minute. SMED was developed by the Japanese engineer Shiego Shingo who made a difference between internal and external setup time. The internal setup time is the part of the setup time where the machine has to be stopped. The external setup time is the remaining setup time, like time for preparations etc., which can be made while the machine is still running. The reduction in changeover time is achieved by radically reducing the internal setup time. This is done by changing it to external setup time and also reducing the overall setup time by simplifying the work. The method includes eight steps:[136]

1. Separate internal and external setup times
2. Convert internal setup time to external
3. Standardize functions
4. Use functional clamps or eliminate fasteners altogether
5. Use intermediate jigs
6. Adopt parallel operations
7. Eliminate adjustments
8. Mechanization

3.6.8 Kaizen vs. Kaikaku

Kaizen is a Japanese term for continuous improvements and represents ongoing work in small and controlled steps, which constitutes the foundation of the improvement work. Kaikaku is the Japanese word for radical change during a limited time. Kaizen is meant to be a part of the daily work and it aims to create an environment where all employees solves issues and eliminates waste. Kaikaku is when a company is introducing new knowledge, new strategies and new approaches and it is usually done in form of a project. The chart below illustrates the two different approaches to improvement work.[137]

[135] Petersson et al., 2008
[136] Ståhl, 2009
[137] Sörqvist, 2004

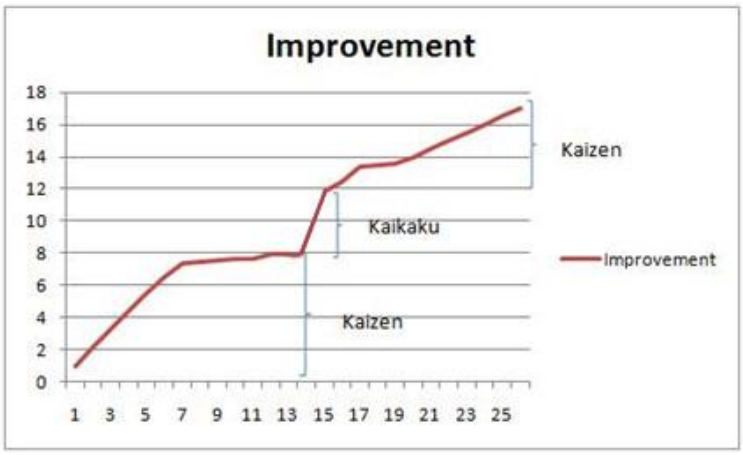


Chart 1: Improvement work

3.6.9 The Deming cycle (Plan-Do-Check-Act)

Edward Deming created a cyclical method with four phases, Plan-Do-Check-Act (PDCA), to structure the work with continuous improvements.[138]

- **Plan -** The first step is to plan the work and determine the projects objectives. This phase includes identifying the customers (internal and/or external) needs, collect data, distinguish and analyze problems and find the root causes.[139]

- **Do -** The plan phase has identified the root causes and set a plan on how to solve the issues. The purpose with this phase is to implement the actions described in the plan. [140]

- **Check -** How did it go? This is the control phase where the outcome is analyzed. Where the objective reached? What went good and what went bad? What lessons has been learned for future actions? [141]

- **Act -** A successful implementation needs to be secured and standardized. This final phase connects the cycle and gives the opportunity to investigate other deviations. The question "Could the new standard be implemented in other areas?" should always be considered at the end of a cycle. Petersson et al. says that it is important to celebrate a successful project for the spirit of continuous improvements; change should be associated with something good.[142]

[138] Petersson et al., 2008
[139] Ibid
[140] Ibid
[141] Ibid
[142] Ibid

4 Current state

This chapter describes the current state of HES in Ronneby and is together with chapter 3 the foundation of the analysis in chapter 5. The current state will be described in the same order that the value flow was mapped by the authors. After that HES currently work with visualization and takt will be described as well as the work organization.

4.1 Customer order to order dispatch overview

Alfa Laval communicates with their customers through a sales company which in turn places a customer order to the order department. The order department creates a production order and acknowledges the order and then the production planner together with the production manager and the team leaders' plans the production. The warehousing staff prints a picking list and collects the included items and then the assembly personnel preassembles modules which later are used in the assembly line or at the one piece production stations before they are dispatched.

HES´s production and their warehouse were moved from another building in January 2010 and they had to adapt to the new available space, which is much smaller than the old one. The shop floor is divided in four main areas: warehouse, preassembly, assembly line and one piece production stations, see appendix 1.

4.1.1 Customer need to customer order

When a customer turns to Alfa Laval they communicate with a sales company which do anything they can to fulfill the customers need and make them place an order. They have a portfolio with standard products but they also gives the customer the option to change the specification, for instance if they have a situation where they need a bigger pump or another valve. Alfa Laval has an engineering department that customizes standard products and creates a special product to satisfy these kinds of needs. The order is then placed direct via EDI to Jeeves, Alfa Laval's MPS system, or by mail to the order department. When an order arrives the order department makes an availability check for material and capacity and then sends an order acknowledgement back to the sales company who communicates the information to the customer. Production order is made to match every customer order and to make a finished product they often have to make several production orders. This is because a finished product often consists of several modules that they assemble in the preassemble area before it goes to the assembly line or to the one piece stations.

Alfa Laval has some of the standard products in stock with a lead time of two days and some are assembled to order with a lead time of approximately 10 days while they for some products have to place an order for material which gives them a longer lead time. An order which will be assembled the following week normally gets Friday as ship date so that the production planner can plan the next weeks production with minimum downtime. If they know that an order is very urgent for the customer they have the ability to check a box in Jeeves called ASAP (As soon as

possible). When ASAP is checked the staff at the distribution center dispatch the order the same day as it is assembled.

4.1.2 Planning process

The production planner meets with the production manager and the production team leaders' one or two times per week to plan the production for the following week. They go through the order book and plan the week by different product families, for instance they place all XXX on Monday and all YYY on Tuesday to minimize the number of changeovers, resulting in less downtime in the assembly line. Observations and experience from the personnel shows that the downtime when they change product families differs from 15 minutes up to 1 hour. HES´s demand works as a pull system and it is the customer order that generates the assembly of most of the product.

The planners work with a production schedule which is an Excel file with all the production orders for the preassembly, the assembly line and the one piece stations for next week. They use production leveling to plan a suitable number of products each day. The schedule shows how many and on what day they should be assembled. It also has a description field that is used to put the full product name and information regarding what differs from the standard product in case of an order unique product. This field is today used moderately and it is only a few of the production staff that can interpret it in case of a customized product. The production schedule is sent to the warehousing personnel in order to communicate what day they need to pick the orders and it is also displayed on the cell status board, described in section 4.3, where a daily meeting is held with the production staff. There is no information on the production schedule about what time to pick the material and when the changeovers are to be made. Currently some of the preassembled articles are not registered as modules, which mean that they do not come up on the production schedule. The production and the sales company do not always agree which articles that should be registered as modules and this creates confusions. Here it is up to the personnel to keep in mind what needs to be preassembled and at what time. The current inconsistency and lack of explanations when having a product that differs from the standard product, force the personnel to go through the production order document and compare them to the standard product to find out what differs. Confusions like this have created a mindset among the personnel that these customized orders always comes with trouble and most of them are therefore against the large number of variants that the sales company offers the customers to choose from. There is neither any information describing which station the change concerns when having a customized product.

4.1.3 Assembly system

The line area has a flow oriented layout where different assembly operations are performed at different stations. The preassembly and one piece stations are organized in a product oriented layout, with parallel production flows. HES assemble approximately 150-250 units per week and about 75% of them are assembled on the assembly line in batches of 10-50 units. A typical product consists of 50-70 components and some of them need to be preassembled to modules for later use in the final assembly of the products.

Figure 5: Assembly line

4.1.3.1 Preassembly

The preassembly area is where the modules are made for the production. HES works with modules in order to keep a balanced flow at the workstations in the assembly line. Most of the modules are made the day before they are needed for final assembly to minimize the risk of material shortage at the assembly line. Depending on what type of module it is placed in stock, on a trolley or directly in grey boxes on the trolleys for the assembly line. Today there is no place to store the preassembled modules going to the line, so they stay on a trolley or in a pallet until they are to be used. The visualization of the modules is deficient and it is sometimes impossible to tell which module corresponds to which article number.

Usually two persons are working with preassembly and sometimes they have a hard time to keep up with the production pace if the production line is fully manned. Most of the preassembly is pipes which are hung on a pipe trolley, shown in figure 6 below. There are two pipe trolleys working as a two-bin system, where one trolley is used at the line while the other is refilled at the preassembly area.

Figure 6: Pipe trolley

4.1.3.2 Assembly line

The assembly line consists of eight stations each manned with one operator. Station 1 to station 6 is very similar and the work consists of assembling modules, pipes, valves, pumps etc. Station 7 is a test station where the product is tested for leakage and electricity problems. Today when there is a leakage there is no standard procedure what to do. The operator knows by heart the most common errors and starts to trouble shoot by tighten mutters and change components. When

there is problem with more than one product in a row it usually builds up a queue in front of the test station, and this leads to running out of palettes at the following stations. They have the possibility to take the unit of the line and have someone else to test it but they rarely use it. The 8th and final station is a package station where the finished products are packed into cardboard boxes.

4.1.3.3 One piece stations

Some of the products are too big for the assembly line or sold at very small volumes and never adapted to the line and therefore has to be assembled at a separate station with a product oriented layout. These stations are manned with one operator who assembles the whole product by himself.

4.1.4 Warehousing

HES currently have three different warehouses: one main warehouse, one in the production and another one outdoors in a tent where they keep bulk material. The personnel have tried to sort the material by which final products they are used in and put mutual material like pipes and heat exchangers at one place, but due to shortage of time they never had the chance to fully structure the warehouse when they moved it from another building.

According to the warehouse personnel the suppliers sometimes send several pallets with the same material at the same time and then there is not space enough to put all the material at one place. This results in having the same material at several places in different warehouses.

There are no defined rules of where to put materials at HES. When the warehousing personnel receive new material they put it where it usually are stored but if that spot is taken they have to find a new available space. There are also no rules for where to pick a specific material. For instance the warehousing personnel picks from the pallet that is easiest to reach instead of always pick from the oldest pallet (First-in-first-out) and this sometimes results in several half-empty pallets with the same material.

All personnel are allowed to pick material from the warehouses. For examples if something is missing in the preassembly or at the assembly line the operators picks from the warehouse what they need. At the end of every production order the inventory level are reduced, by the number of material on the picking list, in the system.

Today HES have a lot of problems with differences between the actual inventory level and the inventory level displayed in their computer system. They are supposed to use continuous stocktaking to go through the inventory level of every article once a year. The personnel experience that they often run out of time and therefore they have to use a lot of overtime and help from inexperienced personnel to go through the inventory level of most articles the last weeks of the year.

4.1.5 Material supply

The material for the assembly line is supplied in batches for the different product families. No exact counting is made and when they produce within the same product family, they use continuous supply. The preassembly also uses continuous supply where the assembly personnel pick components by themselves. Only some components used in preassembly are located in the main warehouse and needs the involvement of the warehousing personnel. The supply for the one piece stations are done in a different way. Here the personnel do kitting of the order in trolleys, which are picked from a material square by the assembly personnel when needed.

The warehousing staff uses the production schedule to plan their week in order to pick the orders at the right day. They print a picking list with all the articles that the order consists of and at what shelf they are stored on at the warehouse. The information on the picking list comes from Jeeves and due to changes in products and lack of updates in the system there are some faults on the picking lists. For instance there could be components that are needed for the order that are not listed on the picking list, due to faulty product structures. The result of this is that not all material gets withdrawn from Jeeves when reporting the order after assembly.

Most of the products are picked by the warehousing staff with a forklift from the main warehouse and the production warehouse. Some of the articles need to be picked with help from personnel that collects the articles from a stock placed in an outside tent. The responsible personnel of the tent are very busy and they therefore need to prepare and collect these items in advanced not to risk that the tent personnel is unavailable when they need the articles.

There is a big square, marked in the middle of the shop floor, for incoming and outgoing material for the preassembly, assembly line and the one-piece stations. The meaning is to show, in a visual way, which material is going in for assembly and what has been used and can be taken away. Today this material square is not managed as intended, as it also is used as buffer for trolleys and material and the left-over material is not returned to the warehouses frequently, see figure 7.

Figure 7: The material market

4.1.5.1 Material supply for preassembly

The preassembly modules are most often planned the day before the rest of the articles on the production schedule so that the warehousing staff can pick the articles. Then the personnel working in the preassembly area can assembly the modules before they are needed at the assembly line. Due to the number of customer specification options there is a lot of unique products and most of those never gets an own article number and their modules are not added on the production schedule and therefore sometimes not picked and assembled in time. In those cases the warehousing staff depends on the experienced team leader in the assembly group to tell them when and what articles that needs to be picked in advance.

Most of the modules use the same pipes and these are not picked in exact number to every order, instead they pick a whole box or pallet. Most of the standard pipes are in the stock right behind the preassembly area and the assembly personnel picks them themselves, except the ones that need a forklift to be reached.

4.1.5.2 Material supply for one piece stations

The products that are assembled in the one piece flow have trolleys with dedicated and marked holders for every article. These orders are kitted by the warehousing staff and placed in the material square with in- and outgoing material, described in section 4.2.5, the day before they are going to be assembled. When kitting the orders, the warehousing staff takes an empty trolley from the material square and put the articles directly to its dedicated holder. Today it is hard to tell which trolley going where and also hard to get the trolley from the material square, due to the disorder.

Figure 8: Trolley for materiel to one piece stations

4.1.5.3 Material supply for assembly line

Bulk material such as heat exchangers and pumps are delivered on a pallet to a lifting tackle to each station. These articles are often heavy and in order to reduce the number of heavy manual lifts the warehousing staff never picks them out of the pallet, instead they deliver the whole pallet to the line. Because there is no information on the picking list regarding which material going to which station, the personnel have made some basic cheat sheets as support for knowing where to put the pallets. When a changeover takes place all pallets need to be changed starting with the ones at the 1st station. Currently there is no chance to prepare for the next order, so when it is time for a changeover the warehousing personnel gathers the pallets as quickly as possible from the warehouse in order to minimize the waiting time at the line. Not all pallets have a dedicated spot in the warehouse according to Jeeves, so in these cases they have to rely on their experience telling them where they usually put them and this causes a lot of searching.

Other material is provided in grey boxes placed on trolleys right behind the line operators. The boxes are divided into different compartments and most compartments are marked with article number. The marking is not always correct because in the same compartment there can be different articles depending on which product they are assembling. Today there are only three sets of boxes and two sets of trolleys, but according to the assembly personnel there should be a set of boxes for every product family to eliminate confusions.

Figure 9: Grey boxes for picked line material

The picking list has no information regarding where to put the material and in which box, so the warehouse staff has to rely on the experienced assembly personal to tell them in what box they should place the material. Most of the materials in the boxes are pipes and modules that are stored close to the assembly line and often picked by the assembly personnel themselves. Sometimes there are confusions about who is supposed to pick which material. No exact counting of this material is made, so when needed the assembly personnel or the warehousing personnel just refills with more material. Between similar end products the changeovers sometimes consist of refilling the boxes with a different pipe or pump mixing it with material from the previous order. Interviews with the warehousing personnel show that they think this is a good way to work. The reason given was that it avoids heavy lifting for the personnel and that it is not as time consuming as exact counting.

When there is a changeover to a new product family the operator at each station is responsible to switch his own trolley with grey boxes. A typical change for the line operators consist of changing palettes and pipe trolley at the first station and change of trolleys at the following four station and boxes at the package station. The excess material in the grey boxes are left on the trolleys and placed at the end of the shop floor until they should assembly that product type again, usually about a week later. The area where the trolley is left is not connected to the line where the material is used. Every time there is a changeover the line personnel walks across the shop floor to get the trolleys. During this time the line is not running. The collected trolley is placed at the line and the warehousing staff and the assembly personnel looks in the boxes to see what material they need to gather from to the new order the stock. These switches between product families take between 15 to 60 minutes depending on how much material that needs to be refilled from the stock.

The warehousing staff continuously keep track on the material levels in the pallets and grey boxes so that the assembly operator never runs out of material. If an operator runs out of a material in the boxes and the warehousing staff is not around, they often leave the line to gather material themselves in order to save time. This is not possible when a pallet is empty and in this case they have to wait for the warehousing personnel to change the pallet with a fork lift.

HES are currently testing to use blue boxes for the order unique material for customized products. They simple put the components for one product in a blue box and send the box right after the palette on the line. For example if the customized product has a different pump than the standard product the special pump is placed in the blue box next to the palette. When the palette together with the blue box arrives to the station where pumps are mounted the operator immediately recognizes that he should use the special pump.

4.1.5.4 Order dispatch

The personnel at the distribution center starts every day by printing a list from Jeeves with all orders that should be dispatched. It is up to them to keep track on the list and collect finished orders from the production and the stock of finished goods. The order department keeps track if

order is finished before the promised date and the customer has requested it as soon as possible and communicates this to the personnel at the distribution centre so they can send the order immediately.

4.2 Visualization and 5S

Problems that occur are written on a Cell Status Board, which are reviewed every morning. The problems are categorized after how long time they take to solve and what actions to be taken. Who is responsible to solve the issues are also discussed and posted on the daily meeting. This is also the board where the production schedule is posted letting everyone take part of it. The board also shows the planned and actual output for every day the current week.

HES are working with 5S and they have realized lots of the benefits with it, but the management does also understand that it takes some time to set the right mindset among the personnel. The managers have the knowledge to implement a lot of changes to make the factory look like they are great at lean, but they have identified the important need of the right mindset among the personnel to be successful and continuously improve their work area. The work is audited on a regularly basis using checklists and the audits show varying results, some areas are well marked and everything is in place while other areas needs more work. For example many tools in the assembly line have its own place, but according to the assembly personnel not always the right place. There are also some tools that have no dedicated place and they are often placed in a grey box together with the components and when a changeover is made the tools disappears together with the trolley. The company uses markings on the floor in order to organize the shop floor. They do this by using standardized 5S colors, for example scrap containers have their own dedicated place marked with red lines, and footpaths that separate pedestrians from the truck aisles are marked with yellow lines.

Apart from the 5S audit, the order on the shop floor is regularly viewed from a customer perspective. This is called Customer/ Waste walk and is a walk where the unit manager brings one of the operators and asks him to describe what he sees, then the unit manager explain how a customer might see it. Things that come up on these walks are often symptoms like “there are a lot of plastic straps lying around on the floor beneath station 5 and it looks messy” and the manger tries to make the operator identify the reason for this mess and how it could be solved. For instance “If we put a bin under the line at station 5 all the straps will fall into the bin and that will make the area cleaner and then we do not have to sweep up the straps all the time”. The manager explains how this solution not only makes it cleaner and save time, it also reduces the risk of injury caused by someone slipping on the plastic straps. The manager does these walks every week with different operators to create a mindset where they understand that 5S is much more than just making the surroundings looks good.

HES use instructions in form of a standard operation procedure (SOP) to ensure that every operator knows how to assemble a product the right way. The SOP is tailor made for every station and placed in front of the operators work area. It consists of a step by step guide with pictures describing how to assemble a product. There is not a SOP for every product due to number of special variants, but they are continuously adding new SOP so there will be one for every product.

4.3 Takt

Alfa Laval's production engineers uses a video based software tool called AviX to determine all operation time that is needed to assemble a product. The software helps them to balance the operations between the stations so that the product can be assembled at an even pace on the line. The team manager uses the operation time and the number of people manning the line to determine how many units the line should produce every day. This number is shown on the cell status board described in section 4.3 and after each day the number of actual produced units is posted on the board. The difference between these numbers is discussed on the daily meetings and the reason for that difference is often material shortage, problems getting the units through the test or lack of staff. Observations by the authors show that the operation time still varies between stations. The takt is close connected to the number of people working at the line, 8 people means maximum pace, four people means 50% pace and so on. The production engineer and the managers want the operator to follow the product from station to station until it is completed if they are an uneven number, for instance 7 people. Observations show that this is rarely done.

The Unit manger is aware of the benefits with fully using takt through the entire supply chain as described in section 3.4.5 and also how to visualize the takt in the production, but he thinks that the current production is to unstable and the maturity among the staff needs to be improved before they can extend their work with takt.

4.4 Work organization

The cycle time of repetitive work are, depending on what kind of product is assembled, approximately 5-10 minutes at the line within HES. One to three times a day the workers are switching work tasks with each other. Today nothing is automated at HES, so everything is done manually except from some help from supporting tools like lifting devices at the work stations.

The assembly personnel have responsibility for the quality of the assembled products and they sign the order before dispatch. Together they are also responsible for the outcome of the assembly work, and have to explain at the production meeting if yesterdays target was not reached. They also have different areas to be responsible for, like spare parts or SOPs.

Today there is no reward system for suggestions at HES. The employees are instead supposed to solve problems continuously or mention the problem at the morning meeting. Then when the unit manager feels like there have been a lot of improvements he rewards the employees with some sort of group activity.

Recently the warehousing personnel became a part of the assembly organization and more integrated in the process as they now have the same manager. The personnel think this is more natural as they work close together with the assembly personnel.

At HES the managers spend a lot of time in the production and listens to what the employees say and in case of a problem they go to the source of the problem themselves. The unit manager has a daily routine where he walks through the production every morning for making sure that everything is alright and to give the employees a natural chance to bring up ideas or problems to him in person. In general the managers at HES understand that the human elements are very important. The managers also continuously tell the employees to write problems that come up on the cell status board and explain that this is necessary for having a chance to improve their work.

4.4.1 Ergonomics

HES have a safety representative among the personnel who is responsible for the work environment and all new suggestions must be approved by him. He looks at the ergonomic aspects and tries to minimize the number of heavy lifts and adverse work postures. They have some supporting tools to ease the work, for instance lifting tackles used to get the pallets at an ergonomic height for the operator that picks the material from the pallet.

5 Current state analysis

With the theoretical framework as foundation the current state at HES is analyzed in this chapter. The analysis identifies gaps, which generate waste and inefficiencies, between how HES currently are working and how they could work according to the theoretical framework. They are then compiled in appendix 2. This analysis will lead to suggestions and implementations further on in the project. 5 Why is frequently used to identify the cause to a gap.

5.1 Layout and value stream

When the production of HES was moved they had to adapt to the new factory as well as they could. Today the shop floor layout is not fully designed after the production flow, see appendix 1. A visual and natural flow would be to place every value creating process after each other according to the value stream. In this case starting in one end with incoming goods to the warehouse and then proceed with the preassembly area followed by the production line and ending with the stock of finished goods and dispatch. The current setup creates waste in form of unnecessary transportations on the shop floor when moving trolleys and pallets back and forth.

By having three different types of warehouses spread out which is not fully organized the warehousing personnel has no natural route when gathering material for the production. This means they need to do a lot of unnecessary movement and searching, which is contrary to lean production. Some of the pallets used at the line are placed in the outside tent, causing a lot of downtime at the line if they have not prepared and gathered this in advance when it is time for a changeover or when running out of material. The reason for the spread out warehouses and unnatural production layout is explained to be due to lack of space in the new factory area and limited time given when moving from the old factory.

5.2 Customer order and planning process

The sales company tries to satisfy the customers´ demand on customized products resulting in a lot of customer unique products, which increases the complexity in the production. Due to the long downtime that occurs at every changeover, the production aims to minimize the number of changeovers every week. According to lean the customer demand should trigger the production creating a pull system and in an optimal production, with a one piece flow without downtime at changeovers, the production should produce in the same number and order that the customer order arrives, see section 3.4.4. The current method to plan the production results in varying lead-times for the customer depending on how well their desired product fits in the current production. Producing with as few changeovers as possible results in larger batches and products is produced before they are needed. In lean this is called overproduction and it is considered to be the most common and also the worst kind of waste. Overproduction like this leads to increased lead time, decreased inventory turnover and more tied up capital in the finished goods stock. HES uses this

as a form of production leveling to even out the work load and to increase the utilization of the line, but to be efficient according to the theory leveling is supposed to be a mix of products that are evened out over a period of time.

Hill describes that an efficient company have a strategy where the production process is aligned and suited for the products that the sales company sells, see section 3.1. At HES the sales company continuously increases the product range while the production has a process which struggles with long downtime and therefore plans their production with as few changeovers as possible. Figure 10 below illustrates how the sales company and production is pulling at different directions in terms of process choice.

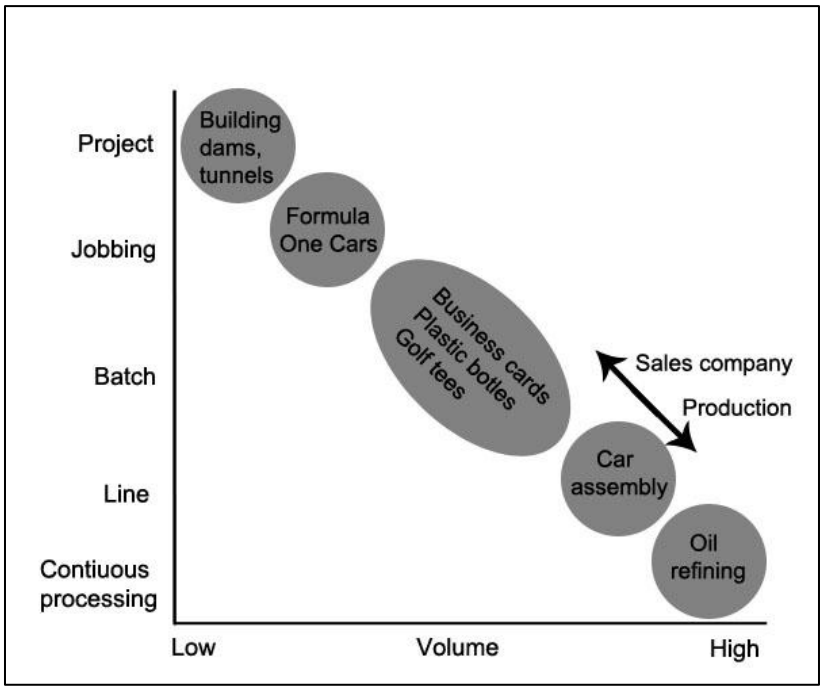


Figure 10: HES´s sales company and the production placed in Hill's model

The attitude towards customized orders that the production have, due to poor communication and lack of standard procedures, is contrary to what Hill says about the close connection and collaboration between the market department and the production that is necessary for having an efficient organization, see section 3.1.

The incomplete and inconsistent production schedule creates confusion for most of the personnel involved in the material supply and in the production. The fact that every module has not got an own article number and therefore not planned on the schedule makes the whole process very sensitive. If the team leaders forget to keep these modules in mind and tell the warehouse personnel to pick the material in time they risk to discover that they have forgot to preassemble the modules when they are needed in the production. This could result in an even longer downtime at the changeover which is classified as waste according to section 3.4.1.

5.3 Assembly systems

The preassembly and one piece stations at HES are product oriented with parallel production flows and are an important complement to the line organization. As HES have some big products including a lot of manual work and which is not frequently ordered this kind of layout is suitable according to section 3.2.3.2. The productions flow parallelization increases the capacity and flexibility of HES assembly system at the same time as it reduces the sensitivity for disturbances, as described in 3.2.3.2.

Due to the high level of customized orders and increasing product range at HES and at the same time having a line organization makes it crucial to have short changeover times, see section 3.2.3.1. This is not the situation today and this increases the lead time for customers and tied up capital, as batch planning is utilized to reduce downtime.

Observations show that the test station is the bottleneck of the line. Once there is a leakage the operator tries to fix it instantly and a queue is building up if he cannot fix it quickly. When investigating the problem the authors found that there are no rules or guidelines of the troubleshooting or how long time to spend on it. The lack of these kinds of guidelines is the reason that this station is the bottleneck. They have the ability to put the unit to the side for troubleshooting by someone else so that they do not interrupt the rest of the line but the authors observations show that it is rarely done.

5.4 Warehousing

The focus on getting the production started as fast as possible without managing the warehouse properly when relocating HES has and will continue to cause waste, in form of searching and unnecessary movements, if not corrected.

The fact that preassembled modules for the line do not have dedicated places in any warehouse causes the preassembly area to be messier than it has to be. Today the warehousing personnel constantly have to interrupt the team leaders, and check which modules to pick and where to put them. According to section 3.6.5 there are a lot of advantages with visualization, like having an environment that is clean, well organized and efficient without waste.

When a pallet is empty and removed from the pallet rack it has to be removed in Jeeves. When the personnel forget this step they are creating more work for themselves. It is critical that Jeeves is up to date to keep control of the inventory; otherwise it is not possible to see where they have available space in the warehouse when they need to add new articles. Instead they have to physically go through the forklift aisles to find available space in the pallet rack. By not having this updated and visual it causes a lot of waste like unnecessary movement and searching. The fact that no first-in-first-out rules are applied lead to spread out material, which creates disorder and makes the material impossible to trace if they pick from several batches at the same time.

The material market is today divided into incoming and outgoing material, but observations show that this is not followed properly. All kinds of material and trolleys are mixed in this zone and also excess material, which has not been returned. This has a negative impact on the visualization and generates waste in buffers and searching of material. The reason is that there is no available place to put the trolleys gathered from the outgoing square, and as a result of this they will be left there until they are to be used again. The disorder in the material market also makes it hard to reach the needed trolley without having to move around several trolleys. This kind of behaviors is very different from how the theoretical framework describes how to make the process visual, sees section 3.6.5, and also causes a lot of waste over and over again.

Currently leftover materials from several orders are placed on a trolley in the outgoing area without any documentation for the warehousing personnel to identify the article number of the left over material with. Thereby there is no way of knowing where to place it in the warehouse. If there are articles on the picking list that are not used for the order this material ends up on a trolley like this and there is no way of knowing which order the excess material belongs to. This makes it impossible to know which picking list to update so that the same excess material will not be picked over and over again. It also hides problems with the product structure as there is no way to see if it is correct or not. This increases the risk of withdrawing wrong components from Jeeves every time reporting those products. This risk is also increased by the fact that everyone are allowed to pick material from the production stock, because when some components are missing the assembly personnel just go pick them without telling anyone to check the product structure. According to section 3.5 it is necessary to bring these kinds of problems to the surface for having a possibility to correct them and improve the process.

Left over material that is left on the trolleys can also cause confusion due to the fact that according to Jeeves the material is on its attended place in the warehouse. Keeping the extra setup of trolleys for the line at the end of the shop floor generates unnecessary transportations and the excess material in the grey boxes is also a buffer that is not shown in the system. Buffers like this could in some cases be the cause to stock difference. The personnel simply cannot find the material when they are stocktaking if it is left in different temporary buffers on the shop floor. As described in section 3.4, extra raw material and work in process like this are contributing to longer lead times, higher grade of obsolescence and more tied up capital. The extra transportation also means extra downtime in the line when a changeover is made.

5.5 Material supply

By not knowing if the picked material is enough for the order or when it is time for a changeover force the warehouse personal to continuously check the situation at the line. This interrupts their other work tasks, like kitting trolleys to the one piece stations and receiving new gods and adding it to the stock. These kinds of interruptions and continuously checkups make their daily work very stressful and a lot of time are wasted driving back and forth, time that could have been used

for other things. The theoretical framework shows that these checkups and interruptions could be eliminated if the situation at the line was more visual. Keeping some material in a tent where they are dependent on the availability of another fork lift means that they risk even more downtime if they forget to gather the material in advance or if the fork lift is busy when needed.

The mixing of different kind of material in the same compartments makes it difficult for the assembly personal to know which article to use on the product they are assembling. This is a big quality issue, as they risk assembling the wrong material and sending a faulty product to their customer. A lean environment should be visualized and have different dedicated places for different kinds of material and thereby not allowing this mixing of material.

One of the reasons that a changeover is very time consuming is because the assembly personnel gathers and refills some of the articles in the grey boxes themselves instead of starting to assembly products for the new order. SMED distinguishes between internal and external changeover time and a manual assembly line like this should not need to have this long internal changeover time.

The current picking lists contains no information regarding which material goes to which station so the warehouse personnel have to interrupt and ask the team leaders with most of the material. Today the warehousing personnel also have problems to separate the modules from each other and state which module that corresponds to a certain article number. This creates waste in form of searching, movement and leads to interrupting the team leaders with questions all the time. Here is a gap between how they are working and how they could be working according to 5S. Every item should have its own place where everyone know where to find it according to 5S.

The orders that are going to be assembled at the one piece stations are kitted and placed at the material market. Here there are no temporary buffers with excess material and this process is working better than the supply for the line, looking from a lean perspective.

Except from the lack of a proper planning on all modules, the material supply for the preassembly works as expected and does not generate a lot of waste. The preassembly personnel pick most of the material for the modules by themselves in a nearby production stock and they are helped, when needed, by the warehousing personnel.

5.6 Visualization and 5S

The 5S work and the management that understands that it takes some time to achieve the right mindset among the personnel is aligned with what is described in section 3.4. HES are currently working with the first two of five steps in 5S, with some exceptions like the SOPs and the color coding. Essential items are being tagged and given a dedicated place, but a lot of work still remains here. The visualization is still poor compared to how the best companies are working

with it, and a lot of work remains for having a transparent production for easy detection of problems.

All unsorted items without a dedicated place contribute to the risk of more downtime. Tools that are placed in the grey boxes follows the boxes when there is a changeover and thereby risks to be missing until the same grey box are to be used again. Disorder like this creates a lot of searching for needed equipment and it is also a matter of ergonomics. Section 3.5.1 says that you should avoid adverse work postures like the kind of movement that occurs when the personnel have to turn around and reach for tools in the boxes, tools that are to be used at the line.

The personnel only get oral feedback from the 5S audits, which are done regularly just as the best companies are doing. Section 3.5 suggest that if the personnel where divided into different groups with specific areas to be responsible for they could compare themselves and be given simple rewards to create an incentive to improve. This is not done at HES today

The daily meeting in front of the cell status board is a good way of going through the daily work and to give everyone an opportunity to discuss problems and solutions. The waste walk is also a good opportunity to show the employers the work area from another perspective and to make them identify waste on their own. Unfortunately everything that comes up on these walk are not corrected today, but HES have come a long way since they moved the production and, as earlier described, it takes some time to create a new mindset without forcing everyone to change.

SOP for every product is not only to ensure that every product is assembled the right way but also that the needed information is right in front of the personnel when needed. By having this standardization HES reduces waste as the products are assembled in the best possible way and the quality for customers are also secured. This standardization work is aligned with what is described in the theoretical framework in section 3.6.5.

5.7 Takt

HES´s only use of takt is to set the number of units they should produce every day. This means that they do not have a visual aid to show if they are going to reach the target of the day or not until the day is finished. Section 3.4.5 state that an efficient value chain uses takt in all processes and demonstrates benefits with having several targets, for instance number of units to produce per hour. To be able to set up hourly output targets the process has to be stable and everyone must know what to do and how to alert others if something is wrong. If a queue is building up in front of the test station the rest of the stations will soon run out of palettes and will have to wait to the test problem is solved. The same thing happens if the operators do not follow the product around the line when they are an uneven number of operators working at the line. This behavior causes a lot of waste in form of waiting. Since the managers are aware of the time losses that are caused by this way of working there seems to be some issues on how they are communicating this

information to the operators since observation show that they do not follow these guidelines appropriately.

Observations also show that some stations are faster than others when assembling some of the products. A system with a defined takt should be balanced to eliminate wastes, but some of the reasons for interruptions in the takt are when the operator leaves his station to gather material himself.

5.8 Work organization

Compared to Toyota HES have longer cycle times and less repetitive work, which has a positive effect on the work environment. At both companies the workers have indirect work and other responsibilities in addition to the direct work and the work tasks are frequently switched. The switching of work tasks results in employees learning different things and creates a more flexible organization, as described in section 3.5. The fact that the warehousing personnel now are more integrated with the assembly personnel has a good impact on the work organization as they feel more communions with the others. This also makes them work more as a unit, as they are more responsible for the daily outcome and problem solving together.

In contrast to Toyota HES has no official reward system and sees problem solving and improvements as a part of the daily work for the employees. Though, the managers continuously motivate the employees to bring up problems they see and the managers are very responsive to what the employees say. They also go to the source themselves when problems occur, just as the lean philosophy emphasizes. Also the respect for the employees and understanding of the importance of human elements is all aligned with lean principles.

5.8.1 Ergonomics

It is important to think through every aspect of the daily work for the employees and how it will be affected by a new work procedure. Having a trained safety representative among the staff reduces the risk of introduction of work patterns that are unhealthy. Supporting tools such as the lifting tackles show that HES are aware of the risks with having adverse work postures. The ideas of not counting the material on pallets exact is right from an ergonomic point of view, as is reduced a lot of heavy lifts. Even if there is more work to do, all this things shows that HES see ergonomics as a pre-requisite of quality an efficient organization, as described in section 3.5.1.

5.9 Summary of problems/gaps found

There are some gaps between how HES currently are working compared to the theoretical framework described in chapter 3. These gaps often appear as problems and wastes and appendix 2 lists these problems where they arise. The list was regrouped so that the similar symptoms and causes were grouped together. The result of this was four groups which are the four major gaps

between how they currently are working and how they could be working according to lean. Those are: flexibility, visualization, supplying material and warehousing- and purchasing policies. The main gaps will be described in this section followed by a list of suggestions of how the gaps could be reduced. As said the layout has no natural flow according to the value adding activities but it is too big of an issue to solve in a project like this and will therefore be discarded from further analysis. Below the main gaps are described.

5.9.1 Flexibility

The amount of customized products increases rapidly, but the production is still producing in large batches resulting in longer lead time. This is contrary to lean and would not be necessary if the production was more flexible. This is also contrary to Hills´s theory on how to choose production process. HES´s sales company needs to have flexibility to win customer orders while the production line currently is adapted to high volumes. The list below describes some of the problems belonging to flexibility issues.

- Batch planning and not according to the actual demand, increasing lead time
- Long changeover times
- No possibility to prepare the next order, leading to stress and downtime

How the flexibility gap could be reduced

- Reduce the changeover time
    - Dedicate an area where the next order is prepared
    - Reduce distances where the operator walks to change his trolley
    - Make sure that everyone knows what to do when it is time for a changeover
    - The warehousing staff needs to know when it is time for a changeover so they can be available when needed

- Reduce other downtime
    - Make sure that all the needed material are kitted in the grey boxes
    - Set up rules for how to troubleshoot at the test station

5.9.2 Visualization

The whole production needs to be more transparent for making detection of problems and deviations easier and in that way be able to reduce waste continuously. This includes visualization of how the production is performing as well as markings of boxes, compartments, trolleys and the shop floor. The list below presents the problems that occur due to poor visualization.

- Very dependent on experienced team leaders
- The production personnel cannot interpret the text string saying what is customized
- Incomplete product structures that has no way to be corrected makes the reporting in Jeeves incomplete and leads to inventory differences
- Disorder in the material market
- Mixing of material for several orders causing confusion and quality problems
- There are no grey boxes for some product families
- A lot of unnecessary searching and movements due to disorder in the material market
- The kitted trolleys for the one piece stations are not separated between product families
- No dedicated place to put preassembled modules
- No standardized rules of what to do at the test station when having errors, building up queues
- No standardized routine of how to handle customized products
- Do follow any rules of how many to be at the line for optimal assembling
- Not all tools have their own spot, leading to waste and adverse work postures

How the visualization gap could be reduced

- Improve all general markings
- Every moveable item needs a dedicated place
- Pick the exact number of components for an order
- Update the picking lists
- Standardizations and guidelines

5.9.3 Supplying material

The material supply process need to be more stable and standardized. The warehousing personnel need to know when and where the material is needed. The current process has problems with the below listed.

- No article number for certain modules and thereby no planning of them
- Lack of times when an order is finished and when changeovers will take place
- Old picking lists are used, which are not up to date
- Dependent on experienced team leaders to know where to put material
- Hard to plan the kitting of components for preassembly
- Material supply personnel need to be available for the preassembly personnel a lot
- Do not know which station the components and pallets are going to
- Do not know which stations is concerned when picking for customized products
- The forklift for the outside tent is not always available when the line needs material
- Continuous checking material levels at all stations and a lot of unnecessary movement

- Left over material stays in the grey boxes instead of being returned to the warehouse
- Confusions about who is picking some of the material
- No dedicated place for the kitted material
- Waiting time when running out of material
- Downtime when the assembly personnel leave for getting material

How the material supply gap could be reduced

- Warehousing staff needs to know when and where to pick and put orders
- Reduce their stress level by creating a process where they can be slightly ahead with prepared orders before it is time for changeover
- Pick the exact number of components for an order instead of continuous checking
- Let the warehousing personnel own and control the warehouses

5.9.4 Warehousing- and purchasing policies

The warehouses as well as the purchasing policies need to be reviewed. Standardized rules such as where to put different material, when and how much to buy at a time, the importance of updating Jeeves when the pallet racks are empty and first in first out rules needs to be applied. Also things like who has access to the warehouses, when and who to perform stocktaking and how to avoid inventory differences needs to be reviewed. Below is a list of problems regarding warehousing and purchasing.

- No directions/instructions on where to put material
- Same material spread out in several warehouses
- The warehouses are not sorted
- No FIFO rules
- To large quantities of one components delivered in the same batch
- Everyone have access to the warehouses
- Do not always update when having empty pallet racks in Jeeves
- Do not have time for stocktaking

How the warehousing- and purchasing policies gap could be reduced

- Sort the warehouse
- Look over reorder points
- Mark arriving goods with dates so that FIFO can be used
- Make sure that the product structures are correct so that Jeeves gets updated and the right components get withdrawn when picking an order
- Set up directions for making sure that stocktaking takes place continuously

5.10 Discussion and explanation on where to focus and why

Because of the limited time and resources in this project the authors wanted to focus on the most important problem areas first. The most important areas were identified as where the largest gaps are today, which prevents HES from having an efficient production flow, and areas which would reduce most of the important problems if solved. Another criterion was that the focused areas also should have potential for quick and safe improvements that would have a great impact on the efficiency as well as the workers attitude to change. Of significant importance was also that the focused areas were not too large for this limited project and that the focused areas were aligned with the strategy of the company. Here a holistic view was of great importance. The way HES supply material was identified as the key area that together with the visualization also would have a great impact on the flexibility. The focus from here on will be to standardize the material supply process, improve visualization and make the line more flexible and thereby align the production´s focus with the sales company according to Hill´s process choice model. The warehousing- and purchasing policy gap was not included in this project, as this is a very big project and by the authors seen as a natural step to take after the other improvements.

6 A new work pattern

In the following part the authors' suggestion will be explained followed by a description of how an implementation was made using PDCA.

6.1 General idea

The main purpose of this suggestion is to make HES´s production more flexible and make the different material flows more stable and visual. The idea is to separate the material supply for the different production flows from each other. The picked material for the line will not be mixed with the picked material for the preassembly or the one piece stations. To make the assembly line more flexible, the time for a changeover has to be reduced and this suggestion will allow that by having the next orders already picked and waiting on an assigned place on the shop floor. Moveable items will be dedicated a marked area to keep the order and to eliminate waste.

6.2 Layout

From the beginning the authors' suggestion was to move the pallet rack behind the line and keep two sets of white trolleys prepared with the following orders for the line there, having them close to the station where they are to be used. This requires a new set of white trolleys and also new space for the pallets that are removed when the pallet rack by the line is taken down. When this was presented for the company, they wanted to see that the new concept worked practically before making any investments. This forced the authors to redesign the layout, adopting it so the concept could be tested with existing equipment and without any moving of pallet racks.

The old material square will be dedicated for the line and redesigned to make room for preparation of material for the next orders to the line. There will be seven marked areas dedicated for pallets that are to be used on the seven lifting tackles on the next order. Each marked area is given a number which corresponds to the number on the lifting tackle, for making it visual which pallet goes where. There are also markings for the white trolleys for the next two orders. This result in two lines with four squares for trolleys with grey boxes and one square for order unique material at the end of each line. Other line material such as palettes and pipe trolleys are also given a dedicated area. By giving every moveable object a dedicated place it will create order and everyone will know where to find everything when it is time for a changeover. By not having available space for excess material, empty trolleys and pallets they will have to be moved to the right place instead of building buffers. It will also be easier to get to your trolley when there are no other trolleys in the way. Keeping all material for the line in the old material square will also minimize the distance that a trolley has to be moved. Appendix 4 and appendix 5 show detailed layouts on how the material market used to be and how it will look like when the suggestion is implemented.

Trolleys with material for the one piece stations are removed from the material market and placed at the end of the shop floor. The areas dedicated for these trolleys will be sorted by product family in order to make it visual and no need to search for a trolley, the area is highlighted in appendix 3. Scrap containers are not frequently used close to the assembly line and are therefore moved to the end of the shop floor as well.

6.3 The material supply process

In the suggestion the warehousing personnel owns the warehouse and are the only people allowed to make withdrawals, except for the material in the production stock at the preassembly. This is for making them feel more responsible for the warehouse and to keep the order. The warehousing personnel will start to pick the exact amount of material needed for the orders into the grey boxes. This is to avoid bringing in excess material, reduce the risk of taking wrong material and bring faulty product structures to the surface, resulting in less inventory differences in the long run. Material for the next two orders at the line are prepared and this allows the warehousing personnel to plan their day as they know that the line have material prepared. Material shortages are also detected in advance, allowing them to reschedule the order and alert the purchasers and eventually the customer.

The picking of material is done by moving the trolleys through the warehouse and picking material directly in the trolley in order to minimize the handling of material. When all material for station one is picked the trolley is put on its dedicated place and then the warehousing personnel are moving on to trolley number two etc.

When doing a changeover the line personnel brings in the prepared trolley, for the station they currently are working on, by themselves. At the same time they leave the empty trolley from the previous order where they got the new one. This is a visual signal showing that the warehousing personnel are able to start picking a new order. By having prepared trolleys close to the line, the internal changeover time would reduce radically. The authors found that reducing the internal changeover time, according to SMED, is absolutely crucial when adopting the layout to a more flexible production.

When the warehousing personnel picks the first orders according to the suggestion, new cheat sheets will be made saying which component going into which station and to which compartment in the grey box. Here the experienced team leaders have a key role in the beginning and need to support the warehousing personnel. The information from the cheat sheets will be used to update Jeeves, enabling the picking list to contain information of which material goes to which station.

6.4 Visualization and 5S

The suggestion aims at making the production more transparent and visual. All things such as containers, pallets and trolleys will have their own location which is clearly marked. The grey boxes will be sorted by product family and all compartments will be labelled with its intended component to avoid doubt of what is supposed to be in it. Faulty components that were detected at the test station was given a small area next to the station so that they would have to take care of them and not just build up a pile with problems, see the blue box in the red square in figure 11.

Figure 11: New markings at the test station

Everyone are supposed to see which order is stranding in queue and if the warehousing personnel have prepared it or not. This is the case both at the line and at the one piece stations.

6.5 Implementation

Section 3.5 describes the importance of everyone's participation in a change to keep them motivated and willing to change. Therefore the new layout and way to prepare next orders was presented to the staff two weeks before the actual implementation. This gave them time to understand the change and also time to come up with new ideas and suggestions on how it could be improved even more. The authors started with explaining the background, purpose and objectives with the implementation and kept a copy of those together with the new layout posted in the production so that the staff could go through it on their own after the presentation.

The team leaders and the team manager were involved in remarking the floor, which resulted in new ideas how to use the floor space which resulted in moving the garbage, to a place behind the packaging station, creating more room for the palettes and a trolley in the material market. To eliminate the risk of interfering the production, marking and other preparations was done a late afternoon after the shift when the line was not running. Due to lack of information on the picking lists the team managers with great experience had a key role in helping the warehousing personnel to create cheat sheets with information on what articles goes in what trolley.

The new set up requires an extra set of trolleys and after having revised the situation three extra sets of grey boxes. Unfortunately there are no extra set of line trolleys available so another kind of trolleys that is not adopted for the line had to be used to test the new method. The extra set of

boxes had to be given a place to be stored when they are not in use so the layout had to be revised again. When this was done another problem arose when the boxes had to be stacked, the delimiters in the boxes were too high which resulted in unstable piles. This problem created a safety risk and was solved by cutting 45mm of the top of each delimiter which resulted in stable stacks of piled boxes.

When the authors lined up the trolleys in its marked squares and started to pick material we realized that the trolleys are kind of hard to maneuver. This knowledge made us redesign the squares and making two one-way lines instead, where the warehousing personnel refill trolleys from the back and the line personnel pick the trolleys from the front. This improves both the ergonomics and speed of the process, as the personnel do not have to make sideways maneuvers in order to put the trolley in its square besides the other trolleys. As a result of this the one-way lines claimed the order unique materials location as well, so the order unique material was given a new location behind the line material square. The revised designed is shown in appendix 6.

During the implementation the authors continuously worked with 5S and assigned every moveable object an own dedicated place and clearly visualized it. Initially different colors were supposed to be used to connect the trolleys with its working station in a visual way. But when the suggestion was presented for the team manager it became clear that this was against their 5S color schemes, and a decision to go with numbers instead was made. All grey boxes were labeled with its product family and all compartments were labeled with article number. For avoiding confusion and mistakes all modules were photographed and the pictures were set in the assigned compartment.

Figure 12: A fully marked pair of grey boxes

A benefit with counting material in exact number for the order is the visual aspect of it, everyone can see what material to use and how many there are left on the order or if the number on the picking list needs to be corrected. During the implementation it also became more visual which equipment that did not have its own place. Another thing now brought to the surface were all kinds of material which maybe would be better to have located at the line, due to the time it takes to count small components that are needed for several products, for example screws and mutters. Components that are kept in front of the line all the time needs to have an indicator that shows when it needs to be refilled. This can be done with some sort of kanban system described in section 3.6.3.

In the authors suggestions the ergonomic aspects were considered and therefore no exact counting of the heavy and bulky components were suggested. Because without having the right supporting tools that would lead to a lot of heavy lifts and adverse work postures for the warehousing personnel.

6.6 Results of the new work pattern

With the new work pattern the material supply has been standardized and everyone knows when and where the material is going. Feedback from the warehousing personnel showed on a less stressful work environment after the implementation and an increased possibility to plan their day.

The downtime in the line when having a changeover has significantly been decreased. Now the line never has to be stopped in the middle of an order due to material shortage and the time for a changeover is reduced from the varying 15 to 60 minutes down to 4 minutes. Four minutes is the time it takes for the first station to change the pipe trolley and palettes for the new order. The following stations only have one trolley to change and it takes about three minutes. The extra time it takes to count the components is not longer than the time they used to spend on continuously checking of the material levels.

The new and faster procedure to perform changeovers gives the planner an opportunity to plan the production after the actual demand, instead of planning to minimize the number of changeovers, without missing out on a lot of valuable production time. The ability to have more changeovers every week creates a whole new flexibility which according to Hill is needed from the production to meet the sales company´s continuously increased product range. It is now possible to discard the production schedule with a more critical order if needed. You can simple prepare the critical order on one of the set of white trolleys and put it in front of the order in queue to the line.

All the markings and dedicated places have made the shop floor more visual and observation show that the new areas are used for the right things. It also shows which things that do not have a dedicated place and might need one. For example after the implementation it become clear that

the preassembled modules needs a clearly marked place to be stored while waiting for final assembly, in order to reduce the risk of taking wrong modules and avoid disorder on the shop floor. This kind of visualization of problems is necessary for making continuous improvements possible, according to Liker.

Figure 13: The new material market

The possibility to detect errors and deviations has also increased with the new work pattern. When having material kitted in exact amount for the orders at the line the personnel can easily discover if something is wrong with the product structure. Bringing this to the surface will reduce the risk of having the same problem generating waste over and over again. The risk of assembling wrong material is also severely reduced by having the compartments in the grey boxes clearly marked. It is easy to see if a component is placed in the wrong compartment and the warehousing personnel can use the markings as a work instruction when kitting.

After the implementation it became more visual how the production is performing according to the production plan. It is now possible to see how many units there are left on the current order by looking into any of the grey boxes and count how many components there are left to assembly. By looking at the material square anyone can see if the next one or two orders are prepared for assembly, and if one set of trolleys is empty it is a visual signal for the warehousing personnel that another order can be prepared.

Appendix 7 shows that the new work pattern at HES will save 150 000-300 000SEK annually just for the time saved for the line operators, depending on the number of changeovers per week, due to the reduced changeover time and the fact that all the needed material are in place at the line after a changeover.

6.6.1 Further implementations

When every moveable thing was given an own dedicated place it became clear that the modules had no place to be stored. Due to the incomplete planning of module that has not got an article number in the system, the modules are sometimes made some days in advance. This results in modules lying around in the production on trolleys and pallets without markings for days. Another thing that came up was the fact that it is almost impossible to sort out the different modules. The personnel that pick the orders have no way to know where to find the right module for the order without asking the experienced team leader. These problems would not exist if all modules were given a dedicated place, which is clearly marked.

So the next step in the PDCA was to correct these problems and make it more visual for everyone. The suggestion for solving this resulted in a production warehouse for frequently used modules. All modules, both those registered in the system and those not, were analyzed by the authors. The frequency and inventory level were studied in order to find out which modules needed a dedicated place in the module warehouse. Here the general idea was to place the most frequently used models at the best picking height, i.e. first and second level, and modules less frequently used on the third and fourth level in the pallet rack. They were sorted by product family and clearly marked with article number, when needed a new temporary name, and pictures of the modules. The reason for putting up pictures was to make it easier for everyone to know where to put and where find the modules, especially the modules without an article number.

The production warehouse with modules is meant to work as a balance stock, where there always are suppose to be units between a minimum and a maximum number. These levels have to be set by the managers after they have decided which product needs to have the shortage lead time. When the levels are set they can use indicators on the pallets, for instance three magnets in different colors that indicates the current stock level and if they need to assembly more modules. This module warehouse is considered to be quite temporary but very necessary until the planning process is stable and when every module is registered in the system. The warehouse can then gradually be phased out or have lowered maximum levels when the production is ready for making the preassembly just in time. Having finished modules in stock will also ease the planning of staff allocation in the production and not have to risk letting personnel leave the line to help at the preassembly to keep up with the pace. Having modules in stock means that it will shorten the lead time of an order and that could mean that they can reduce the finished goods stock and still have a high service level.

Figure 14: The new module stock

6.6.2 Feedback from the employees

During and after the implementation the authors observed and talked to the warehouse and assembly personnel to see the effect of the change. Understanding that an anonymous survey was the only way to know that the employees would answer our questions honestly, a survey was handed out to the employees a month after the implementation so their feedback could be compiled after having worked accordingly to the new work pattern some time.

The answers from the 14 respondents of the survey are presented in appendix 8. Overall the respondents where happy with the change and the answers are aligned with the results described in section 6.6. For instance 13/14 thinks that there is better order in the material market and that the changeover runs smoother. The survey also shows how the employees' mindsets, and how they experience their work environment, have changed. For instance 4/14 says that they are more optimistic to change and 3/14 feels less stressed out at work.

7 Conclusions

In this chapter we summarize the outcome of the project and present the conclusions. Important things for HES to do next and to make the improvements last are also presented here.

When comparing the current state at HES with lean philosophies the largest gaps where identified as lack of flexibility and visualization in the production, an unstable material supply process and warehousing- and purchasing policies that needs to be reviewed. All these gaps, except the latter one, were reduced within this project and the results are by the authors considered valuable for Alfa Laval.

After this project the HES production is more adapted to meet the needs of the sales company, as they now are able to plan the production more flexible. Now when the time for a changeover is reduced to four minutes it not necessary to produce in long batches any more. Instead HES should plan the production more according to the customers, as this will reduce the tied up capital and result in shorter lead times. Due to the reduced changeover time and the fact that all the needed material are in place at the line after a changeover HES will also save 150 000-300 000 SEK annually just for the saved time for the eight operators at the line, depending on the number of changeovers per week.

As the production and material supply have become more visual and transparent it is now easier for everyone to see how the production is managing compared to the production plan. It is also easier to detect problems, like deficient product structures or if wrong components are picked. The amount of unnecessary searching and movements has also decreased as moveable things are given dedicated places and due to line material now are kitted in the right amount, which removes the need of continuously checking and refilling material. Now it is also more visual which tools and frequently used material that do not have a dedicated spot, as they now comes to the surface when the grey boxes are supposed to be empty when the order is finished.

To make sure that these improvements are maintained it is crucial that the management gives the right support to the employees and that the trolleys used in the implementations are reviewed for making the material supply process smoother. It is also important to continue with all 5S work in order to visualize waste and new improvement opportunities. A standardization of the text string on the production schedule would, in combination with education of the personnel, reduce a lot of troubles concerning customized products. The only way to change the attitude towards these products is to make everyone understand what differs from the standard product.

Observations show that HES needs to balance the assembly line even more for some products. The communication of what is supposed to happen when the employees are at uneven numbers on the assembly line also needs to be improved. The employees need to follow the palette at uneven numbers in order to reduce the balance losses. It is also crucial that the test station is

standardized with specific guidelines for how long to troubleshoot and what to do when the troubleshooting takes too long time. It is a prerequisite to utilize the other test stations in a separate flow to be able to introduce and keep a certain takt in the assembly line.

The established balance stock for preassembled modules should gradually be phased out, when all modules are registered and a proper planning process is in place. Today though, it is beneficial to use the stock as some modules are registered and not planned and there is no way to keep track of them. Another important thing is to introduce first-in-first-out rules in the warehouses to avoid picking same material from several different places, mixing of batches and to keep the order. To keep the order the warehousing personnel also need to update Jeeves when a place in the pallet rack is empty.

8 Reflections

In this chapter the author's make recommendations for further studies and what HES should focus on after this project is finished. This chapter also includes the author's personal reflections about the project and the methodology used.

8.1 Further studies

There is more problem areas needed to be solved than was included in this project. The next step, according to the authors, should be to review the warehouses as well as the purchasing policies. Standardized rules needs to be applied, such as where to put different material, when and how much to buy at a time and when to perform stocktaking. The warehouses also needs to be sorted, like frequently used material in a good picking height etc., for avoiding waste while gathering material. When the warehouse and purchasing policies are reviewed it is probably possible to reduce the inventory levels gradually and start using Just-In-Time to some extent. This has not been analyzed by the authors.

Introducing takt in the production would visualize which parts of the value chain that has problems keeping the pace and visualize where new improvements are necessary. Meanwhile takt is introduced the daily production target might be beneficial to break down more than today and visualize it for everyone. By doing this the production gets more predictable and the employees knows better at which takt they are supposed to assembly and where they are according to the production plan.

In the future it might be suitable to review the layout of HES. As earlier said/written in the report the production flow does not follow a natural route according to how the products are processed, and this generates a lot of waste.

Further studies could also investigate how the communication between the production and the sales company could be increased in the future. Here is probably a lot of work to do to get them fully synchronized striving towards the same goal.

8.2 Author's reflections about the project and the methodology used

Through the project the time schedule made in the project specification was followed and the chosen methodology proved to be successful. As the management at HES is well informed about lean principles it was always possible to get an agreement with them what was needed to be done. The mainly qualitative approach was enough and the authors did not have to come up with a lot of quantitative data for that reason. The fact that the supervisor is unit manager for HES made the ways of decision very short, which speeded up the work.

Initially it was sometimes difficult to know where to focus as during the pre-study everyone interviewed had a lot of ideas which parts were the most important ones to improve. The authors also found a lot of problem areas that needed to be looked at. The main reason for this, according to the authors, is that the motivation of the employees for making improvements has been low since the moving of the factory and personnel reductions. Thereby we found problems that would have been quite easy for the personnel to solve if they just had the right mindset and willingness to do it. The triangulation was of good help for keeping the holistic view and not to be stuck in complex problems with small potential. The authors also worked with staying objective, when decisions were to be made.

The authors consider the project reliable, as they always went back to the source of information to make sure that they got the information right and by the fact that data was measured several times. The validity was secured by using triangulation during interviews and well defined processes when performing quantitative measures, and also by using many different written sources about the subject.

The authors applied a leadership approach were the personnel were invited at an early stage in the changes, letting them participate and be a key part of the improvements with their experience. Afterwards the authors think this is the best way to create lasting improvements and to set the right mindset among the personnel. This was also confirmed by the survey made among the production personnel afterwards. Now almost a third of the personnel feel more optimistic to change than they did before this project. It is also satisfying that not only the efficiency for HES was improved, but also questions regarding the work environment and daily stress was answered positively.

The project gave very valuable experience for the authors and their future careers, and they realized that something that makes sense in the theory is not always that easy to implement. Also the experience of having several aspects to think about when making changes such as economical, leadership, human elements and ergonomic aspects was a good experience.

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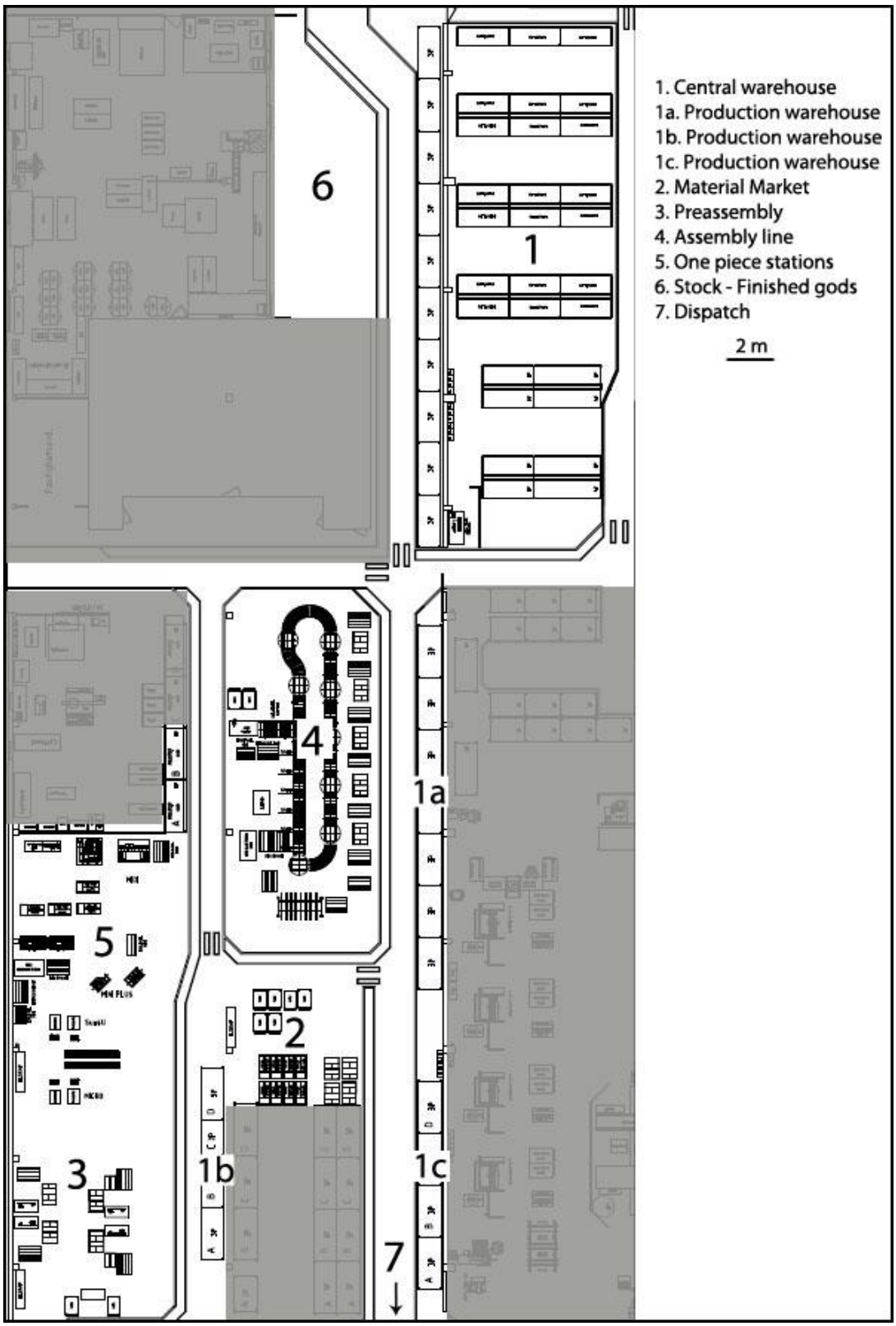
Appendix 1: HES Layout



Appendix 2: Identified problems at the different stages in the process

This appendix lists problems that the author's have identified at the different stages at HES in Ronneby.

Planning process

- Batch planning and not according to the actual demand, increasing lead time
- Lack of times when an order is finished and when changeovers will take place
- No article number for certain modules and thereby no planning of them
- Very dependent on experienced team leaders
- The production personnel cannot interpret the text string saying what is customized

Material supply general

- Old picking lists are used, which are not up to date
- Incomplete product structures make the reporting in Jeeves incomplete, leads to inventory differences
- Dependent on experienced team leaders to know where to put and when to pick material
- Disorder in the material market

Material supply for preassembly

- Difficult to plan the kitting of components for preassembly
- Material supply personnel need to be available for the preassembly personnel a lot

Material supply for the line

- Long changeover times
- Do not know which station the components and pallets are going to
- Do not know which stations is concerned when picking for customized products
- The forklift for the outside tent is not always available when the line needs material
- No possibility to prepare the next order, leading to stress and downtime
- Deficient markings of grey boxes and their compartments
- Mixing of material for several orders causing confusion and quality problems
- Continuous checking material levels at all stations and a lot of unnecessary movement
- Left over material stays in the grey boxes instead of being returned to the warehouse

- There are no marked grey boxes for some product families
- Long way to transport the trolleys when having a changeover
- Confusions about who is picking some of the material

Material supply for one piece station

- A lot of unnecessary searching and movements due to disorder in the material market
- No dedicated place for the kitted material
- The kitted trolleys for one piece stations are not separated between product families

Preassembly

- No dedicated place to put preassembled modules
- Waiting time when running out of material

Assembly line

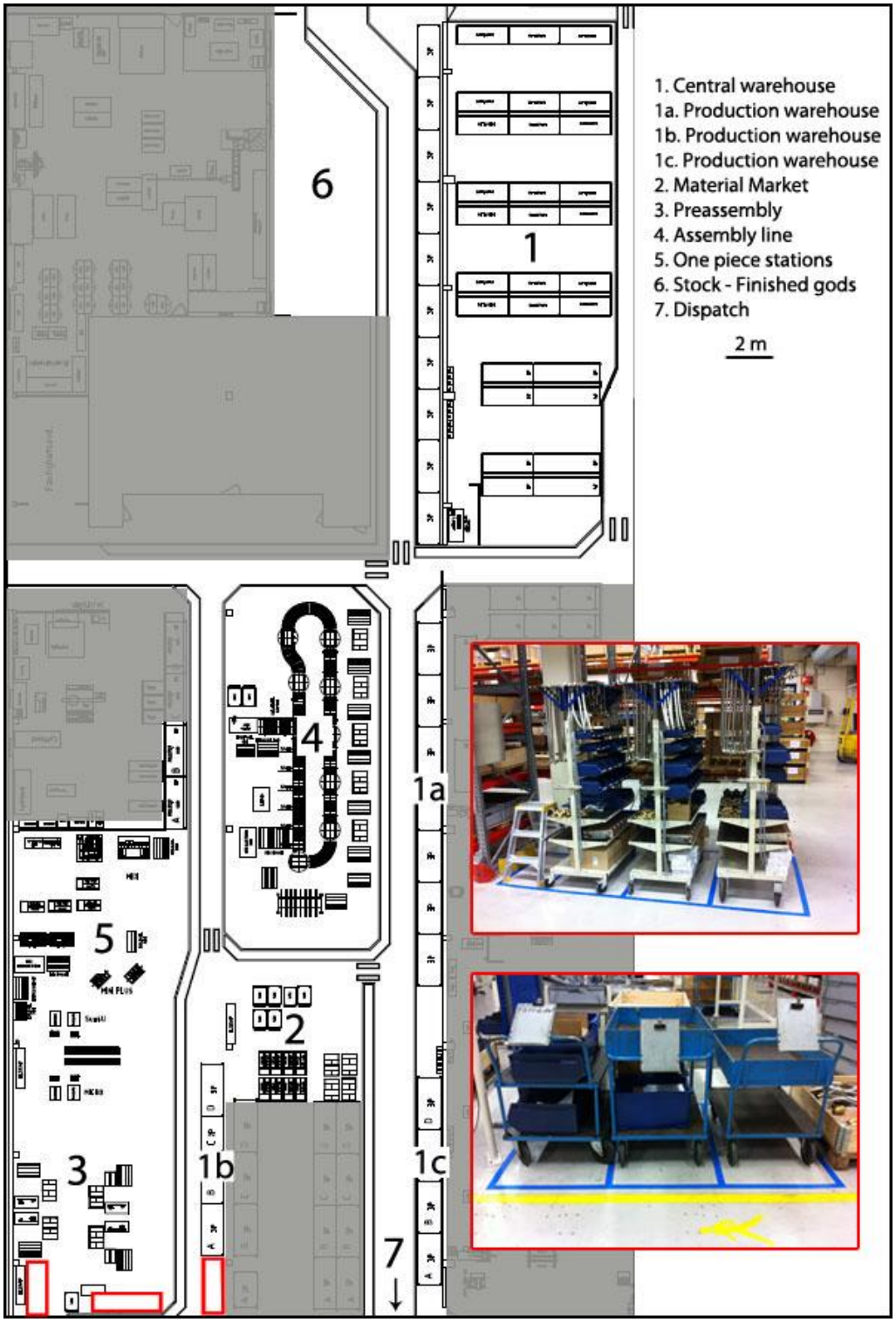
- No standardized rules of what to do at the test station when having errors, building up queues
- No standardized routine of how to handle customized products
- Downtime when the assembly personnel leave for getting material
- Do follow any rules of how many to be at the line for optimal assembling
- Not all tools have their own spot, leading to waste and adverse work postures

Warehousing

- No directions on where to put arriving material
- Same material spread out in several warehouses
- The warehouses are not sorted
- No FIFO rules
- To large quantities of one components delivered in the same batch
- Everyone have access to the warehouses
- Do not always update when having empty pallet racks in Jeeves
- Do not have time for stocktaking
- Inventory differences

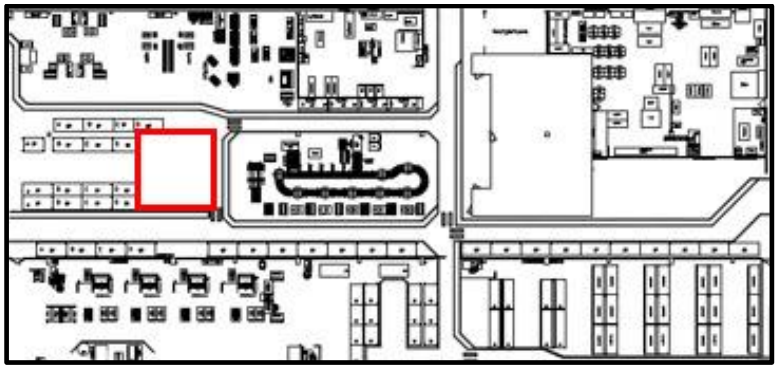
Appendix 3: New separated areas for trolleys to the one piece flow

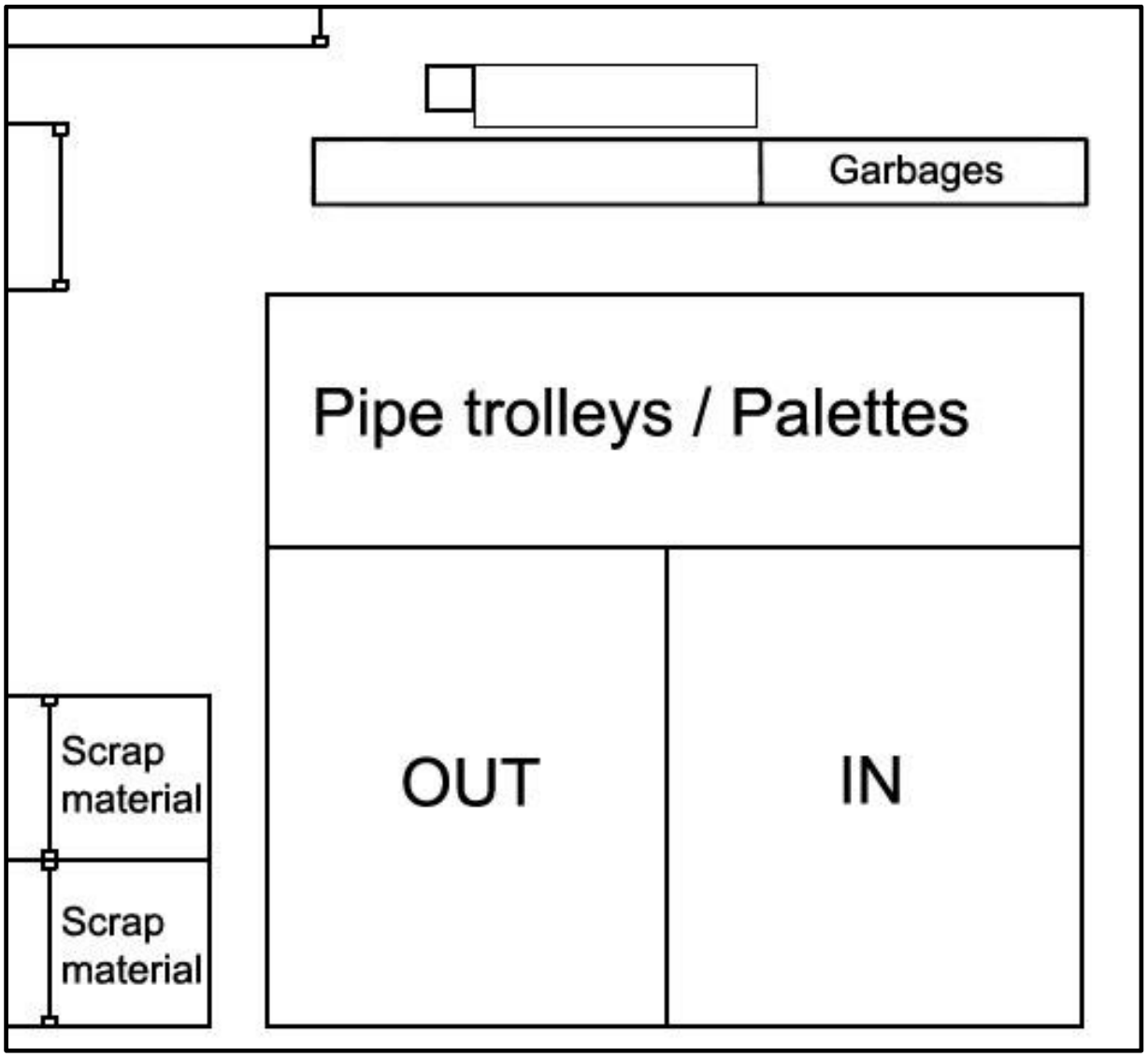
This appendix shows how the area next to the preassembly now is used for trolleys for the one piece flow.



Appendix 4: The material market before any changes

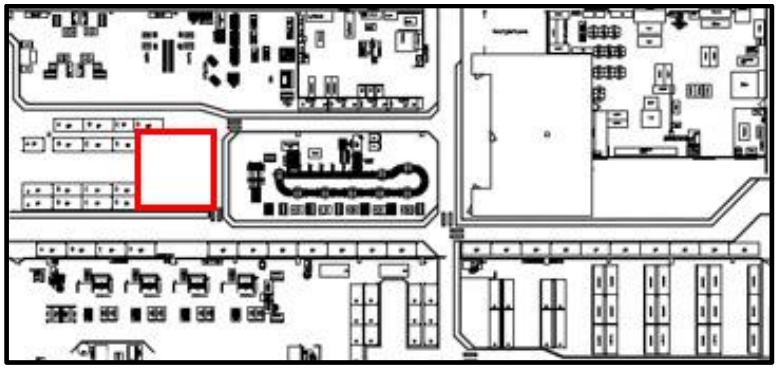
Below is an illustration of how the material square was designed before this project.

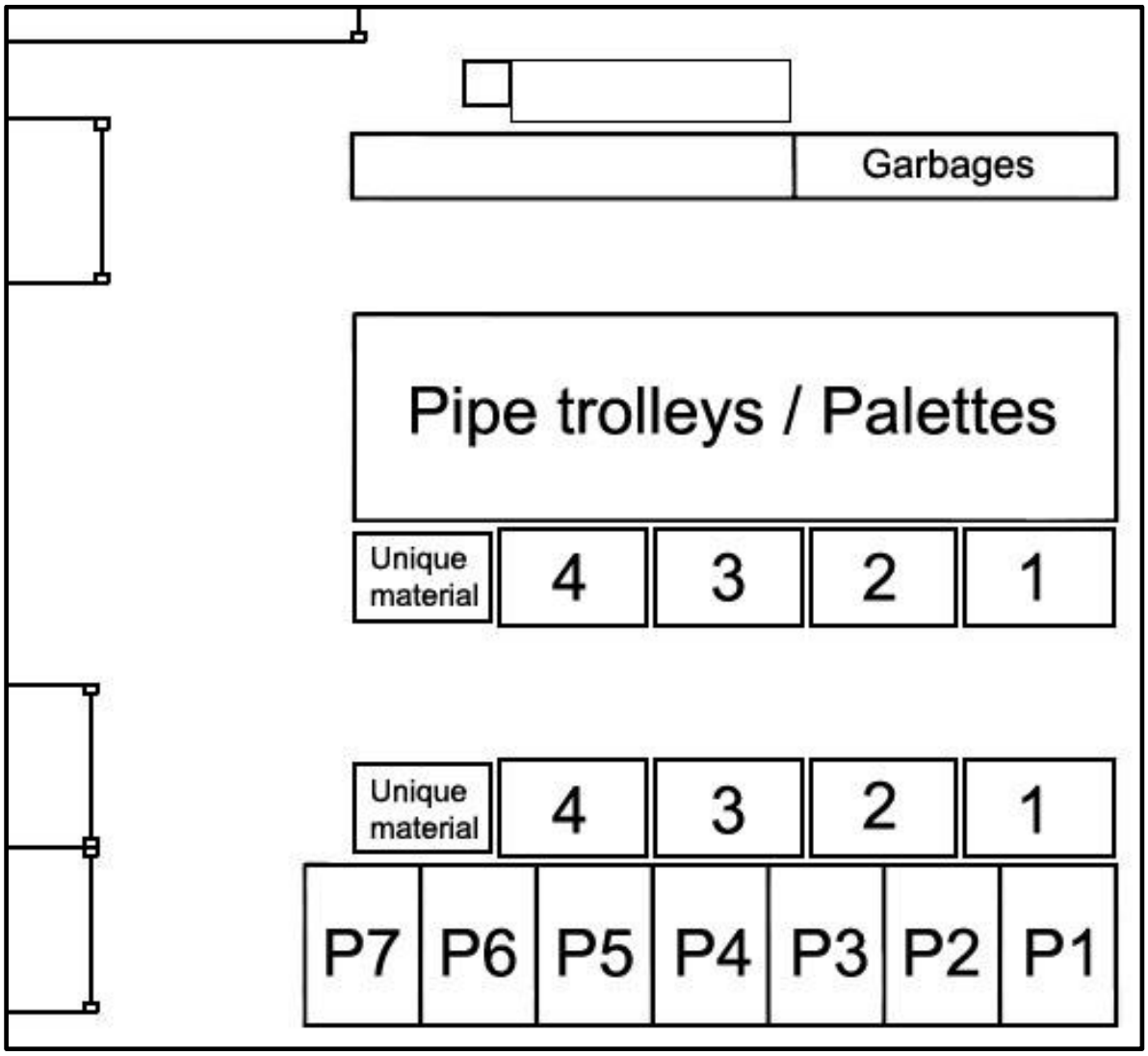




Appendix 5: The first suggested layout

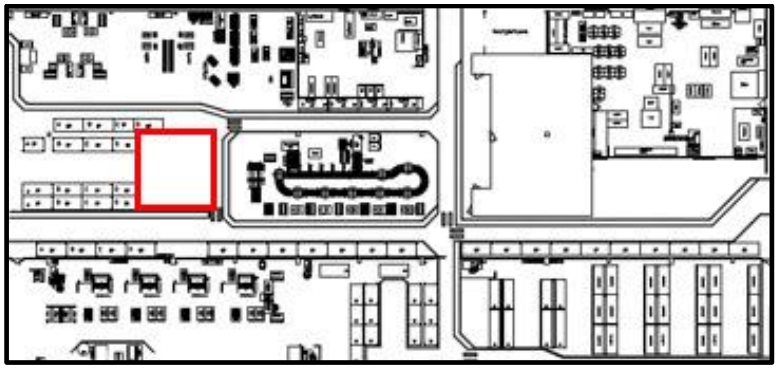
The illustration below is the author´s first suggested layout of the material square.

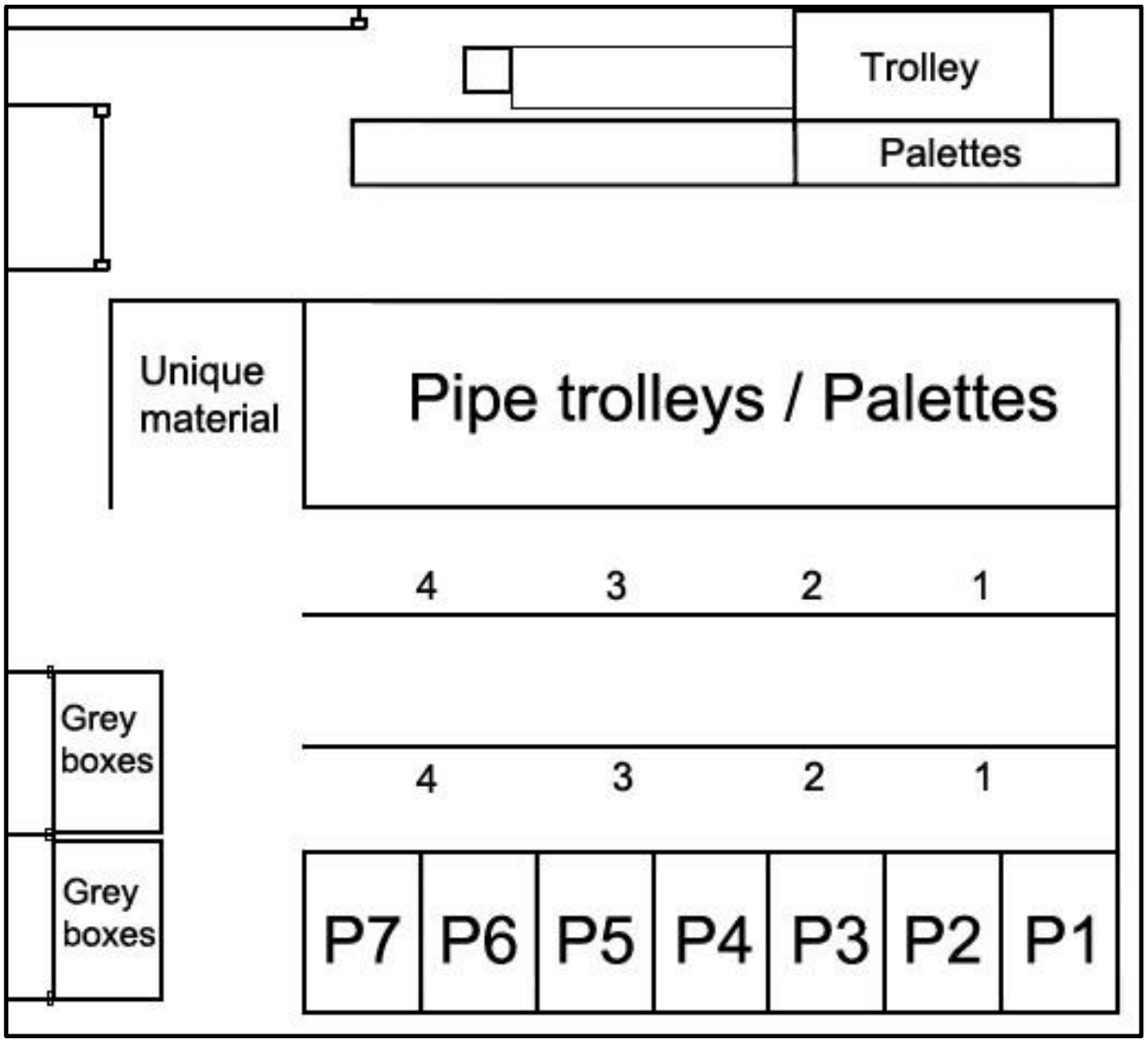




Appendix 6: The new work pattern

Below is an illustration of how the layout looks like after the implementation.





Appendix 7: The savings with the new work pattern

This appendix illustrates the resulted savings of the changes made in this project.

Estimates used in the calculations:

- The line is manned with 8 persons 6 hours a day, 5 days a week, for 50 weeks each year
- The cost for an employee is 250SEK per hour
- Every station had to gather or wait for components 2 min per hour, which is no longer needed when all the material are in place after a changeover
- The time for a changeover is reduced with 30minutes

Those estimates results in the following savings at the production line:

Annually savings if they have 1 changeover every week = 600h =150 000SEK

Annually savings if they have 2 changeovers every week = 800h = 200 000SEK

Annually savings if they have 3 changeovers every week = 1000h = 250 000SEK

Annually savings if they have 4 changeovers every week = 1200h = 300 000SEK

These numbers just considers the time that are saved for the operators in the line, they do not consider the time that are saved for the warehousing staff and the operators at the one piece stations, since they no longer have the same need for searching and continuously check the status at the line.

Appendix 8: Survey about changes at HES

This is a compilation of the result from a survey that was performed, by the personnel working in the production and in the warehouse, a month after the implementation of the new work pattern. The survey was answered by 14 blue collars/workers.

How do you experience the order in the area where in- and outgoing material used to be?

Compare with how it was before the changes

- Worse
- Unchanged **1/14**
- Improved **13/14**

Is it easy to find needed trolleys?

Compare with how it was before the changes

- More difficult
- Unchanged **2/14**
- Easier **12/14**

How do you experience the changeovers now?

The change of white trolleys

- It is more complicated
- Unchanged **1/14**
- It is smoother **13/14**

What do you think of general markings?

Markings of floor, boxes and trolleys

- Messy
- Inadequate **3/14**
- Clear **11/14**

Does everyone comply with the markings?

Is it used as it is attend to be used? Compare with how it was before the change

- Worse than before
- Unchanged **1/14**
- Better than before **13/14**

What do you think about the new warehouse for modules?
Your general impression of a dedicated place where there are a number of units between a minimum and a maximum level of the most common modules

You can check several statements:

- Excess inventory, worked well without it
- Good to always know where to put assembled modules **9/14**
- Nice to know that there always are modules in stock when needed **11/14**
- Avoids last-minute assembly **5/14**
- More flexible planning of modules **7/14**

What do you think of the markings with pictures on pallets and in the grey boxes?

- Unnecessary, article number is enough
- Great, it helps **14/14**

How many disruptions at the line do you experience?
The station is waiting due to material shortage, compare to how it was before.

- More disruptions
- Unchanged **1/14**
- Less disruptions **13/14**

What do you think of your work environment?
Compared to how it used to be

- Worse
- Unchanged **12/14**
- Improved **2/14**

How often do you feel stressed out?
Compared to how it used to be

- More often
- Unchanged **11/14**
- Less often **3/14**

Have the number of unnecessary movements and transportation of material changed?
For instance the distance you go to search for something and the distance you go when changing trolleys

- The distances have increased **1/14**
- Unchanged **5/14**
- The distances are reduced **8/14**

Do problems like faulty product structures get more attention?
Compare to how it used to be

- Problems was more obvious before **2/14**
- Unchanged **10/14**
- It is easier to detect problems now **2/14**

How has your attitude to change of work procedures been affected?
If you have been influenced by this change where you have been able to affect the changes and see the results.

- More opposed to change
- Unchanged **10/14**
- More optimistically to change **4/14**

Do you think that we have utilized the experience from the personnel in a good way?

- Not at all
- Partially **7/14**
- Yes **7/14**

What is the best thing with having the next orders prepared in the area where the in- and outgoing material used to be?

Answers:

- Reduced wainting time
- Smoother changeovers
- Easier to know what to do
- Less searching
- more rapid changeovers
- All material is secured to every order before we begin to assembly it
- Do not have to leave due to material shortage
- Easier to see when it is time for a changeover

What could we have done different?
How could we have utilized the area more efficiently and what could we have done to make the implementation smoother?

Answers:

- Increased the available area for HES
- A pallet rack for the pallets so that we can prepare pallets for two orders instead of one
- Also looked at improving the sorting of the warehouse instead of just making improvements for the line

What is the next thing that needs to be changed at HES?
Since the production was moved there have been a lot of changes but there are still areas that need to be improved. Which is the most important area to improve now?

Answers:

- Sort the warehouse
- The faulty product structures
- Adapt trolleys so they are easier to move (new wheels) and add a feature so they can be transported with a fork lift
- Identify what tools we need at every station and where they should be placed
- Utilize color coding