

Master Thesis

LUTMDN/(TMMV-5249)/1-97/2012



Optimizing the Process of Tool Development

**- HOW TO CREATE AN EFFICIENT VALUE FLOW FOR CUSTOMIZED SOLUTIONS, FROM
DESIGN THROUGH MANUFACTURE**

Sofia Thörnqvist

2012

DEPARTMENT OF MECHANICAL ENGINEERING
LUND UNIVERSITY FACULTY OF ENGINEERING

Preface

This Master Thesis corresponds to 30 ECT and was performed during the spring of 2012. It constitutes my final studies to a Master in Science within Mechanical Engineering at Lund University Faculty of Engineering. The thesis was commissioned by and conducted at Alfa Laval, Operation and Development Forming and Tool Technology (OD-FTT), Lund.

First I would like to express my gratitude to my supervisors at Alfa Laval, Fredrik Berglund and Per Gabrielson. Thank you for all your effort, kindness and expertise. Your advice and support has been truly priceless and thanks to you this project has progressed very well and setbacks were easily resolved. Your engagement has definitely contributed to a better outcome of this thesis.

Secondly, I would also like to thank Christian Wolfe for making it possible for me to do this Master Thesis. Thank you for providing resources, relevant data and foremost thank you for time and feedback throughout the whole project.

I would also like to thank all personnel for your time, effort and openness. Thank you for treating me with respect and as a college. Your friendly and helpful attitudes have made this a great experience for me.

Finally, I would like to thank my supervisor, Jan-Eric Ståhl, for his expertise, advices and his time throughout this project.

I am very pleased that I had the opportunity to complete my studies under these circumstances. The experience have been exciting, worthwhile, and most of all fun. I hope that this Master Thesis will help to reduce lead-time for developing production tools. Finally I wish OD-FTT all my best and good luck in the future.

Lund, May 2012

Sofia Thörnqvist

Abbreviations

| | |
|--------|---|
| NPD | New Product Development |
| DPT | Design and Manufacture Production Tool |
| MPT | Maintenance Production Tool |
| OD-FTT | Operation Development Forming and Tool Technology |
| PROMAL | Alfa Laval's general project model |
| PPB | Portfolio Board Meeting |
| R&D | Research & Development |

Abstract

| | |
|--------------------|---|
| Title | Optimization of tool development process <i>– How to create an efficient value flow for customized solutions from design through manufacture</i> |
| Author | Sofia Thörnqvist, Mechanical Engineering, Lund University Faculty of Engineering |
| Supervisors | Per Gabrielson, Team Manager Operation Development Forming and Tool Technology, Alfa Laval, Lund Fredrik Berglund, Operation Development, Alfa Laval, Lund Jan-Eric Ståhl, Division of Production and Material Engineering, Lund University Faculty of Engineering |
| Purpose | The purpose of this Master Thesis is to understand Alfa Laval's DPT process, find ways to reduce the process lead-time and provide an action plan for implementing new solutions. |
| Methodology | The current situation has been mapped through a case-study of the DPT process. The to-be process has been mapped through an action-study, in order to find the most appropriate solution. Data was collected through interviews, observations, literature review and provided process data. |
| Conclusions | The study showed that the company must reduce waiting time and improve communication, planning and quality. The company is recommended to improve communication by improving their meeting structure, work in process team throughout the whole process and update the existing checklists. In order to improve planning the company is recommended to plan every project through one planning point, allocate specific resources for manufacturing, visualize the project status in the process map and clarify boundaries for projects. At last it is important that the company has a clear quality focus, to spend extra time on securing quality will save time downstream in the process. |
| Keywords | Process Mapping, Process Optimization, Value Stream Mapping, Production Security Matrix, Lean Production. |

Contents

| | |
|---|----|
| Preface | 3 |
| Abbreviations..... | 5 |
| Abstract..... | 7 |
| Contents | 9 |
| Introduction..... | 13 |
| 1.1 Company Background..... | 13 |
| 1.1.1 Alfa Laval | 13 |
| 1.1.2 Operation Development Forming & Tool Technology..... | 13 |
| 1.2 Problem Description | 14 |
| 1.3 Objective | 15 |
| 1.4 Focus and Limitations..... | 16 |
| 1.5 Target Group | 16 |
| 1.5.1 Alfa Laval | 16 |
| 1.5.2 Generally..... | 16 |
| 1.6 Report Outline..... | 16 |
| 2 Methodology..... | 19 |
| 2.1 Research Approach | 19 |
| 2.1.1 Research Characteristics | 19 |
| 2.1.2 Relevant Methods | 19 |
| 2.1.3 Data Collection Approach..... | 21 |
| 2.2 Trustworthiness..... | 23 |
| 2.2.1 Validity | 23 |
| 2.2.2 Reliability..... | 24 |
| 2.3 Definition of Terms..... | 24 |
| 2.4 Project Structure..... | 24 |
| 2.4.1 Choice of Method..... | 24 |
| 2.4.2 Time Plan | 26 |
| 3 Frame of References | 27 |

| | | |
|-------|--|----|
| 3.1 | Lean Production | 27 |
| 3.2 | Process-Orientation | 27 |
| 3.2.1 | What Is a Process? | 27 |
| 3.2.2 | Process-Oriented Organizations | 29 |
| 3.3 | Process Optimization | 29 |
| 3.3.1 | Methodology of Mapping Processes | 29 |
| 3.3.2 | Mapping As-Is Process | 33 |
| 3.3.3 | Modification of As-Is Mapping Method | 35 |
| 3.4 | Analyzing Processes | 36 |
| 3.4.1 | Value Stream Mapping | 37 |
| 3.4.2 | Product Security Matrix | 43 |
| 3.4.3 | Production Efficiency | 47 |
| 3.4.4 | Layout | 50 |
| 3.5 | Mapping To-Be Process | 51 |
| 3.6 | Project Scheduling | 51 |
| 4 | Empirical Study | 53 |
| 4.1 | Company Presentation | 53 |
| 4.2 | Design and Manufacture Production Tool Process | 55 |
| 4.3 | General Project Model | 56 |
| 4.3.1 | Feasibility Phase | 57 |
| 4.3.2 | Pre-Study Phase | 57 |
| 4.3.3 | Realization Phase | 59 |
| 4.3.4 | Closure Phase | 60 |
| 4.4 | Measurement System | 60 |
| 4.4.1 | Documentation | 60 |
| 4.5 | Meetings | 66 |
| 4.5.1 | Product Portfolio Board | 66 |
| 4.5.2 | NPD Project Meetings | 66 |
| 4.6 | Material Flow | 66 |
| 5 | Analysis | 69 |

| | | |
|-------|--|-----|
| 5.1 | Value Stream Mapping | 69 |
| 5.1.1 | Value Analysis | 69 |
| 5.1.2 | Reduce Movement in Workshop..... | 78 |
| 5.1.3 | Production Security Matrix | 80 |
| 5.2 | Mapping the To-Be Process | 81 |
| 5.2.1 | Draft a To-Be Process Map..... | 81 |
| 5.2.2 | Present and Communicate the Drafted To-Be Process Map | 82 |
| 5.2.3 | Review and Improve the To-Be Process with Process Participants | 83 |
| 6 | Results..... | 95 |
| 6.1 | Understand and Improve the DPT process..... | 95 |
| 6.1.1 | Analysis of Concept Process..... | 95 |
| 6.1.2 | Resource Planning Process | 97 |
| 6.1.3 | Pre-Study Process | 99 |
| 6.1.4 | Design Tools and Order Process | 103 |
| 6.1.5 | Manufacturing Process..... | 108 |
| 6.1.6 | Setup Process | 111 |
| 6.1.1 | Follow-Up Process..... | 111 |
| 6.2 | Recommended Actions | 113 |
| 6.2.1 | Actions for Improving Information Flow | 114 |
| 6.2.2 | Actions for Improved Planning..... | 115 |
| 6.2.3 | Actions for Improved Quality | 116 |
| 6.2.4 | Actions for Improved Efficiency in the Workshop..... | 117 |
| 6.2.5 | Implementing the To-Be Process..... | 117 |
| 7 | Discussion..... | 119 |
| 7.1 | Further studies..... | 120 |
| 7.2 | Personal reflections | 120 |
| 8 | References..... | 121 |
| 8.1 | Interviews..... | 122 |
| | Appendix 1 | 123 |
| | Appendix 2..... | 125 |

Introduction

This chapter introduces the report. It starts with a brief description of the environment of where the study takes place. It continues with the problem description and the objectives of the thesis as well as limitations and finally the target group is defined.

1.1 Company Background

1.1.1 Alfa Laval

Alfa Laval is a global company. It is located in approximately 100 countries and has approximately 11,500 employees all over the world. 125 years ago, Gustav de Laval founded the company. He is famous for inventing the centrifugal separator and the first working steam turbine.

Alfa Laval is a world-leading company in three primary technologies:

1. Heat transfer
2. Centrifugal separation
3. Fluid handling

1.1.2 Operation Development Forming & Tool Technology

This study considers the department Operation Development Forming and Tool Technology (OD-FTT). The department is a project-driven organization that design and manufacture forming and cutting tools to a number of product groups and their globally distributed manufacturing sites.

The main customers are Operations Manufacturing and Product Centers, primarily through New Product Development projects. OD-FTT's main strategy is: *“Develop and supply tool technology that in a cost-efficient way yields product competitiveness and secures stable manufacturing processes.”*

The strategy is supported by technology development projects, standardized designs and continuous improvements of the manufacturing processes.

OD-FTT's core competences are tool design, tool manufacturing, tool surface technology, forming simulation and 3-D full part scanning.¹

¹Alfa Laval. Internal [18]

OD-FTT has defined two core processes: the Design and Manufacture Production Tool (DPT) process and the Maintain Production Tool (MPT) process, whereas the DPT process have been studied in this Master Thesis. The DPT process is today divided into two processes; “Develop New Tool for Gasket Heat Exchangers” and “Develop New Tool for Brazed Heat Exchangers”.

The studied tool development processes starts when the department for research and development (R&D) requests a production tool for manufacturing a new heat exchanger, and the process ends with a functioning production tool used in the production. Thus, the whole value chain, from idea to design to manufacture to set-up, is considered in this study.

1.2 Problem Description

Some years ago Alfa Laval mapped out all existing processes in the company. Two core processes were identified for OD-FTT, the DPT and the MPT process. These two process maps are available in the company’s quality system and are thereby available for all personnel at Alfa Laval. In addition to these maps, two other internal process maps exist for developing new tools. These maps are not up-to-date and need to be reviewed and improved since the processes are dynamic and constantly changing to fit customer requirements and competitors. Alfa Laval provided the following project description at the inception of this project:

“In a structured way study the existing process based on today’s process map and propose changes in order to create a more efficient value flow in the process. Input data considering deviation reports is available today and is preferably used as basic data in the study. Identify value in the process and waste of different types. Improvements in form of templates, routines, systems, checklists etc. Study the interaction between different functions according to figure 1 below that describes the interaction between customer/market, product development/design and production. Today the process considers everything from production development/design to delivery of finished product (tools that OD-FTT deliver to internal customers).”

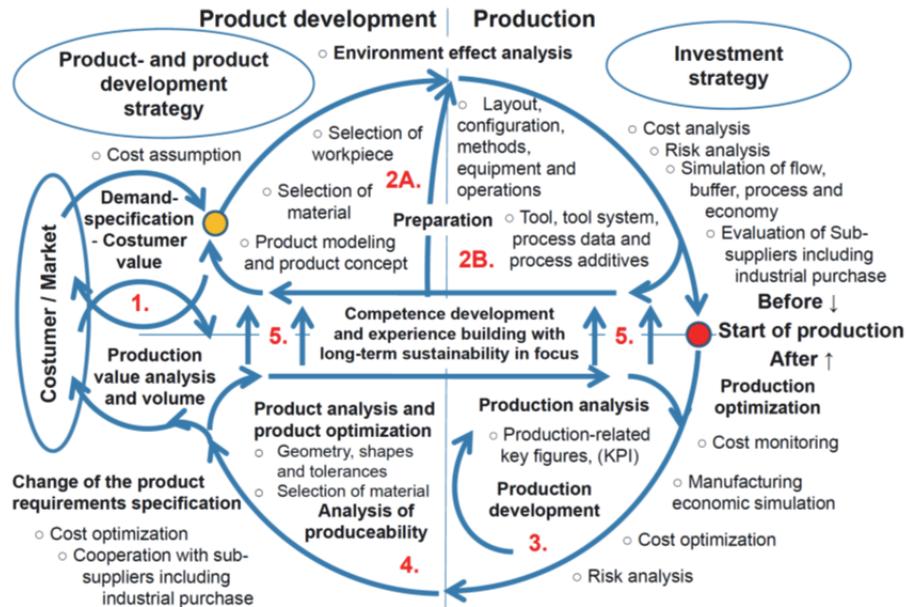


Figure 1. Ongoing interaction between customer/market, product development and production Ståhl [24].

The process issues that OD-FTT is facing today are:

- How can project lead-time be reduced with maintained quality and cost goals?
- How can internal and external interfaces be clearer?

1.3 Objective

The key-question of this thesis is:

- How can lead-time be reduced for customized solutions?

This study aims at finding improvements of the process that can reduce the lead-time. The DPT process will be studied and proposals for a more efficient value flow will be presented. The key-question has been divided into two sub-objectives:

1. Understand the current process
 - a. Identify process value
 - b. Identify process waste
 - c. Identify problem areas
2. Develop an improved DPT process map
 - a. Draw proposed process map
 - b. Compile an implementation plan

1.4 Focus and Limitations

As mention earlier OD-FTT has two core processes, but this study focuses only on reducing lead-time in the DPT process, when it is initialed by R&D.

Today a detailed process map for developing new tools for gasket heat exchangers exists. This map, however, does not correspond to the processes for developing tools for other types of heat exchangers, but it will still be used as a basis for understanding the processes of interest. The study will be made within the established process boundaries as defined in the existing process map.

The goal of this study is to reduce lead-time by improving the process. Process improvements will be made by rearranging activities, areas of responsibility, etc. How activities technically can be executed more efficiently is not considered.

Only available statistics are analyzed, no new measurements are made. The data used in this study is not exclusively for the purpose of this study alone rather it is also used for other purposes. Information about designers' work is collected by interviews and is thereby subjective data.

1.5 Target Group

1.5.1 Alfa Laval

The target group for the thesis is mainly managers and employees at OD-FTT department. Nonetheless, the study is also interesting for other departments within Alfa Laval since the proposed process improvements can be applied to interfacing departments and possibly at other departments within Alfa Laval as well.

1.5.2 Generally

In general the thesis is relevant to companies with customized production. It is also relevant for persons who drive improvement projects in companies delivering either products or services. It is relevant to students at Lund University Faculty of Engineering as a basis for future research within the field.

1.6 Report Outline

The report has a traditional structure and every chapter is opened with a brief summary to facilitate readability. The structure of the thesis is outlined below:

| | |
|----------------------------|--|
| Methodology | Provides basic knowledge about research methodology. Motivation for the choice of method for this study is also presented. |
| Frame of References | Presents the basis for the theoretical framework of the thesis. The major part of the chapter explains process-orientation, process mapping, process optimization and tools for analyzing processes e.g. value stream mapping and production security matrix. In addition, a different method for calculating production efficiency, layout and production planning are presented. |
| Empirical | Describes the company, the department, the general project structure, the new tool development process, today's measurement systems, meetings and available capacity at the department. |
| Analysis | Tools and theories, presented in the "Frames of reference" chapter, are used for analyzing the empirics. The analysis is divided into two major parts. The first part focus on analyzing the current situation and the second part is focusing on analyzing the proposed process map. |
| Conclusions | Presentation of results and recommended actions. |
| Discussion | Discussion about how well the results met the stated objectives proposes further studies and closes with some personal reflection about the study. |

2 Methodology

This chapter provides basic knowledge about the methodology and the motivation for the choice of methodology used in the thesis. The purpose is to find an appropriate approach to increase knowledge in the subject matter.

2.1 Research Approach

2.1.1 Research Characteristics

Choice of methodology is based on the objectives and characteristics of the task. The general purpose of a task can differ between:²

1. **Descriptive** – *the main purpose is to **find out and describe** how something is working or is executed.*
2. **Exploratory** – *the main purpose is to gain a **deeper understanding** about how something is working or is executed.*
3. **Explanatory** – *the main purpose is to find **cause and effect relationship and explanations** for how things are working or are executed.*
4. **Improving/normative** – *the main purpose is to **find a solution** to an identified problem.*

A study can consist of a number of sub-studies, which can have different purposes.³

Based on the objectives (see chapter 1.3), the study is divided into three sub-studies; one *exploratory study* where the existing process and the interaction between different functions are studied, one *explanatory study* where value and waste and root-causes to problems in the process are identified and lastly one *improving study* where solutions for a more efficient value flow are proposed and evaluated.

2.1.2 Relevant Methods

There exist four relevant methods for research in the applied areas of science. These four methods are described in the following sections.

2.1.2.1 Survey

A survey is a question sampling with purpose to describe or explain a phenomenon. In other words, surveys are appropriate for describing which problems are

² Höst; Regnell; Runesson [7]

³ Ibid.

considered to be most important to fix. A survey is often used for describing a wider question. For small populations, the researcher can study the whole population, but for larger populations a few representatives (a sample) must be chosen instead. Conclusions about the whole group will be taken based on the sample group's answers. In order to get a representative sample one must choose a random-based sample method.⁴

1. **Random sample** – *A subset of the sample frame are chosen by random number generation.*
2. **Systematic sample** – *Every n:th person or unit are chosen.*
3. **Stratified sample** – *The group are divided into categories, and a sample are chosen from each category.*
4. **Full range** – *Sample contain every persons or unit.*

A survey has a fix design; therefore it cannot be changed during the study.⁵

2.1.2.2 Case Study

When the purpose of a research study is to describe and understand the phenomena or objective it is appropriate to perform a case study. For example, a case study can be used in an organization for studying how working tasks are executed. A case study doesn't provide statistically significant results, since the cases have not been chosen with a random-based sample methodology.

A case study has a flexible design that can be changed during the study. Data are mostly quantitative, and the most commonly used techniques are interviews, observations and archive analysis.⁶

2.1.2.3 Experiment

Experiments are used to find cause-and-effect relationships that explain what the source is of different phenomena. A systematic experimental design should be used in order to obtain the most knowledge from the experiments. Experiments are of the type fix design.⁷

2.1.2.4 Action Study

The purpose of action studies is to improve the objective or phenomenon during the study. The phenomenon or situation is first observed in order to clarify the problems, usually through a survey or a case study. The next step is to develop a

⁴ Höst; Regnell; Runesson [7]

⁵ Ibid.

⁶ Ibid.

⁷ Ibid.

solution to the problem. The solution is then evaluated in its context. This is an iterative process that is repeated based on the evaluation of the results.⁸

2.1.3 Data Collection Approach

2.1.3.1 Quantitative

Quantitative data can be counted and classified like weight, color percentages etc. Quantitative data are often processed through statistical analysis.⁹

Quantitative objectives can be gradually achieved. Thus it is possible to measure to what extent a quantitative objective has been achieved. For example “to reach a specific destination as fast as possible” is a quantitative objective since the success can be measured.¹⁰

2.1.3.2 Qualitative

Qualitative data are often processed through sorting and categorizing.¹¹

Qualitative objectives can either be achieved or not achieved. There exists no “in between”. For example “to reach a specific destination in less the 60 minutes” is a qualitative objective. There is one failure mode: the destination is not reached in less than 60 minutes, and one success mode: the destination is reached in less than 60 minutes.¹²

2.1.3.3 Interviews

There are three types of interviews: structured, semi-structured and unstructured.¹³

Unstructured Interviews – In the unstructured interviews both the interviewees and the interviewer decide in what direction the interview is going. Fewer questions are predetermined and the interviews are very flexible but the downside is that researchers might waste time on discussing things that are not important for the focus of their research.

Semi-structured Interviews – In semi-structured interviews, more questions are predetermined, but the interview process is still flexible enough to let the interviewee decide the direction of the interview.

⁸ Höst; Regnell; Runesson [7]

⁹ Ibid.

¹⁰ Ackoff [8]

¹¹ Höst; Regnell; Runeson [7]

¹² Ackoff [8]

¹³ Wilkinson; Brimingham [9]

Structured Interviews – In a structured interview, the interviewer has determined all questions in advance and he/she has full control over the interview. Structured interviews are easier to schedule and are also easier to analyze.

Wilkinson and Brimingham have created a map over a number of stages for developing and using interviews¹⁴.

1. **Draft the interview** – *Decide what type of questions, how many questions, in what format and in what order will the question be asked. Group questions in different themes. Predetermine which are the key-questions. Decide how the interview will be recorded.*
2. **Pilot your questions** – *Pilot the interview in order to get rid of over ambitious questions, and to make sure that the questions are easy to understand.*
3. **Select your interviewees** – *The central research questions should help to decide whom and how many should be interviewed.*
4. **Conduct the interviews** – *Start with indicating how the data from the interview will be used and whether anonymity will be preserved. Open-end questions aloud the interviewee to contribute with more information than closed-end questions. Silence can also be used as a tool to extract more information from the interviewee as the interviewee has time to collect thoughts and formulate an answer during silence. It can also encourage to a more developed answer.*

2.1.3.4 Observation

A situation or a phenomenon can be directly observed with the human senses or with technical resources. The observers interact with the studied phenomena at different levels, and the observed have different levels of awareness that they are observed.¹⁵

There are four different types of observers. *Observing participants* are trying to be integrated into the observed group and the group is well aware about the observer. *Total participants* are also trying to be a part of the observed group, but the group is not well aware about the observer. *Participating observers* are not integrated in

¹⁴ Wilkinson; Brimingham [9], p.44

¹⁵ Höst; Regnell; Runesson [7]

the situation, but present and collects data in an open way. *Total observers* are ideally invisibly, and collect data undercover.¹⁶

| | <i>High awareness about observation</i> | <i>Low awareness about observation</i> |
|-------------------------|---|--|
| <i>High interaction</i> | Observing participants | Total participants |
| <i>Low interaction</i> | Participating observers | Total observers |

Table 1. Four different types of observers.¹⁷

2.1.3.5 Literature Review

Literature review is an iterative process throughout the study. In the beginning of the study, literature review is an appropriate way to gather knowledge in the studied area. Once the study has clear objectives and defined sub-problems, further literature studies with a specific focus can be made. A literature review can also be in use for comparing the result of the study with others' results.¹⁸

2.2 Trustworthiness

2.2.1 Validity

Validity considers the connection between what is measured and what is intended to be measured. Validity can increase with triangulation, which means that the same object is studied with different methods. Limitations and threats towards the validity must be presented in an open and clear way.¹⁹

¹⁶ Höst; Regnell; Runesson [7]

¹⁷ Ibid., p. 93

¹⁸ Ibid.

¹⁹ Ibid.

2.2.2 Reliability

For every source that is used, one should question whether the material is reviewed, and if so, by whom. It should also be questioned if the research methodology is reliable, if the results has been certified or have led to recognition and been referred to in other reliable circumstances. Inconclusive results and preliminary indications are also of value, but one must be aware of the limitations.²⁰

2.3 Definition of Terms

The title of this thesis is: Optimizing develop production tool process - How to create an efficient value flow for customized production, from design to manufacture.

Efficient value flow – refers to a value flow with no waste and minimum of non-value adding activities.

Customized solutions – Customization mean that customers need and expectations are tailored more after the customers own special wishes. Every customer shall have a unique treatment and unique offers. Products are produced for order and not for inventory.²¹ Since tools are only produced for orders it can be seen as a customized production. Customized solutions refer to a non-repetitive production, where the manufacturing process is the same but manufacturing data (cutting depth, cutting speed, tool etc.) is changed.

2.4 Project Structure

2.4.1 Choice of Method

The goal of the thesis is to find ways to reduce lead-time for design and manufacture customized solutions. The study is limited to the process for developing production tools for a new product development (NPD) project. The main goal has been divided into two sub-goals, and appropriate methods to achieve the sub-goals are motivated in the following sections.

2.4.1.1 Method for Understanding the Current Process

The first sub-goal is to understand the current process. The purpose is to describe the actual process, i.e. to find out how the process works in reality. A case study was performed in order to understand the current process since it is an appropriate

²⁰ Höst; Regnell; Runesson [7]

²¹ Bergman; Kelfsjö [3]

approach for explaining the phenomenon and objective at deeper level. Data have been gathered through interviews, observations, working instructions, project reports and a deviation report.

Every designer and project manager was interviewed, making up an interview group of five persons. The team leaders were also interviewed about the planning process. The interviews were semi-structured. 19 questions (see appendix 1) were prepared on the basis of the process map. The purpose of the interviews was to find out what the activity cycles time and waiting time between activities were, but also to find out root-causes to waiting time and other problems in the process.

The key-questions during the interview were:

1. What starts the activity?
2. How long time does it take to execute the activity?
3. What do you do after the activity?
4. How long does it take before next activity is started?

The initial plan for the interview process was to ask the same questions about every activity in the process map, but since it was revised during the first interview that only one of the interviewees followed the process map, the interview process had to be changed from semi-structured to unstructured.

It was decided that the interview would be recorded on tape if the interviewee permitted. Recording the interview is much more reliable than taking notes, since there is a constant flow of information during the interview that is not possible to write down in real-time.²²

Participating observations were made every day during the study in the form of asking questions, listening, watching and by attending some morning and weekly staff meetings.

Working instructions for the workshop were used to understand the material and workflow and from the compile project report activity cycle time could be estimated.

Deviation reports were compiled in a production safety matrix in order to understand quality problems in the process.

²² Wilkinson; Birmingham [9]

2.4.1.2 Method for Developing an Improved DPT Process Map

The second sub-goal is to develop an improved DPT process map. The purpose is to find the most appropriate proposed process map. A common problem when mapping processes is to try to make it perfect and correct from the beginning.²³ In order to avoid this problem an action study approach is chosen for this part of the study. Action studies are appropriate when the purpose is to improve the objective or phenomena during the study.

The proposed process was not implemented, however. Rather suggestions for improving the process were communicated to process participants and their opinions were noted which in turn resulted in changes and refinements of the proposed process.

A solution to the identified problems were developed and presented. Data was gathered through observations of opinions and other feedback during and after the midterm presentation of the study. The process proposal was modified and finally a workshop was held to discuss the proposed process. Based on the input from the workshop a final solution was created.

2.4.2 Time Plan

The project can be divided into six phases, shown in the time line below (figure 2). The phases interrelate with each other and therefore, as one can see in the diagram, the phases overlap.

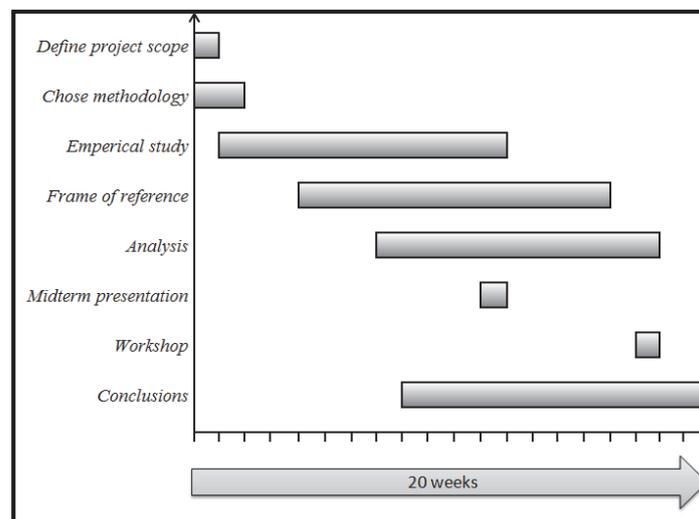


Figure 2. Time line showing the allocation of time between different phases of this study.

²³ Ljungberg; Larsson [2]

3 Frame of References

This chapter is a summary of the studied literature from relevant areas. It states the theoretical framework of the thesis. The major part of the chapter explains process-orientation, process mapping, process optimization and tools for analyzing processes e.g. value stream mapping and production security matrix. Also different method for calculating production efficiency, layout and production planning are presented.

3.1 Lean Production

Henry Ford (*Today and tomorrow*) was the first known man to point out the importance of creating continuous flow throughout the manufacturing process, standardize working tasks and eliminate waste. In order to have a lean production one must focus on continuous flow of products through value-adding processes, manufacture to customer's need and having a business culture where everyone strives for continuous improvements.²⁴ Linker claims that a pull system reflects the customer need by only filling up components that will be used in the next working task.²⁵ Hill, in the other hand, claims that in markets with high-volume, standard products, orders can be pulled through shop-floors using Kanban systems, but low-volume customized orders should be pushed through the shop-floor by skilled operators. Hill points out that no panaceas exist and pull system is not always the best solution. A push-system is complex and the changeover costs between jobs tend to be high, but variation in demand is easier to meet.²⁶ Lean production seems easy to implement since it exists a number of tools that can be used, but the key to lean production is the lean thinking. To process-orient the business is one step towards lean manufacturing.

3.2 Process-Orientation

3.2.1 What Is a Process?

The word "process" is widely used and the meaning of the word differs. In literature regarding process management "process" aims at the repetitive element.²⁷ Three different, relevant definitions of the word "process" are presented below in order to get a clearer understanding of the term.

²⁴ Linker [28]

²⁵ Ibid.

²⁶ Hill [4]

²⁷ Bergman; Kelfsjö [3]

Definition 1:

A process is a repetitive used network of in order linked activities that uses information and resources to transform “object in” to “object out”, from identifying to satisfying the customer’s need.²⁸

Definition 2:

A process is a network of activities that are repeated in time and whose purpose is to create value for an external or internal customer.²⁹

Definition 3:

A process is a completely closed, timely and logical sequence of activities which are required to work on a process-oriented business object.³⁰

It should be pointed out that processes are not only considering machines but also team work and coordination between humans. It’s important to realize this since most potential for improvements generally lies in the administrative flows.³¹

Three types of processes exists – core processes, support processes and management processes.

Core processes describes the purpose of organizations on a high level and a core process map provides a holistic view over an organization. The core process map helps to understand which part of the organization are most important.³²

Support processes have no direct relationship to the company-external market; only company-internal demands exist for the process. Even if the company-internal demands has no direct impact on the external market, disturbance in the support process will after a certain time affect the core processes. Therefore support processes have an indirect effect in the company-external market. They are needed for the organization to work, even if not critical for business competitiveness.³³

²⁸ Ljungberg; Larsson [2], p.23

²⁹ Bergman; Kelfsjö [3], p. 470

³⁰ Becker; Kugeler; Rosemann [6], p.4

³¹ Bergman; Klefsjö [3]

³² Ljungberg; Larsson [2]

³³ Becker; Kugeler; Rosemann [6]

Management processes are needed to control and coordinate an organizations core and support processes. Process management can be concluded as³⁴:

1. Organize for improvements
2. Understand the process
3. Observe the process
4. Continuously improve the process

3.2.2 Process-Oriented Organizations

In a process-oriented organization, processes are the base for the way to look at, shape, manage and develop the business. In a process-oriented organization the business is seen as a system of value-adding activities. A process-oriented organization focus on what staff does rather than who they are.

Functions have no authority to manage or develop the business, instead functions are transformed to resource and competence centers.³⁵

3.3 Process Optimization

The process should lead to a specified goal, before it is optimized. The basic for develop a process are specified below:³⁶

1. Identify and map processes
2. Analyze and reconstruct processes
3. Implementation of new/reconstructed processes
4. Measure processes
5. Continuous improvements of processes

3.3.1 Methodology of Mapping Processes

When organizations grow, working methods and routines must be redefined to fit the new conditions. Redefinition of working methods and routines are often made internal in each department, which make the overall view of the company very complex. Consequently collaboration between departments can be vaguely defined in the descriptions of organizations. As an effect of the complex organization, only a few persons fully understand the organization and its processes. Since process maps show the value flow in organizations and how different departments relate to each other, it helps to clarify the collaboration between the departments. The process maps visualize how each individual's work fits into the process.³⁷

³⁴ Bergman; Kelfsjö [3]

³⁵ Ljungberg; Larsson [2]

³⁶ Ibid.

³⁷ Ibid.

Mapping processes doesn't provide great improvements in itself, but it creates a base from which process optimization can proceed.³⁸ There are both pros and cons with mapping the as-is process in a process optimization project, some are represented in table 3.³⁹

| Pros | Cons |
|---|--|
| Identifies shortcomings in current situation | Might limit the creativity of participating employees, start to think in constraints |
| Gives an overview of current situation for new and external participants | Time-consuming and expensive |
| Can be used as a checklist in order to prevent relevant issues to be overlooked | Old structures might be insufficient questioned |

Table 2. Pros & cons with as-is process mapping

Mapping the as-is process is a systematic approach for documenting processes and their related cycle times. Step by step instructions help employees to perform tasks, but they can't be analyzed to see whether the process is adding any value or not.⁴⁰

3.3.1.1 Illustrating Flows

Ljungberg & Larsson argue that mapping processes according to the SIPOC-theory is insufficient. The SIPOC-theory defines processes as:

Supplier → Input → Process → Output → Customer

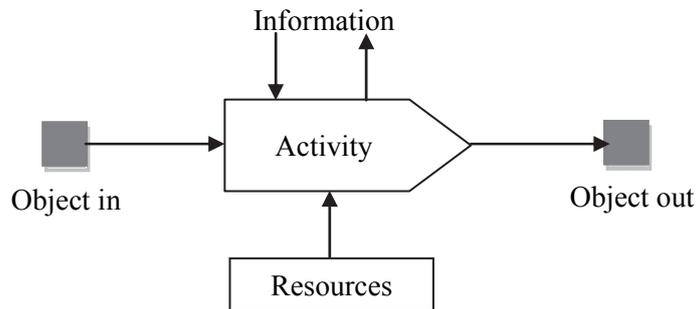
Input and output represents everything that flows through the process. But object in, object out, information and resources should to be separated in order to clarify what creates customer value.⁴¹

³⁸ Ljungberg; Larsson [2]

³⁹ Becker; Kugeler; Rosemann [6]

⁴⁰ Jacka; Keller [12]

⁴¹ Ljungberg; Larsson [2]



| | |
|--------------------|---|
| Object in | Start the activity |
| Activity | Processes object in |
| Resource | Needed for executing activity |
| Information | Support or/and control the process |
| Object out | Result of the processed object in and are the object in for the next activity |

Figure 3. Illustration of mapping different flows through the process

If more than one object is needed to start the process this is illustrated with the required number of object from which parallel arrows go into the process, see figure 4.

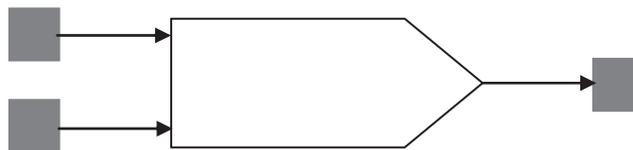


Figure 4. Two objectives are necessary

If a process give more than one object out, it is illustrated in the same way, see figure 5.



Figure 5. One process gives two objects out

If only one of two objects is required to start the process, it is illustrated with two objects that merge into one arrow into the process, see figure 6.



Figure 6. Two alternative objects in

If the process can give two alternative objects out it is illustrated with one arrow out that split up to two objects, see figure 7.

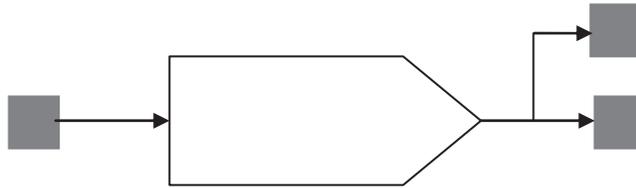


Figure 7. One process gives two alternative objects out

If there are two alternative flows for one object it is represented with one arrow out of the object that split into two processes, see figure 8.

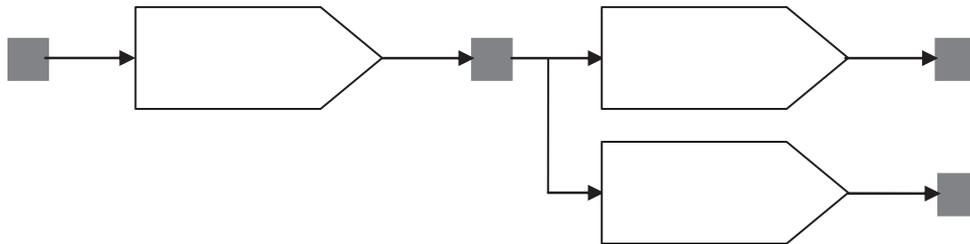


Figure 8. Alternative flows

If one object out trigs two processes it is illustrated with two arrows out from the process, see figure 9.

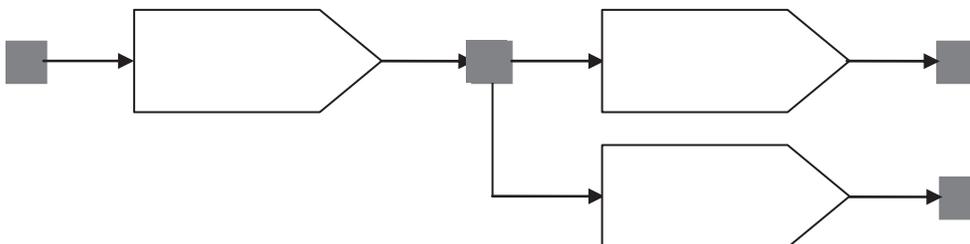


Figure 9. Parallel flows

3.3.1.2 Naming Processes, Activities and Objects

Flexible processes are mandatory for customized production. Employees are with their creativity the most flexible resource businesses have. Therefore, processes name shouldn't limit the human creativity. Process names should describe **the purpose** of the process and **not what or how** it should be executed.

In order to break the boundaries of the old organizational structure process names should not be connected to functions. The name should contain one verb and one substantive. It should be possible to write "To" before the name.⁴²



3.3.2 Mapping As-Is Process

As mention earlier mapping the as-is process can either limit or create opportunities for optimizing the to-be process. A common mistake when mapping the as-is process map is to make the map too detailed and trying to make it correct from the beginning. This is both time consuming and the map might feel forcing and inflexible. In general it is enough to describe the process in a more general way that are focused on "what" are made rather than "how" things are made.⁴³

Ljungberg & Larsson suggest the following methodology for mapping the as-is process:⁴⁴

1. Brainstorm all eventual activities and write them on post-it notes – *This activity require some representatives from different parts of the process.*
2. Arrange the activities in right order
3. Merge and add activities
4. Define object in and object out for each activity
5. Make sure that all activities are connected through the objects
6. Control that activities are at common and correct detail level, and that they have appropriate names
7. Modify until a satisfying description of the process is obtained

⁴² Ljungberg; Larsson [2]

⁴³ Ibid.

⁴⁴ Ibid.

Jacka & Keller⁴⁵ have developed a method for mapping the process through audits. They suggest the following steps for mapping processes:

1. **Establish process boundaries** – *This is a way to define the scope of the project.*
2. **Develop a data gathering plan** – *This is a way to define which methodology to use, and plan the project.*
3. **Interview process participants** – *This can be considered as a shortcoming with this method. Interviews are just one methodology that could be used; other methods should be taken in consideration.*
4. **Generate process map**– *This is a way to compile the gathered information, and visualize the process.*
5. **Analyze and use the map**– *Analyze the map is the main work of the value stream analysis. To communicate and use the map are the greatest challenge in the project.*

The different steps for mapping process are described in the text below.

3.3.2.1 Establish Process Boundaries

Processes are naturally enmeshed with other processes. Process boundaries must therefore be established from the beginning when mapping the as-is process; it is a way of defining the scope of the process mapping project.⁴⁶ The process starting- and endpoint are its boundaries, and before those can be established the purpose of the process must be defined.⁴⁷ Defining the purpose of the process will facilitate the process mapping project.

3.3.2.2 Develop the Data Gathering Plan

The first step in making the project plan is to decide the level of details. The need of details depends on the size of the organization and the purpose of mapping. Sometimes it is necessary to break down the process in many levels to get a satisfying level of details.⁴⁸ A process consists of sub-processes. Sub-processes, in their turn, consist of single activities executed to transform a customer need to customer satisfaction (see figure 10).

⁴⁵ Jacka; Keller [12]

⁴⁶ Ibid.

⁴⁷ Ljungberg; Larsson [2]

⁴⁸ Ibid.

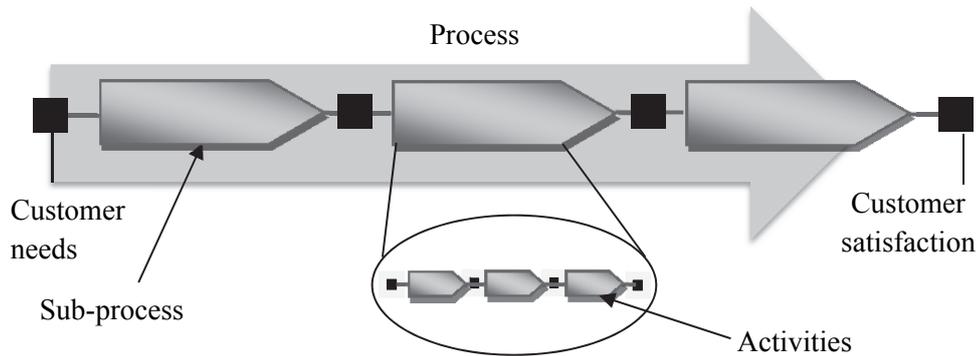


Figure 10. General process map structure

Ljungberg & Larsson recommends three different approaches for gathering data to as-is process mapping.⁴⁹

“Walk through”, an approach where one or more person literally walks through the process and interviews persons that perform the process during the way. The strength with this method is that it is lean and the map becomes homogenous, but the downside is that the personal who do not work with the mapping becomes passive and unengaged in the project.

An alternative is to make a **“virtual walk through”**. This method collect different people that represent different areas of the process and let each of them describe their area. This method has approximately the same strengths and downside as the “walk through” method.

The third method is to create a **mapping team** that consists of representatives from the whole process. The strength with this method is that it does not only contribute to a process map, but also a greater understanding for how different parts of the process are collaborating and what a process actually is.

3.3.2.3 Interview the Process Participants

It is recommend that interviews are made by two persons were one of the interviewer concentrate on the discussion in itself and the other focus on making the process map.⁵⁰

3.3.3 Modification of As-Is Mapping Method

Ljungberg’s & Larsson’s⁵¹ methodology for mapping processes during a workshop is developed for mapping process that has never been mapped before. Jacka’s &

⁴⁹ Ljungberg; Larsson [2], p.204-205

⁵⁰ Jacka; Keller [12]

Keller's⁵² methods are also developed for first time mapping, but through audits. In this study the processes have already been mapped once, but must be updated and improved.

A new more general method was therefore developed on basis of Jacka's & Keller's methodology, whereas the step "draw to-be process map" was complemented with Ljungberg's & Larsson's methodology. The new method is presented below:

1. **Establish process boundaries** – *The project scope is defined in chapter 1.4, p. 7, "Focus & delimitations". It is stated that the process boundaries will be the same as the existing boundaries.*
2. **Develop a data gathering plan** – *The methodology chapter motivates the methodology for this study and the structure of the project.*
3. **Plan and prepare data collection** – *Those were made in the first project week, by calling for interview and investigate which data was available.*
4. **Gather data** – *In this study data were collected both with interviews, observations, project reports and deviation reports.*
5. **Generate process map** – *A process map was generated during the empirical study.*
6. **Analyze map** – *The process map generated in the previous step were analyzed in this step.*
7. **Make a "to-be" process map** – *The second part of the study is an action study where the process map are developed and modified. This is an iterative analysis aiming to find the most appropriate process.*
8. **Communicate and use the map** – *This task fall under the management of OD-FTT and is critical for success. Since the process actually is a sub-process in the New Tool Development process, it is dependent of this process working correct as well. An implementation plan will be provided in order to facilitate the implementation.*

3.4 Analyzing Processes

Process analysis can be used to solve problems with the processes. The contents of the analysis are determined by the problems and possibilities that the situation offers. Different analysis demand different background information about the process. Since resources are always limited the central issue will be to tackle the greatest problems. Therefore the analysis needs to be focused on identifying the causes that contribute to greatest problems. If the purpose with the analysis is to

⁵¹ Ljungberg; Larsson [2]

⁵² Jacka; Keller [12]

make radical changes there are no need for analyzing details in the existing process, and in the other hand, there is no need to search for radical improvements if they are not needed to reach determined goals.⁵³

3.4.1 Value Stream Mapping

There are several tools for mapping the value stream. A value stream map can be made for complementing the process map with information needed for analyzing the process.

Value stream mapping is a specific process benchmarking where the process are not compared with external processes but with how good it could be in itself. It compares the as-is process with how the process would look like if all waste were removed.⁵⁴

3.4.1.1 Seven Wastes

Toyota has identified seven major types of non-value adding waste. They apply to all processes, not only production but also product development, order registering, administration etc.⁵⁵

1. **Overproduction** – Products that don't reach the customer or are waiting for customers.⁵⁶Overproduction leads to overstaffing and unnecessary costs for stocking and transportation.⁵⁷
2. **Waiting** – A machine or operator that has to wait for a resource (e.g. a tool or information)
3. **Transport and unnecessary motion** – Transportation do not in itself create any value.⁵⁸
4. **Over processing or incorrect processing** – Producing product with higher quality than requested.
5. **Unnecessary inventory** – Unnecessary amount of raw material, work in process etc.
6. **Inefficient working tasks** – For example unnecessary motions, walking.⁵⁹
7. **Defects** – Produce and rework defect details.⁶⁰For example reparations, rework, controlling.⁶¹

⁵³ Ljungberg; Larsson [2]

⁵⁴ Hines; Rich; Esain [10]

⁵⁵ Linker [28], p 50-51

⁵⁶ Bergman; Kelfsjö [3]

⁵⁷ Linker [28]

⁵⁸ Bergman; Kelfsjö [3]

⁵⁹ Linker [28]

⁶⁰ Bergman; Kelfsjö [3]

Linker has added an extra type of waste:

8. **Unused creativity** – If the management does not listen to the employees, they will lose time, ideas, competence, improvements and opportunities to learn.

The greatest improvements in lean production come from removing non-value adding activities.⁶²

3.4.1.2 Seven Value Stream Mapping Tools

Hines & Rich⁶³ have presented seven different value stream mapping tools. The typology of those tools is presented in terms of the seven wastes; if there is an outlined understanding for the particular waste to be removed the most appropriate mapping tool can be chosen (see figure 10).

| Wastes/structure | Mapping tool | | | | | | Physical structure (a) volume (b) value |
|--------------------------|--------------------------|------------------------------|---------------------------|------------------------|------------------------------|-------------------------|---|
| | Process activity mapping | Supply chain response matrix | Production variety funnel | Quality filter mapping | Demand amplification mapping | Decision point analysis | |
| Overproduction | L | M | | L | M | M | |
| Waiting | H | H | L | | M | M | |
| Transport | H | | | | | | L |
| Inappropriate processing | H | | M | L | | L | |
| Unnecessary inventory | M | H | M | | H | M | L |
| Unnecessary motion | H | L | | | | | |
| Defects | L | | | H | | | |
| Overall structure | L | L | M | L | H | M | H |

Notes: H =High correlation and usefulness
M = Medium correlation and usefulness
L = Low correlation and usefulness

Figure 11. Seven value stream mapping tools⁶⁴

⁶¹ Linker [28]

⁶² Linker [28]

⁶³ Hines; Rich [22]

⁶⁴ Ibid.

The general approach for process activity mapping is:⁶⁵

1. Study the flow of the process
2. Identify waste
3. Consider if the process can be rearrange in a more efficient sequence
4. Consider better flow pattern, involving different flow layout or transport routing
5. Consider whether everything that is being done at each stage is really necessary and what would happen if superfluous tasks were removed

3.4.1.3 Study the Flow of the Process

For each activity in the process investigate type of flow, which machine is needed, distance moved, time and number of people needed for performing the activity is mapped. This can for example be illustrated in a matrix:⁶⁶

| # | Activity | Flow | Machine | Dist [m] | Time [h] | People | Comments |
|---|--------------------------|----------------|-----------------|----------|----------|--------|----------|
| 1 | Receive materials | Operational | | | 1 | 1 | |
| 2 | Load | Transportation | Overhead crane | 10 | 0,002 | 1 | |
| 3 | Rough mill stamp and die | Operational | Milling machine | | 70 | 1 | |

Figure 12. Process flow matrix

Another way to illustrate the value flow is to make a map with different symbols for different flows and resources.⁶⁷

⁶⁵ Hines; Rich [22]

⁶⁶ Ibid.

⁶⁷ Alfa Laval Internal [23]

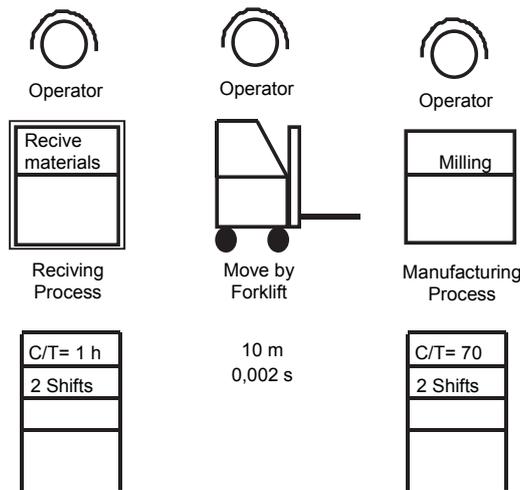


Figure 13. Example of general symbols for Value Stream Mapping

3.4.1.4 General Analysis with Help of the Process Map

While studying the flow of the process it is convenient at the same time connect problems along the process to specific activities/sub-processes. Ljungberg & Larsson⁶⁸ presents a methodology “General analysis with help of the process map”, whereas the process map is used as a guideline for concretize where problems occur in the process. The following steps are recommended for making the analysis:

1. Walk through the process map and let the participants connect problems to the map
2. Categorize problems based on type, cause and possible solution
3. Investigate consequences due to different problems
4. Investigate root-causes
5. Identify and focus on the most important root-causes

3.4.1.5 Value Analysis

All activities in a process can be categorized into the following categories:⁶⁹

1. Value adding activities
2. Non-value adding activities
3. Waste

⁶⁸ Ljungberg; Larsson [2], p.282-283

⁶⁹ Ljungberg; Larsson [2]

Value adding activities do in direct way contribute to solve customers' problems. Value adding activities are not necessary efficient and satisfying and should therefore be **developed**. Value adding activities increase the value on the product that is to be delivered to the customer. Therefore all physical processing are value adding activities.

Non-value adding activities do not produce value for the customer but are necessary for the business or the specific process to work. These activities can also create value for other stakeholders than the customer. Those activities should be **minimized**.

Waste is activities that do not create value for the customer, the organization or any other stakeholder. Typical wastes are mentioned in chapter 3.4.1.1; some of those wastes are necessary for the process and are then categorized as non-value adding activities. Waste activities should be **avoided**.

A value analysis is made for not only identifying waste, but also for identifying non-value adding activities that are to be minimized. Organizations have historically been more efficient in reducing waste than non-value adding activities,⁷⁰ therefore it also important to identify non-value adding activities.

Ljungberg⁷¹ suggest in his teaching that diagram 14 below is used for guidance for classification of activities.

⁷⁰ Ljungberg; Larsson [2]

⁷¹ Ljungberg;Larsson [21]

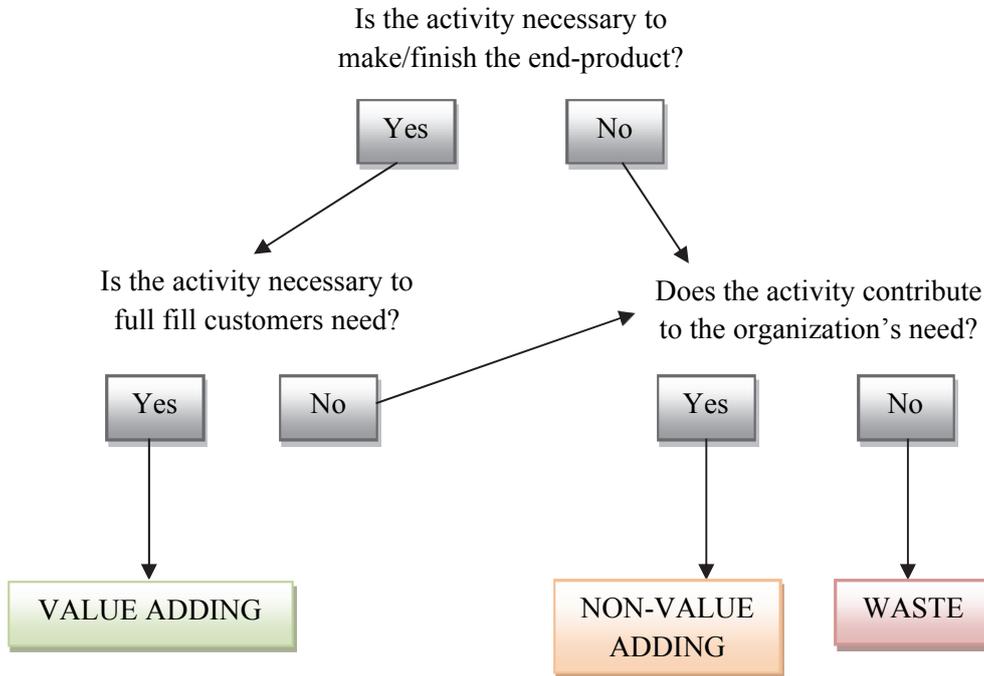


Figure 14. Guidance for classification of activities

3.4.1.7 Modification of Value Stream Mapping Method

The value stream will be mapped with different symbols. Usually a triangle is used to symbolize inventory. Waiting time in the process where in case also symbolized with triangles, since information waiting can be seen as inventory of information. New symbols were implemented, since a lot of the activities were administrative. A paper roll was used to illustrate administrative work and speech balloons were used to illustrate meetings. The symbols used were:

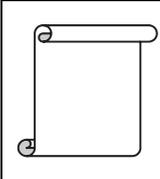
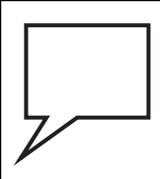
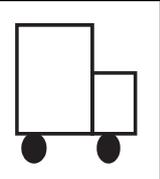
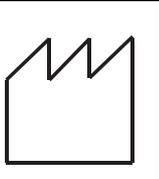
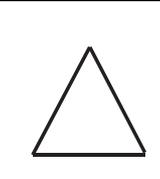
| | | | | | |
|---|---|---|---|--|---|
|  |  |  |  |  |  |
| Administrative work | Meetings | Movement | Transportation | Subcontractor | Inventory/Waiting |

Figure 15. New and current symbols for Value Stream Mapping

3.4.2 Product Security Matrix

A major shortcoming with the “Process activity mapping” is that it doesn’t detect defects. According to Ståhl⁷² one should prioritize to solve quality deficiencies before dealing with downtime and rate losses, if the total efficiency E_q is the objective function. The order of priority is illustrated by the lean triangle below:

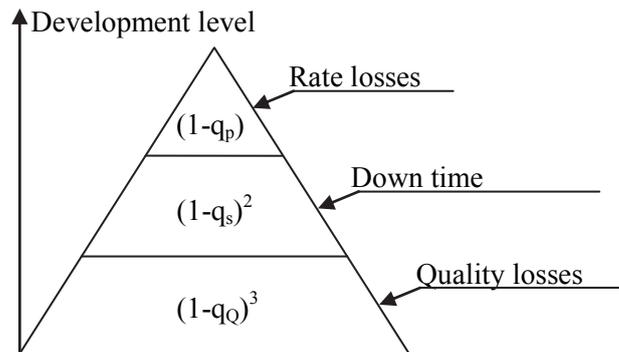


Figure 16. Lean triangle⁷³.

PSM are a tool for sorting and structure data to a production analysis. The PSM provides information about what disturbances leads to scrap, down time and rate losses.

3.4.2.1 Result Parameters

Four result parameters drives the production efficiency when producing a specific product; production rate, down time, rejection rate and environment. The result parameters depend on each other such as if the production rate increases, technical development and higher competence are needed to prevent quality losses and increased downtime.⁷⁴ Each result parameter consists of several single parameters, see figure 17.

⁷² Ståhl [1]

⁷³ Ibid., p.79

⁷⁴ Ståhl [1]

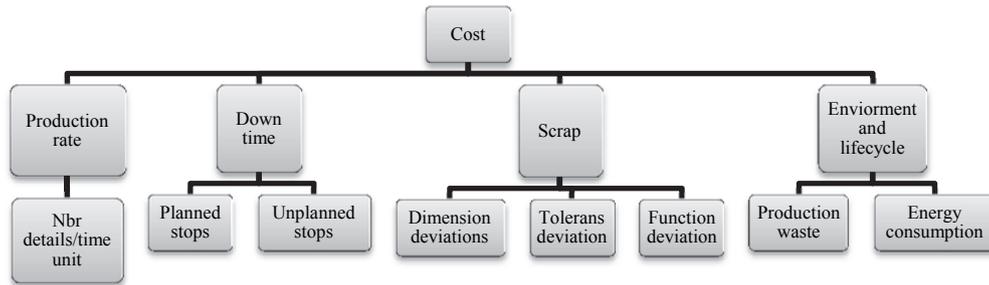


Figure 17. Distribution of cost parameters.

3.4.2.2 Factor Groups

Factors that are affecting the result parameters can be distributed in different factor groups. For industrial manufacturing methods factors can be distributed to seven following factor groups:⁷⁵

1. **Tool** – Geometrical factors, material factor or surface related factors.
2. **Working material** – Geometrical factors, material factor or surface related factors.
3. **Process** – Equipment related factors, process data, process additives, process related factors.
4. **Personal and organization** – Instructions, routines, responsibility, administration, action plans, etc.
5. **Wear and maintenance** – Tool related factors, process and equipment related factors, planned and unplanned maintenance.
6. **Special process behavior** – Unique process characteristics
7. **Peripheral equipment** – Material handling equipment, conveyers, gripping device, etc.

Those factor groups are general and can be applied to almost every industrial manufacturing method with some modification. Each factor group can in turn be divided into sub-factor groups. Factors should be measured in time units. Material losses due to scrap are to be recalculated to losses in machine time. The accumulated time can thereafter be recalculated to costs.

Sometime a factor group for unknown factors is created; this is made so that the qualities on other registers are kept high. The amount of registers under “unknown

⁷⁵ Ståhl [1]

factors” visualizes a lack of process knowledge and highlights needs for a general competence development.⁷⁶

3.4.2.3 Structure of the Production Security Matrix

The correlation between result parameters and factors can be illustrated in a correlation matrix, see figure 18.

| Factor group | Quality parameters Q | Down time parameters S | Production rate param. P | Environment and lifecycle param. MK | Σ Factors |
|------------------------------|-------------------------|---------------------------|-----------------------------|-------------------------------------|---------------------|
| A. Tool | | | | | |
| B. Working material | | | | | |
| C. Process | | | | | |
| D. Personal and organization | | | | | |
| E. Wear and maintenance | | | | | → |
| F. Special process behavior | | | | | |
| G. Peripheral equipment | | | | | |
| H. Unknown factors | | | | | ↓ |
| Σ Result parameters | | | | | → |

Figure 18. The production security matrix principal structure⁷⁷.

As one can see in the figure, if measurements are summarized horizontal one will receive the cost for a specific factor group. If the measurements instead are summarized vertical one will receive the cost for a given result parameter.⁷⁸

Ståhl⁷⁹ recommends the following steps for simplifying the matrix built-up:

1. **Define scrap parameters Q** – Define the reason to why the detail didn't met the quality requirements. For example surface defect, dimension defect, etc.
2. **Define down time parameters S** – It is appropriate to define two down time groups; planned down time and unplanned down time.
3. **Define production rate parameters P** – The reason to production rate losses can be staff shortages, testing, some kind of leak, etc. For some cases it is appropriate to define some levels of production rate losses, for example Production with 1/4 of planned rate, production with 2/4 of planned rate, etc.

⁷⁶ Ibid.

⁷⁷ Ståhl [1]

⁷⁸ Ibid.

⁷⁹ Ibid.

4. **Define environment and lifecycle parameters MK** – *For example liters of cutting fluid, energy consumption, kilograms of waste, etc.*

Factors can be hard to predefine. Those factors that aren't obvious from the start should be added during the follow-up.⁸⁰

3.4.2.4 Data Gathering for Production Security Matrix

For customized production, many hours might be needed for collecting relevant data since the working tasks varies from one product to another. At the same time it is hard to make an automated system for collecting data.

Data collection for a PSM at manual working stations are often time consuming and are also very sensitive since disturbances often are generated by how people work. Open and tolerant working conditions are vital so that self-made mistakes are reported.⁸¹

The following steps are recommended for a production follow-up:⁸²

1. Identify important result parameters for the function of the detail and the production conditions.
2. Distinguish influencing factors in the respective factor groups.
3. If possible, identify connections between result parameters and factors.
4. Make priorities amongst these connections.
5. Monitoring of the production where disturbances are registered against underlying factor and affected result parameter.
6. Analysis of gathered data.
7. Construct an action plan to optimize and change the production unit.
8. Implementation of suggested action plan after decisions based on a manufacturing economic analysis.
9. Follow-up and evaluation of actions that have been carried out.

3.4.2.5 Modification of the Production Security Matrix

The PSM has been complemented with some sub-factors in the personal and organization factor group.

⁸⁰ Ståhl [1]

⁸¹ Ibid.

⁸² Ekman; Jacobsson [13]

| Factor group | Production losses | | | |
|---------------------------------|--------------------------------|---------------------|----------------------|----------------|
| | Time for correcting action [h] | Material cost [SEK] | Personnel cost [SEK] | Σ Cost Factors |
| A. Tool | | | | |
| B. Working material | | | | |
| C. Process | | | | |
| D. Personnel and organization | | | | |
| • Drawing mistake | | | | |
| • Dimension/tolerance deviation | | | | |
| • NC-preparation | | | | |
| E. Ware and maintenance | | | | |
| F. Special process behavior | | | | |
| G. Peripheral equipment | | | | |
| H. Unknown factors | | | | |
| Σ Result parameters | | | | |

Figure 19. Modified PSM

3.4.3 Production Efficiency

3.4.3.1 Overall Equipment Efficiency (OEE)

Production efficiency is often measured with OEE. OEE is calculated as:

$$OEE = Availability * Performance * Quality \quad \text{Equation 3.1}$$

The definition of *availability* differs in literature. *Availability* often means how often a machine is scheduled to be running versus how often the machine actually ran.⁸³ Thus, a measurement of how much of the time the machine is able to produce.⁸⁴ *Availability* is calculated as:

$$A = \frac{Avalible\ time}{Scheduled\ time} = \frac{T_{OK}}{T_{plan}} \quad \text{Equation 3.2}$$

Availability is, in literature, often calculated as:⁸⁵

$$A = \frac{MTTF}{MWT+MTTR+MTTF} \quad \text{Equation 3.3}$$

⁸³ Gazdziak.[11]

⁸⁴ Ståhl [1]

⁸⁵ Hagberg, Henriksson [30]

Whereas the different letter combinations mean:

$$MTTF = \text{Mean time to failure} = \frac{\text{Actual utilized up time}}{\text{Number of stops}}$$

$$MTTR = \text{Mean time to repair} = \frac{\text{Total reparation time}}{\text{Number of stops}}$$

$$MWT = \text{Mean waiting time} = \frac{\text{Total waiting time}}{\text{Number of stops}}$$

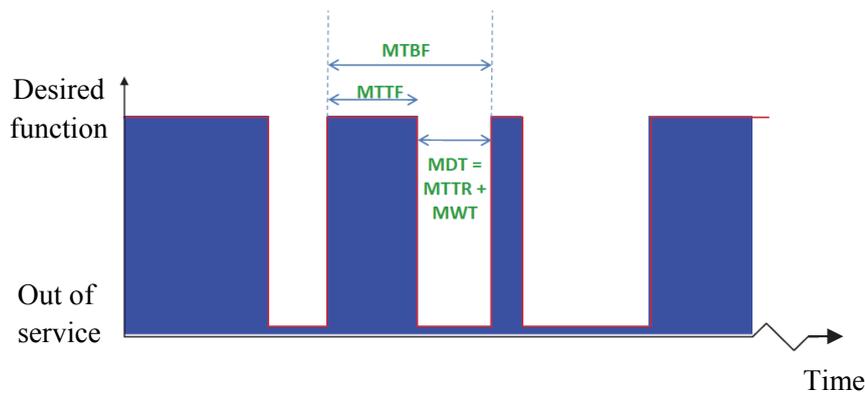


Figure 20. Illustration of how to calculate availability⁸⁶.

3.4.3.2 Total Efficiency (E)

When measuring production effectiveness and other KPI's it is crucial to use a liner correlation in order to be able to compare KPI's over time. To achieve a liner correlation the denominator in the KPI formula has to be constant.

The denominator in available time is scheduled time. The amount of scheduled time is dynamic. By scheduling less machine time the OEE can seem to be improved, even if nothing has actually changed. This is not a satisfying way to measure a KPI's. Ståhl⁸⁷ claim that availability should be based on error-free time (which is the same as available time) and planned paid staff hours (*equation 4.1*). The expression does not take into account the availability for unmanned production. This availability should be calculated separate from the manned time. Availability can thereby be evaluated with three different KPIs; availability for

⁸⁶ Hagberg;Henriksson [30]

⁸⁷ Ståhl [31]

manned production A_{mp} , availability for unmanned production A_{unmp} and availability for the machines at all hours A_{24h} .

$$A_{mp} = \frac{\Sigma \text{Manned processing}}{T_{plan}} \quad \text{Equation 3.4}$$

$$A_{unmp} = \frac{\Sigma \text{Unmanned processing}}{24 - T_{plan}} \quad \text{Equation 3.5}$$

$$A_{24h} = \frac{\Sigma(\text{Manned+unmanned processing})}{24} \quad \text{Equation 3.6}$$

It's only possible to see the positive effects of increasing unmanned production if we separate KPI for manned and unmanned production. Therefore *equations 3.4* and *3.5* have been chosen for calculating availability in this Master Thesis.

If the unmanned time is not taken into account availability will only increase with increased efficiency in the manned hours. Therefore the KPI for A_{mp} doesn't show that equipment efficiency can increase with increasing unmanned processing.

The measure helps management to discover problems that can't be seen by just observing the production process. By visualizing problems the measurement helps to point out improvement areas.⁸⁸ The total equipment efficiency can be calculated as:

$$E = K * A * U_{tech} \quad \text{Equation 3.11}$$

Simplified:

$$K = (1 - q_Q)$$

$$A = (1 - q_Q)(1 - q_S)$$

$$U = (1 - q_Q)(1 - q_S)(1 - q_P)$$

$$E = (1 - q_Q)^3 * (1 - q_S)^2 * (1 - q_P)$$

This correlation is only used for visualizing the savings of solving quality deficiencies and machine down times before increasing production rate.⁸⁹

⁸⁸ Gadazki [11]

⁸⁹ Ståhl [1]

3.4.4 Layout

Layouts for factory planning have different faces. A block layout is used in an early state of the layout design. In this type of layout, machines are just conceptually represented by blocks or divisions of the space. A detailed layout, in the other hand, contains all information that is needed to describe the system. Thus a detailed layout reflects the real factory. A media layout describes process fluid, ventilation, water system and so on, and a foundation layout contains information about foundations in the factory in form of bearing capacity, dimension and material etc.⁹⁰

For factory planning two types of layout are usually considered; process/function layout and product layout. A combination between product and process/functional layout can be realized with administrative controlled flow in a more or less product oriented workshop. Another way to increase the utilization of expensive machines in a product layout is to have two flows through the expensive machines. This requires a buffer before the machine which will increase WIP.⁹¹ A cellular layout is a mix between a function and product layout. A cell is a batch-line hybrid. A cellular layout reduces lead times and lower work-in-progress inventory compared to process/function layout, and are more flexible and has higher over all utilization than a product layout.⁹²

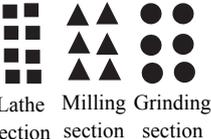
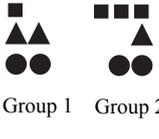
| Characteristics | Product layout | Process/function layout | Cellular layout |
|-----------------------------------|--|--|--|
| Type of process | Line | Jobbing/batch | Cells |
| Layout format |  Series workstations in operational sequence |  Lathe section Milling section Grinding section |  Group 1 Group 2 |
| Batch lead-time | Low | High | Medium |
| Work-in-progress inventory | Low | High | Medium |
| Disturbances sensibility | High | Low | Medium |
| Utilization of capacity | Low | High | Medium |
| Planning needs | Low | High | Medium |

Figure 21. Different types of layouts.

⁹⁰ Chen [14]

⁹¹ Ståhl [1]

⁹² Hill;Hill [4]

3.5 Mapping To-Be Process

If the as-is process are mapped and analyzed, this can be the basis of the to-be analyzed. The to-be process is based on the as-is process and the belonging identified issues. The to-be map must be so detailed so that employees involved in the process can judge their impact on the organizational structure, activities to be executed and on communications between processes.⁹³ Therefore it is most likely that the to-be process map needs to be more detailed than an as-is process map. The new process map should eliminate waste, minimize value-adding activities and hand-over.

3.6 Project Scheduling

The critical path method (CPM) is useful for preparing and administrate schedules for project that consists of many interrelates activates that must be completed in a specific sequence.⁵ CPM only deals with deterministic problems⁵, but in many project problems are not deterministic. These problems can be solved with the project evaluation and review technique (PERT) since PERT allows randomness in the activities. But both PERT and CPM doesn't consider insufficient resources as a constraint. When the resources are a constraint non critical activities should be rescheduled within the available slack if possible. If not, non-critical activities may have to be delayed and project completion date moved ahead.⁹⁴

⁹³ Becker; Kugeler; Rosemann [6]

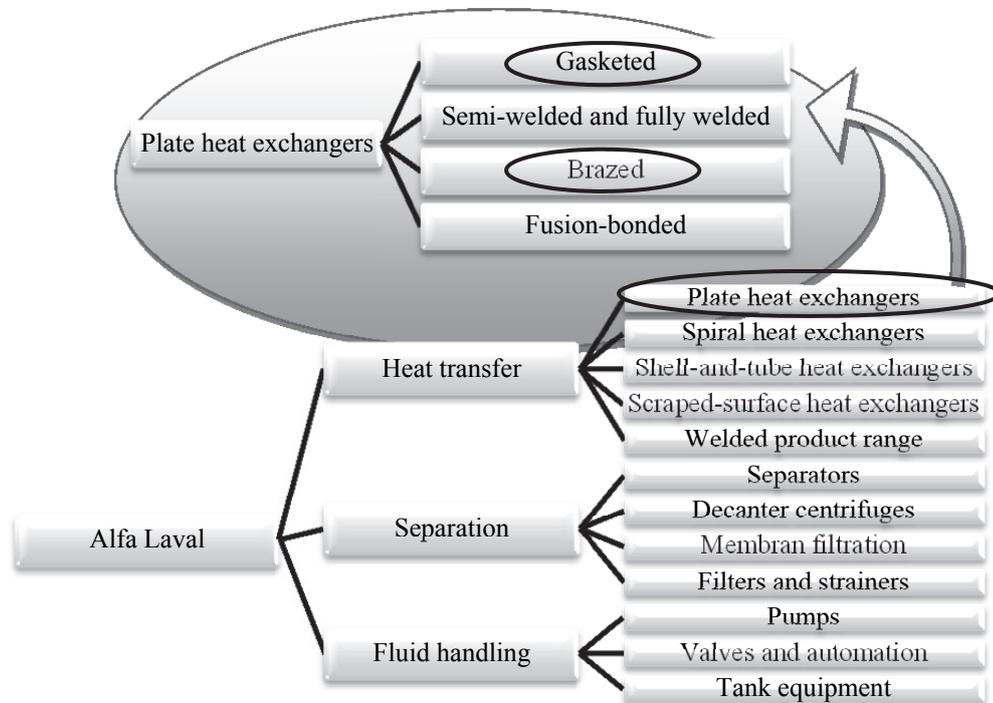
⁹⁴ Nahimas [5]

4 Empirical Study

The first part of this chapter outlines the environment where the study takes place. The second part of the chapter describes the actual process studied, how it is conducted, measured and documented.

4.1 Company Presentation

Alfa Laval's core of operations is based on three key technologies: heat transfer, separation and fluid handling.⁹⁵ The process for developing new tools for producing gasket and brazed heat exchangers are studied in this thesis.



Figur 22. Alfa Laval core technologies and there under groups.

Alfa Laval has identified ten customer segments and has divided these into two divisions; Process Technology and Equipment.⁹⁶

⁹⁵ Alfa Laval. Key Technologies [15]

The company has identified five core processes; develop, market, sell, supply and service for satisfying the customers need.

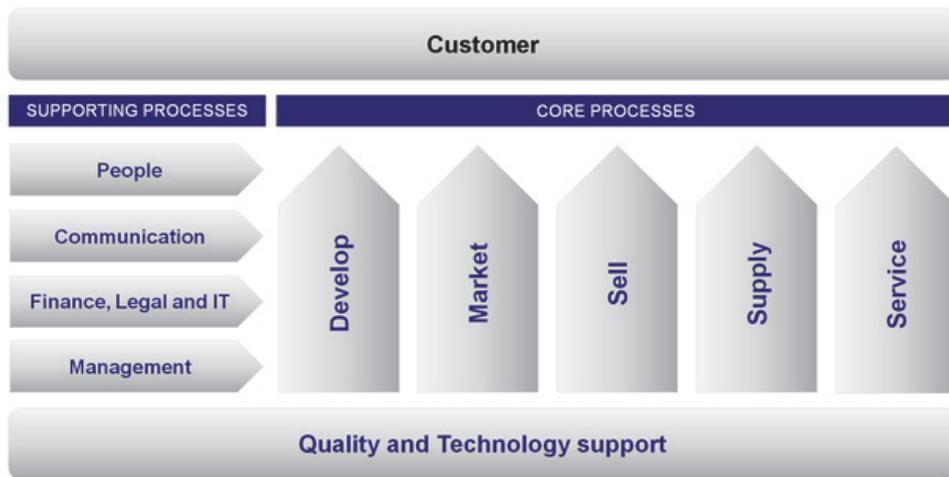


Figure 23. Alfa Laval overall process⁹⁷.

4.1.1.1 Core Values

Alfa Laval has defined four core values which should characterize all employees' way of working.

Action – “Be alert; act now. You need to realize that speed is an essential business asset in achieving performance. Now is the best time for you to get things done. Both internally and externally.”

Courage – “Have the courage to change. You are part of a performance-driven organization that plays to win. You must dare to try, and dare to do things differently.”

Teamwork – “Think flexibly. It is only by being adaptable and combining your resources and strengths with others that you can be truly effective and keep our promises.”

Profit – “Look at the bottom line. Controlling costs and managing prices is essential for our ongoing success. We shall take every opportunity to improve financial performance for both our customers and ourselves.”⁹⁸

⁹⁶ Alfa Laval. About us [16]

⁹⁷ Alfa Laval. Internal [19]

⁹⁸ Ibid.

4.2 Design and Manufacture Production Tool Process

OD-FTT has two core processes:

- 
1. Develop Production Tool (DPT) process
 2. Maintain Production Tool (MPT) process

The DPT process has two inputs:

1. Preliminary product design model **or** detailed design
2. Customer order **or** request of the department for Research and Development (R&D)

The process studied is the DPT process, in the specific case when the tools are request by R&D, and the customer is the production site that will manufacture the tool. The DPT process is, in this case, actually a sub-process in the New Product Development (NPD) process.

Today OD-FTT has three different process maps for developing new production tools. Two of the maps are quite similar to each other. They are general and are intended to be applicable to every DPT project. The third process map is, in the other hand, very detailed. It is unique for the DPT process, when it is triggered by requests, from R&D, of tools for producing gasket heat exchangers. This detailed process map has been used as a basis when gathering data for both gasket and brazed heat exchangers.

Using a “*walk through*” approach interviews were made to gain a deeper understanding about the actual DPT process. During the interviews it was found that the processes for developing new tools differed depending on:

1. Project manager/designer
2. Customer
3. Type of heat exchanger/Tool technology

The detailed process map was therefore not applicable to any other process than the specific one it was designed for. The DPT process for brazed heat exchangers therefore had to be mapped. The process flow was studied through value stream mapping. The value stream map was created based on interviews, project reports and working instructions for manufacturing. For each activity in the process the estimated times for executing the activity was registered. The built-in waiting times in every activity, and the waiting times between activities, were also noted.

Common problems and comments from the interviews were connected to the associated activity. Information needed for starting an activity was noted. A unique value stream maps was made for every project manager. The separate maps were then compiled in one value stream map. The value stream map has been removed from the report of confidential reasons.

The greatest differences between developing gasket and brazed heat exchangers are that development of gasket heat exchangers follows a more standardized process.

4.3 General Project Model

The NPD process is the process for developing new products i.e. heat exchangers at Alfa Laval. The NPD process is guided by Alfa Laval’s general project model, PROMAL. Figure 25 shows a schematic illustration of PROMAL. Every gate represents a go, hold or kill decision taken by a central decision point in the company. Often the gate decisions are taken on steering committee meetings. These meetings are held on a regular basis, ones a month. If time is short, an extra steering committee meeting is sometimes held.

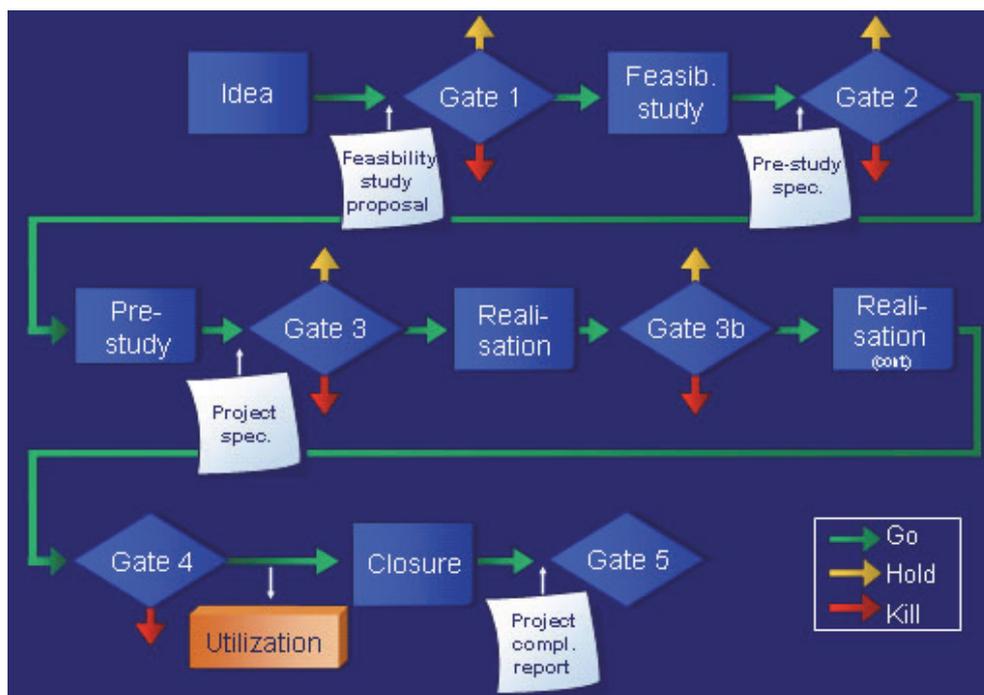


Figure 24. Flowchart of the product screening and development process⁹⁹

⁹⁹ Alfa Laval Internal [20]

4.3.1 Feasibility Phase

Every project starts with an idea, that can come from anywhere in the company. If the proposed project is of great interest, it continues to the feasibility phase. A feasibility or product concept study is conducted by R&D. The purpose of the feasibility study is to see if the proposed project shows an acceptable level profit, is doable and fit with the strategy.¹⁰⁰ If the project fulfills every criterion it will continue to the pre-study phase.

Tools that are in use in production today and designing new tools have higher priority than feasibility study projects. Therefore can an internal waiting time up to two weeks occur at OD-FTT.

4.3.2 Pre-Study Phase

The purpose of the pre-study is to define the scope, rules and objectives of the project. Every aspects of the project, e.g. budget, time plan, risks etc. should be considered. The deliverable from OD-FTT is a tool specification report. The tool specification outlines the design of tools used for manufacturing the new product.

Generally the project for develop a pressing tool for a new gasket heat exchangers starts right before the NPD project's pre-study starts. When developing pressing tools for brazed heat exchanger the tool project starts either during the NPD project's concept study, pre-study or realization phase. If the tool project does not start until the NPD project's realization phase, it will result in high time pressure on the tool project.

External waiting usually occurs in the DPT process during pre-study since other departments have more work to do in this phase. Therefore, in most cases, there is no time pressure on the tool project in this phase.

The tool project managers wish to have a defined project group before the pre-study starts. This is not easily solved since it is complicated to plan as far ahead as needed to be able to tell which tool maker can be responsible for the manufacture the tool.

The pre-study for gasket heat exchanger does not start until the tool project manager has the required information from other departments. In the pre-study for brazed heat exchangers the project manager must collect information about dimensions of the press, pressing force, interface between presses and input dimensions. They also need information about the line and the product, so that

¹⁰⁰ Ibid.

material can be ordered. The information is the base for analyzing cost, risks and time plan, which is the base in the tool specification. The tool specification contains information about:¹⁰¹

1. Objectives for the project
2. Deliveries – *What will be delivered?*
3. Limitations – *During the interviews it was pointed out that limitations, i.e. what is not included in the project, are extreme important to define.*
4. Time schedule/checklist – *Rough draft, will be adjusted during the project.*
5. Dependencies
6. Risk – *Usually risks do not differ much between different projects.*
7. Organizations
8. Tool cost
9. Closure/ Tool approval – *During interview with project managers it was found that the tool approval were considered to be the most important document.*
10. Communication plan
11. Profitability calculation (if applicable)
12. Attachment
13. Revision history

The tool specification is produced by the tool project manager, and reviewed by the team managers. Some of the tool project managers review the tool specification with their manager, and some send it directly to the NPD project manager. The tool specification is usually presented on the weekly NPD project group meeting; occasionally there is a special meeting for presenting the tool specification.

The tool is designed on basis of the tool specification. It is possible to start designing and manufacturing before all information is settled. The information needed for different actions are:

1. **Plate's outer dimensions** – When the tools outer dimensions are determined, the tool designer can start to design the tool. Material for pressing parts can be bought in this stadium, but the outer dimensions can't be changed after that.
2. **Manufacturing site and press** – When outer dimensions and manufacturing site are determined it is possible to complete the entire tool design, except the pattern. If manufacturing start before the entire design is

¹⁰¹ Alfa Laval. Internal. [25]

finished, there is a risk that something must be changed which can lead to rework.

3. **Pattern** – When the pattern is determined, the NC-program can be prepared and pattern can be milled.

4.3.3 Realization Phase

The realization phase is divided into two phases. In the first phase OD-FTT is allowed to start investing time in the project, which basically means that they can start designing the tools. In the second phase OD-FTT is allowed to start investing money in the project which means that they can start manufacturing the tools.

According to PROMAL it is allowed to start designing if the project gets a GO decision in Gate 3. Project managers are however authorized to decide if designing should start earlier.

Waiting time during designing often occurs due to:

1. Waiting for information from R&D
2. Waiting for information from manufacturing site
3. Only one person work with the project, if he/she is disturbed the project becomes waiting. Disturbances usually are:
 - a. Meetings
 - b. Work with other projects
 - c. Re-work on old projects ← *definitely waste!*

According to PROMAL manufacturing of the tool should start after GO-decision in Gate 3b. Producing the tool is a bottleneck in the NPD process. Therefore manufacturing of tools are sometimes started before Gate 3b.

When the design is finished, the tool specification is verified ones more. Then the tool project manager order manufacturing of the tool. The team managers suggest price and time, which are then approved by the tool project manager. The project is allocated order number, account and cost number. The team managers plan production and order material.

The tool is then manufactured. There is usually one tool maker that are responsible for the tool. During the manufacturing the team managers follow-up and the tool designers supervises the manufacturing. The tool makers register processing time in the machines in project reports.

The tool pieces are transported to annealing and hardening when they are ready, no booking is needed. Annealing usually takes three days and hardening usually takes

five days, but can be made in three days when the time is short. One can therefore assume that at least two days waste exists in the hardening process, but this is not considered closer in this thesis due to the limitations to only study OD-FTT.

Some tools are tested in Lund before they are transported to the producing site. If so, the tool project manager book test pressing in Lund as soon as the final delivery time is set.

As a result of a more complex organization, the tool designer experience that they constantly have to do more work. Earlier there was no need for reports because the decisions-maker was a part of the NPD project group.

4.3.4 Closure Phase

OD-FTT often closes their project in the end of the realization phase. Only development of production tool for gasket heat exchangers has a closure phase. The purpose of the closure phase is to review the project and consider improvements for the future.

The tools are at last delivered; test run and start-up are made on site. Then there is a period of time where R&D verifies the plate. The project can be closed when “Tool approval” is signed.

4.4 Measurement System

4.4.1 Documentation

4.4.1.1 OD-database

OD-database is a database for ongoing or completed projects. In the data-base customers and other personnel can follow-up the product portfolio. KPI's can be extracted from the system. Sites can also use it to search for how other sites have solved problems.

4.4.1.2 Deviation Reports

Deviations reports are meant to be written for every deviation. A standard template is used. During last year the department changed from handwritten to a digital system. The most relevant information specified in the deviations reports are:¹⁰²

1. Identification
2. Title
3. Batch size

¹⁰² Alfa Laval Internal [26]

4. Description
5. Adjustment time
6. Deviation discovered by
7. Date
8. Reason to deviation
9. Corrective action
10. Corrected by
11. Real completion date
12. Estimated cost

For this study the deviation reports for last year, 124 reports, were used.

4.4.1.3 Registering of Time

All manufacturing in the workshop is registered in project reports. The tool maker registers time in different machines on the project number. The project report specifies:¹⁰³

1. What type of processing i.e. material and component ordering, NC-milling, assembly etc.
2. Employee number
3. Starting date and time
4. End date and time
5. Manned processing
6. Unmanned Processing
7. Price
8. Estimated
 - a. Time
 - b. Price

In the system one can also find operation time for each machine. Order number, starting time, end time, unmanned processing and manned processing are specified in the reports.

A shortcoming with the project reports is the resolution where changing between operation is not registered.

A number of project reports were compiled in diagrams showing how many hours was spent each day on the different tools.

¹⁰³ Alfa Laval Internal [27]

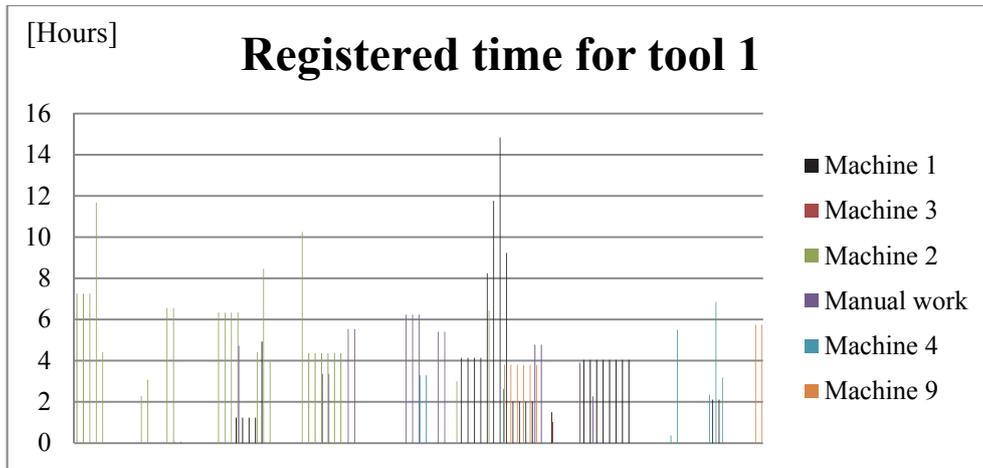


Diagram 1

This diagram show registered time for manufacturing of a normal pressing tool to a brazed heat exchanger. The diagram does not show the hours that the tool was on heat treatment.

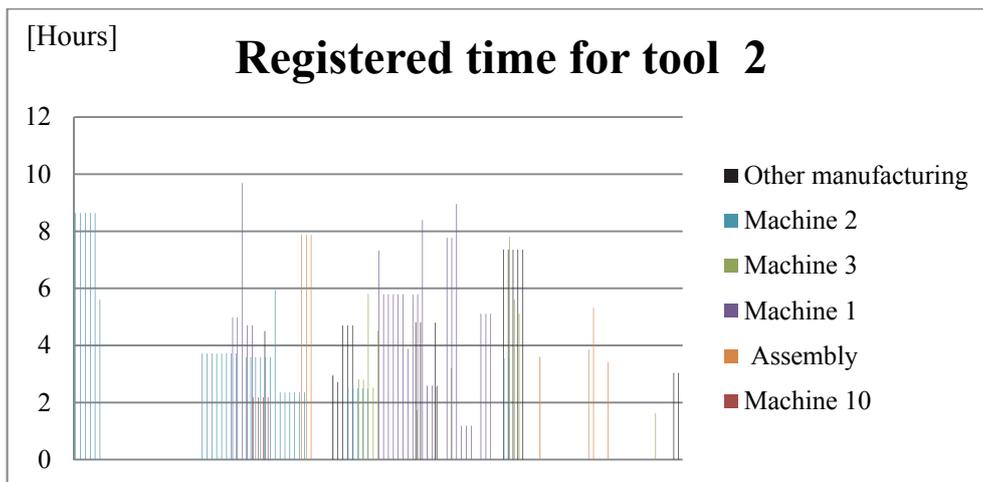


Diagram 2

This diagram also shows registered time for manufacturing of a normal pressing tool to a brazed heat exchanger. The diagram does not show the hours that the tool was on heat treatment.

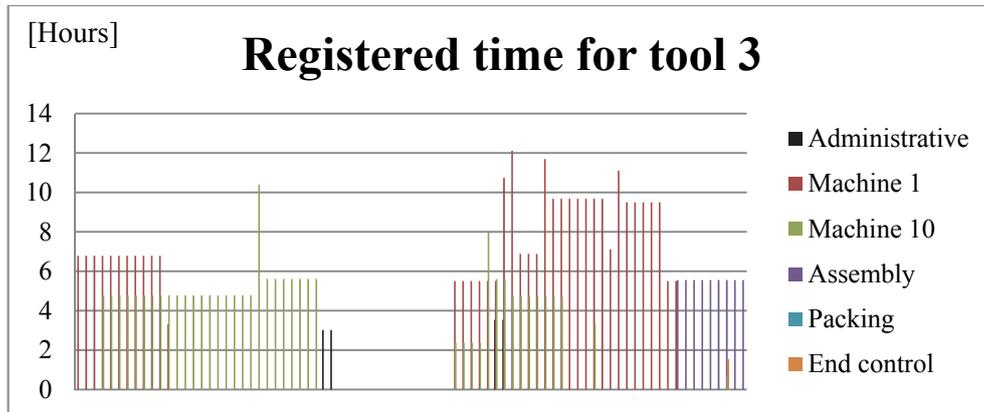


Diagram 3

Diagram 3 shows a DPT project that went very well.

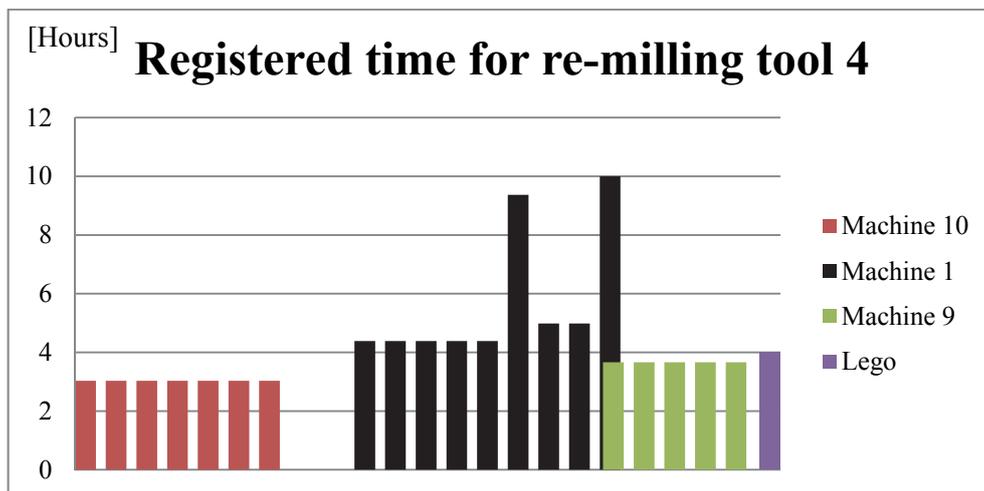


Diagram 4

This diagram shows re-milling time of a pressing tool.

A specific DPT project was studied closer where all tools were included, as well as the heat treatment. The project was a typical project where a tool for a brazed heat exchanger was produced. When looking at the whole project, one can see the distribution of time between different tool parts.

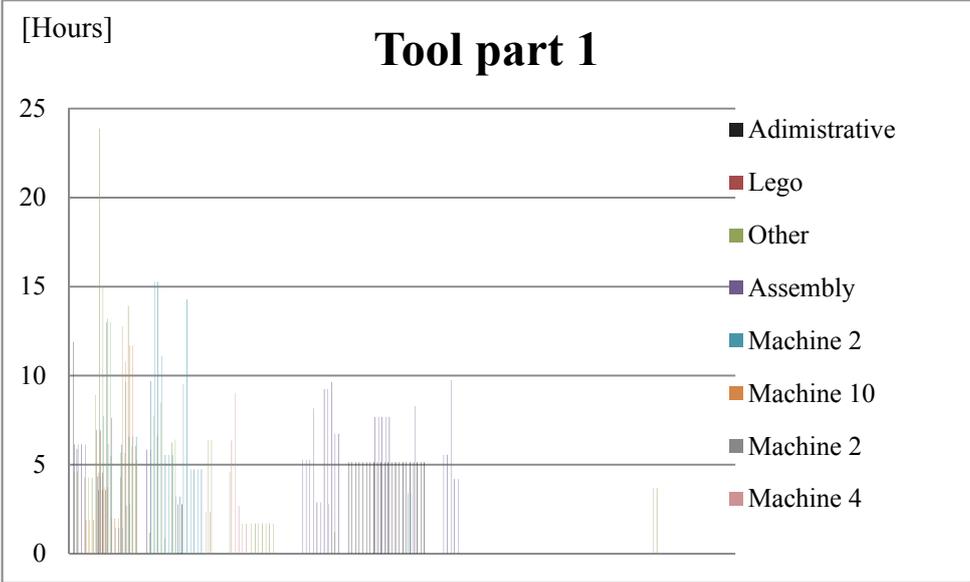


Diagram 5

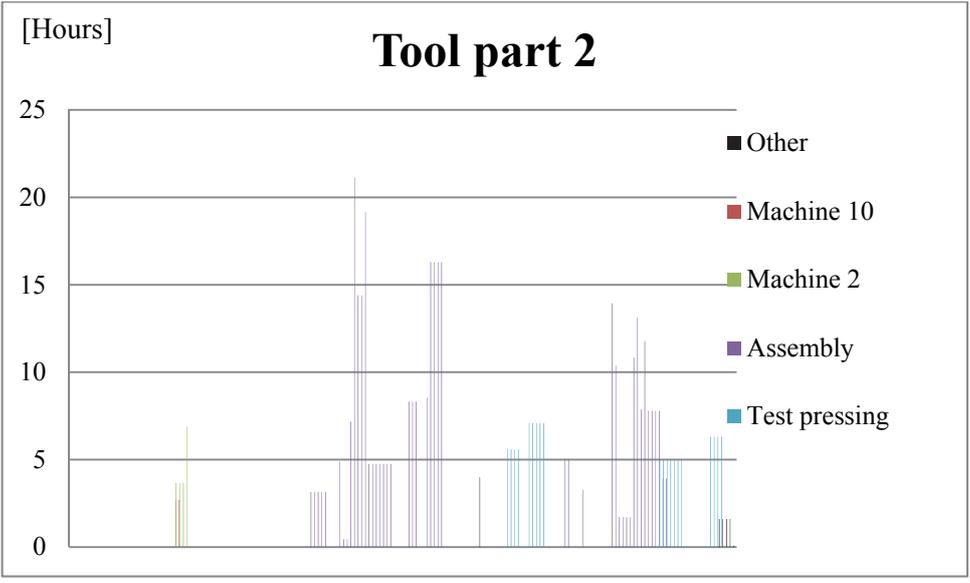


Diagram 6

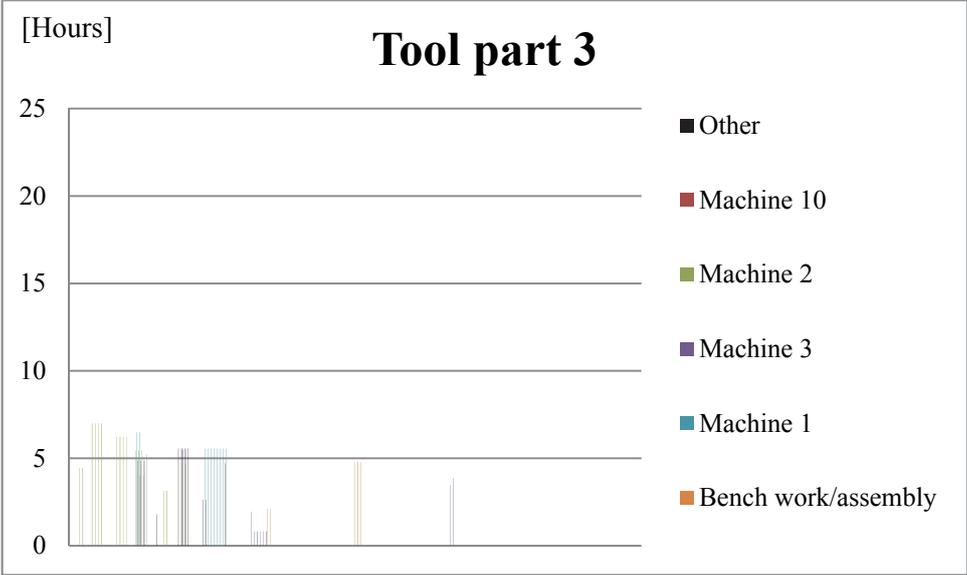


Diagram 7

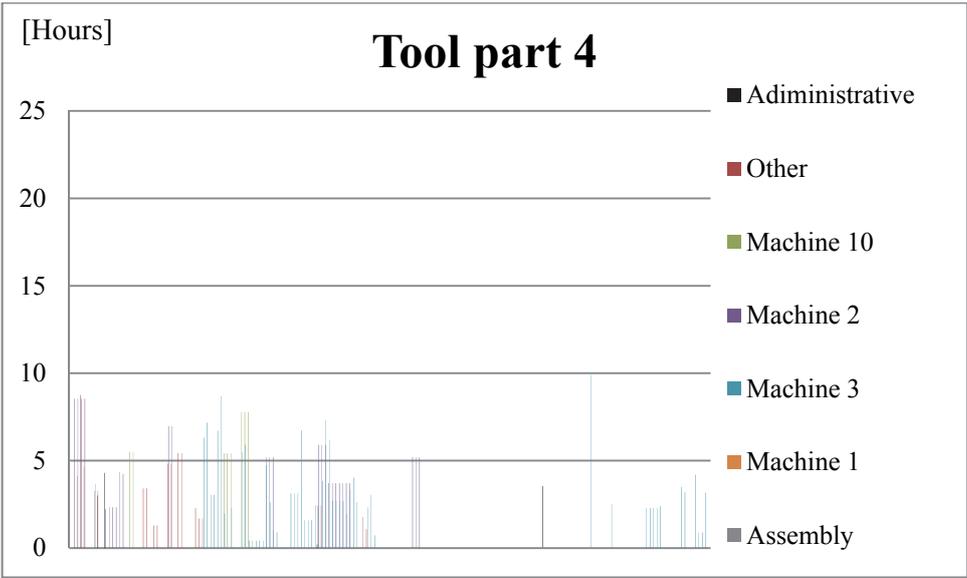


Diagram 8

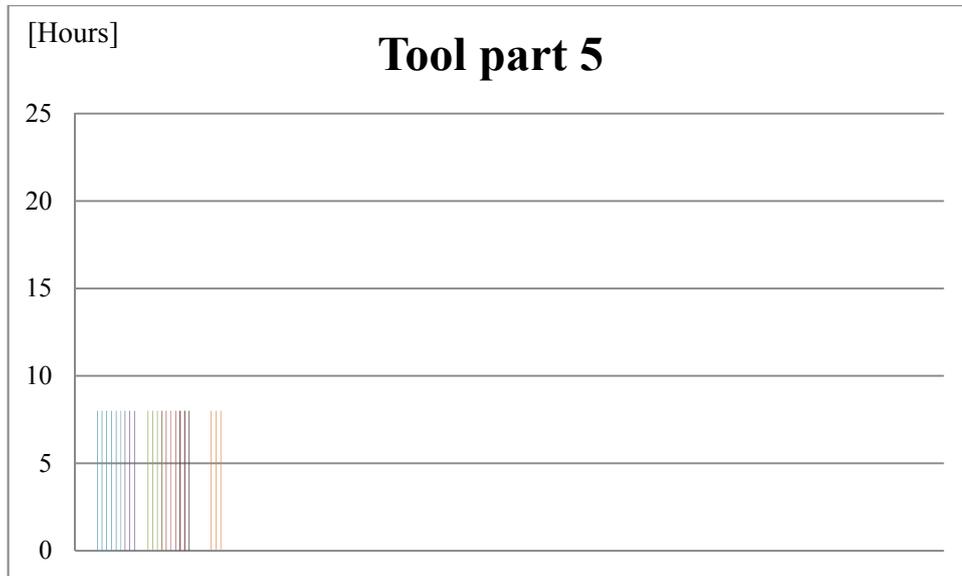


Diagram 9

These diagrams will be used for analyzing in which part of the project the tool is worked on less and where the bottle-necks in the production occur.

4.5 Meetings

4.5.1 Product Portfolio Board

The department has a Product Portfolio Board (PPB) meeting every Monday. The purpose of the PPB is to rapidly visualize and provide an overview of ongoing projects and how they proceed. Deviations that have occurred during the week are highlighted and discussed. Actions and responsible person for finding a solution is chosen. If the deviation already has been solved the department discuss if it is the best solution and if the solution secure that the problem won't occur again.

4.5.2 NPD Project Meetings

The NPD project team exists of project managers from different departments and one overall project manager. The NPD project team usually has weekly meetings throughout the project.

4.6 Material Flow

The material flow in the work shop has been studied. The material flow map provides a base for analyzing of how movement can be reduced, which will be considered in the next chapter.

Since the throughput time for manufacturing a new tool for gasket or brazed heat exchangers are more than 10 weeks, the material flow could not be observed visually. Instead the project reports were used to map the material flow.

Project reports for producing pillar stands, imprinting parts, cutting steel, others and documents from annealing and hardening was used for mapping the material flow. The mapped flow was then reviewed together with a team leader from the workshop.

The value flow map also shows that there is a lot of movement in the workshop. Even if the time for moving a tool is small comparing to how long processing time, the time for movement is waste¹⁰⁴ and should be minimized. This can be made by building a new gateway in the workshop. It is assumed that it take 1 second to move a heavy tool 1 meter¹⁰⁵.

The moved distance was measured in an auto cad drawing over the workshop, this approach are used for measuring every distance in the workshop. It is assumed that it takes one second to move the tools one meter for all different alternatives presented below.

The material flow for producing pressing and cutting tools is presented below. Material flow for producing pillar stands is, in general, the same as for producing pressing tools for gasket heat exchangers. The other parts are mainly manufactured external for gasket heat exchangers. It should be pointed out that the figure shows the material flow for a single tool piece. One new pressing tool can exist from one up to 25 pieces, depending on the size of the tool.

To produce a new tool takes several of weeks; therefore it would be very time consuming to study the material flow visually. The movement was instead mapped by studying project reports to see in which order machines was usually used. The map was then reviewed with one of the team leaders for the workshop.

Figure 25 show the material flow when producing pressing tools for brazed heat exchangers and cutting steels:

¹⁰⁴ Linker [28]

¹⁰⁵ Berglund [29]

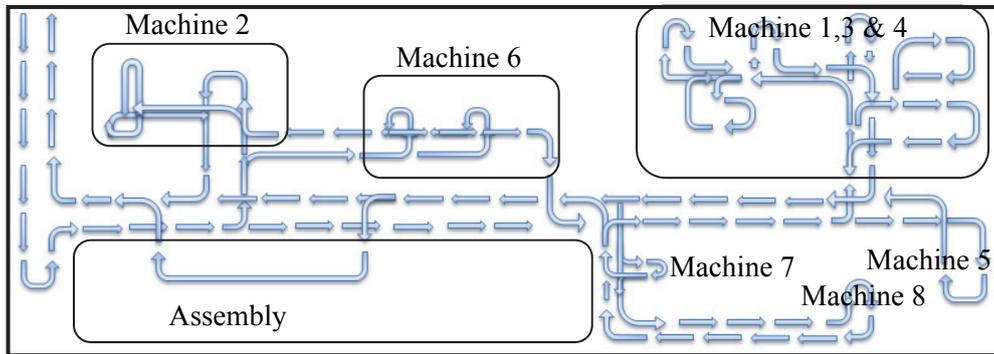


Figure 25 Today's material flow for producing pressing and cutting tool for brazed heat exchangers

The movement distance for producing new tools for a brazed heat exchanger is 555.5 meter.

$$Movement\ time_{Brazed} = \frac{555.5 * 1}{60} = 9.258\ min/tool$$

Figure 26 show the material flow when producing pressing tools for gasket heat exchangers and pillar stands:

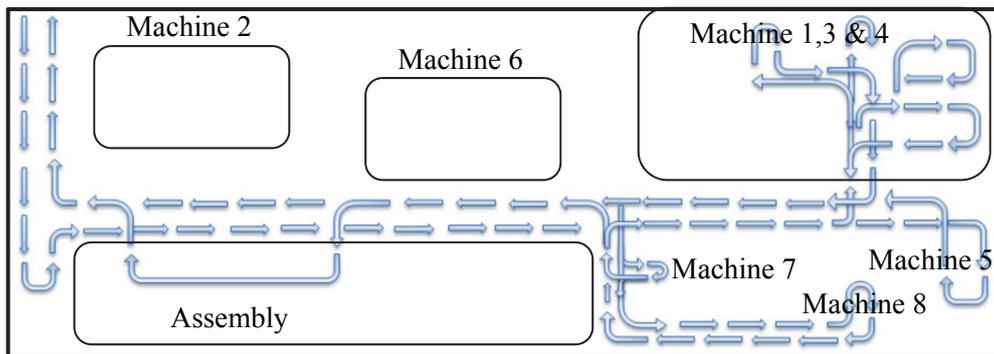


Figure 26 Today's material flow for producing pressing tools for gasket heat exchangers and pillar stands.

The movement distance for producing new tools for a gasket heat exchanger is 268 meter.

$$Movement\ time_{Gasket} = \frac{268 * 1}{60} = 4.5\ min/tool$$

5 Analysis

5.1 Value Stream Mapping

As stated in chapter 1.3 the main objective of this thesis is to reduce lead-time in the DPT process. Primarily, wastes in form of waiting time are to be reduced. Either “Process activity mapping” or “Supply chain response matrix” should therefore be chosen for mapping the value stream flow, since these methods has high correlation and usefulness for the waste “waiting”. “Process activity mapping” has higher correlation and usefulness in other areas as well and will be used for this study.

The general approach for process activity mapping is:¹⁰⁶

1. Study the flow of the process
2. Identify waste
3. Consider if the process can be rearrange in a more efficient sequence
4. Consider better flow pattern, involving different flow layout or transport routing
5. Consider whether everything that is being done at each stage is really necessary and what would happen if superfluous tasks were removed

The first step “*Study the flow of the process*” aims to achieve the first sub-objective¹⁰⁷ of this thesis. Process activities, activity cycle time and waiting time between activities were mapped with the modified value stream mapping method. A map was made for every tool project manager. The maps were compared with each other, and areas where time for executing the activity differed much between the employees was marked to be investigated further. By comparing the different processes, it was possible to see which solution that worked best.

5.1.1 Value Analysis

The second step for value stream mapping with a process activity mapping approach is “*Identifying waste*”. Non-value adding activities do not create customer value and are therefore also identified and minimized in this study. Ljungberg’s and Larsson’s methodology, presented in chapter 3.4.1.5 was used when making a value analysis. Value adding activities were marked with green, non-value adding with yellow and waste with red, see figure 28 and 29. External waiting time (i.e. waiting for information/material from another department) is

¹⁰⁶ Hines; Rich [22]

¹⁰⁷ Understand the as-is process

marked with blue triangle and internal waiting time (i.e. waiting for something within the department) is marked with black triangles.



Figure 27. Value analysis for gasket heat exchangers.



Figure 28. Value analysis for brazed heat exchangers

The value analysis shows frequencies of value-adding activities, non-value adding activities and waste.

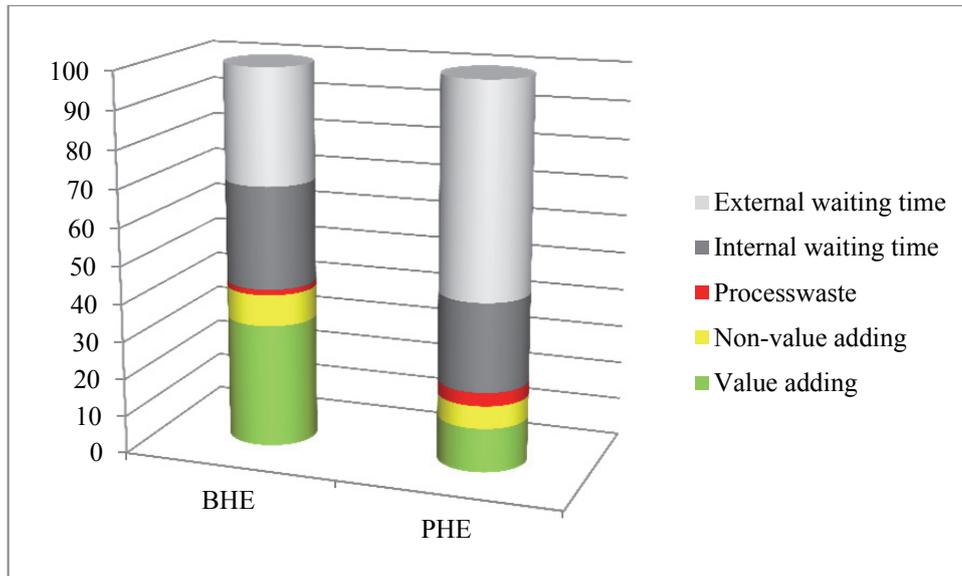


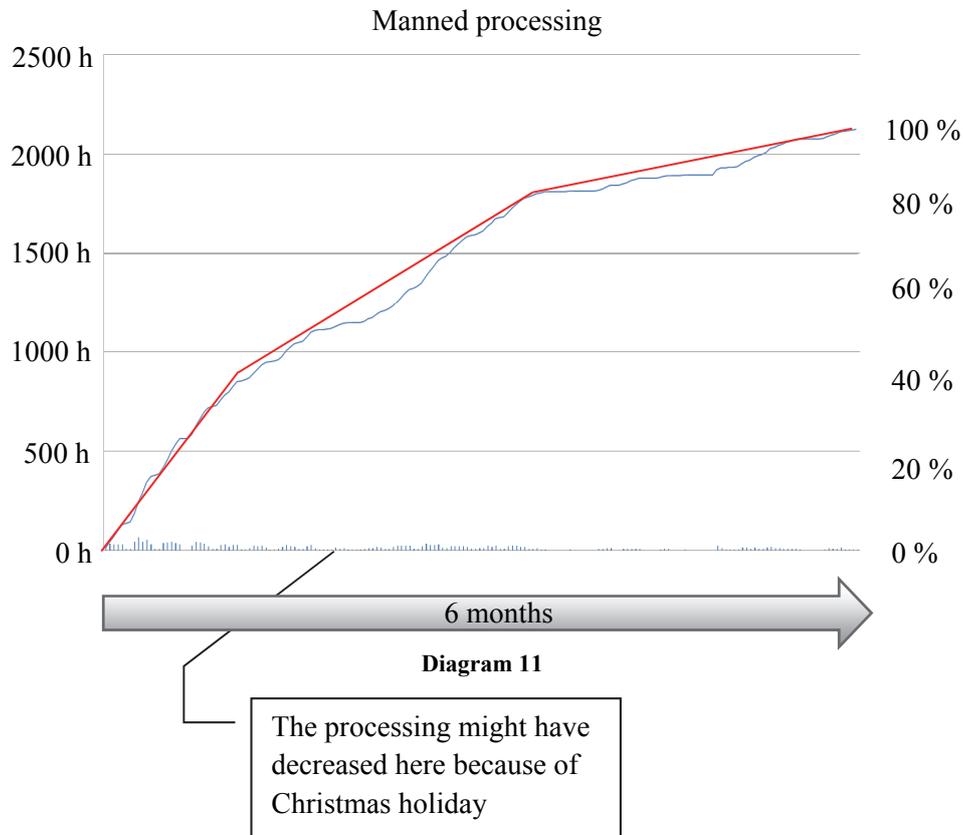
Diagram 10. Distribution of time between value-adding, non-value adding and waste activities

Diagram 10 shows where most time is spent. It is not known whether the external waiting time is value-adding, non-value-adding or waste, because it is not included in this study. According to the main objective “reduce lead-time”, the focus should be on reducing waste and non-value adding activities that take longest time.

5.1.1.1 Case Study of Producing a General Tool

A case study of the manufacturing of a specific tool for producing brazed heat exchangers was made. Project report from the production of pillar stands, pressing tool, cutting steel and other parts were studied. Heat treating documents was also used to see between which day the parts were away for heat treating.

The studied project reports was compiled in two diagrams, manned processing and unmanned processing. The columns show how many hours of manned processing that were spent on studied project each day, and the line shows the accumulated hours spend on the project.



The blue line in diagram 11 shows the accumulated processing hours. The red line is an asymptotic line that was drawn to illustrate the three different manufacturing speeds. The diagram shows that manufacturing speed is decreasing over time. One explanation is that almost one third of the processing time is assembly time. To retain the initial processing speed four tool makers must work with assembling the tools, but at most three persons can work with assembly at the same time. Another reason can be waiting time for external manufactured components.

The diagram is still interesting because it shows that the bottleneck exists in the end of the manufacturing process. The activities made in the last third are bench work, assembly and test pressing.

The same analysis was made for the unmanned processing. The columns show how many hours of unmanned processing and heat treatment that were spent on studied project each day, and the line shows the accumulated hours spend on the project.

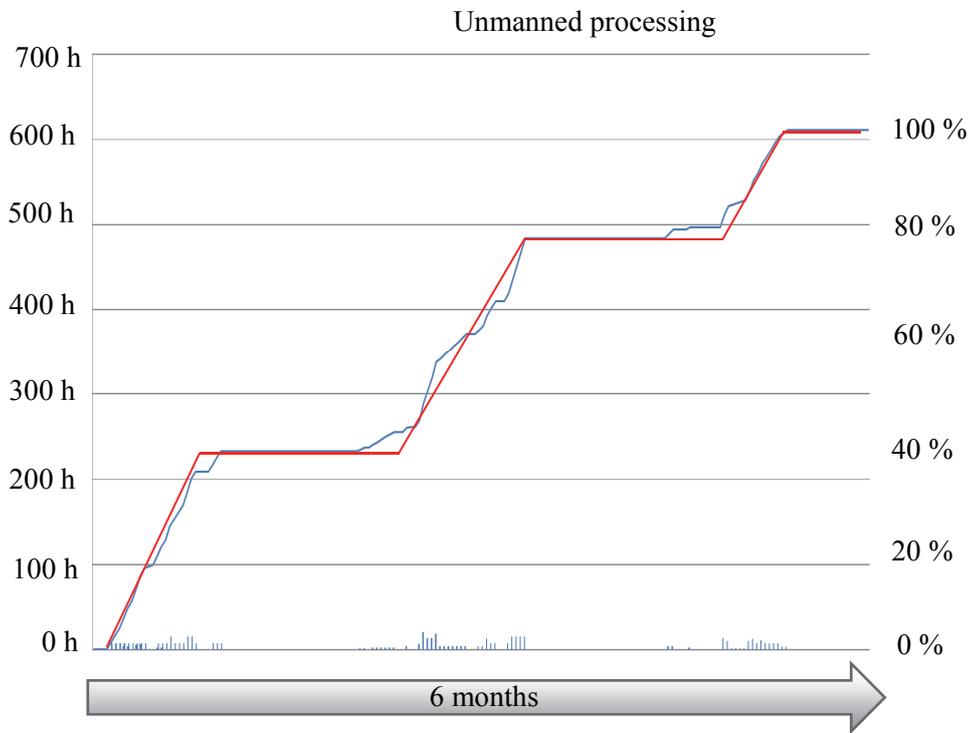


Diagram 12 shows that unmanned processing are made in periods of time, with approximately the same manufacturing speed.

The result of this analysis shows that improvement of the efficiency in the workshop should focused on easing assembly, bench work and test pressing. Thus expand the bottle neck, and not the bottle.

5.1.1.2 General Process Map Analysis

The process map was also analyzed using Ljungberg's & Larsson's¹⁰⁸ "general process map analysis" approach presented in chapter 4.2.1.4. A general process analysis was made in order to identify problem areas.

The first step "*Walk through the process map and let the participants connect problems to the map*" was made through interviews described in the empirical study. The following step was then followed:

¹⁰⁸ Ljungberg;Larsson [2]

1. Categorize problems based on type, cause and possible solution
2. Investigate consequences due to different problems
3. Investigate root-causes
4. Identify and focus on the most important root-causes

The problems were categorized into six different categories:

- Planning
- Communication
- Quality deficiencies
- Disturbances
- Systems/routines
- Others

The problem, the consequences of each problem and possible solutions were compiled in a document. This document has been removed due to confidential reasons.

The identified root-causes to problems are:

Planning

- Urgent jobs are mixed with planned production.
- Four planning systems that requires manual converting between systems.
- Complicated planning systems.

Communication

- Project leaders do not get required information on time, because other departments do not know what kind of tool they want.
- Unclear handshakes when handing over projects from the design department to tool workshop which leads to unclear area of responsibility.
- Meetings are spread out during the day, which leads to abrupt workdays.

Quality deficiencies

- Lack of time leads to hasty solutions.
- Late changes from other departments lead to re-work.

Disturbances

- The root-causes to disturbances are problems with planning, communication and quality deficiencies.

System/routines

- Deviation from PROMAL and other routines.

The risk for late changes increases when a project deviate from PROMAL’s gate model. Late changes in turn lead to re-work, unplanned and urgent jobs. Re-work contribute to lack of time. Lack of time leads to hasty solutions, which in turn increases the risk for quality deficiencies. Quality deficiencies leads to even more re-work which leads to more lack of time, unplanned and urgent jobs. The unplanned and urgent job in turn complicates planning. A cycle of deviations occurs, illustrated in figure 29 below.

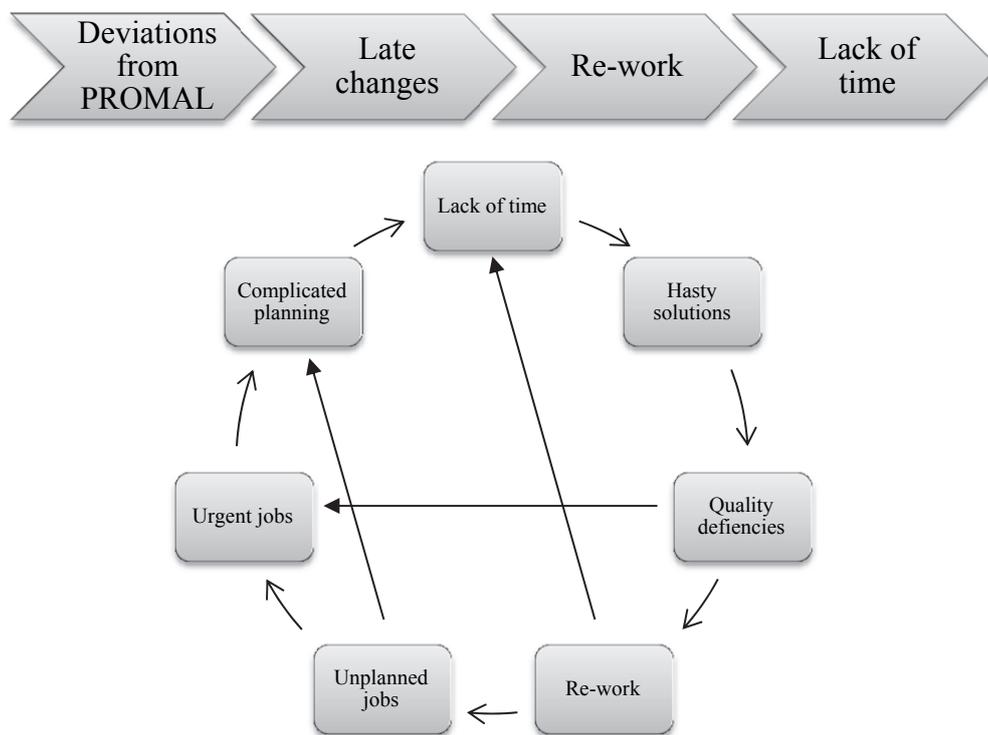


Figure 29. Correlations between deviations.

It is important to point out the consequences of late changes, since not only budget and planning for the specific project are affected, but every ongoing project at the department.

Figure 29 shows that hasty solutions only lead to more lack of time, and the sequence are repeated over and over again. Therefore even when time is short, hasty solution should not be accepted and quality should always be secured as early

as possible in the process. Ljungberg & Larsson¹⁰⁹ have reflected over this, and writes:

“If we don’t have time to do the right thing from the beginning, then when will we find the time to correct our mistakes?”

5.1.1.3 Utilization Rate

In order to know whether the machines are utilized in an efficient manner the utilization rates have been calculated.

The available manned time was calculated as:

$$T_{available} = (Number\ paid\ staff\ hours) * (Number\ of\ machines)$$

$$Number\ paid\ staff\ hours/day = (observation\ period) * (paid\ staff\ hours/day)$$

The available unmanned time was calculated as:

$$T_{available, unmanned} = 24\ h * (Observation\ period) * (Number\ of\ machines) - T_{available}$$

| Machine | Machine 1 | Machine 2 | Machine 3 | Machine 4 | Machine 5 | Sum |
|--------------------------------------|------------------|------------------|------------------|------------------|------------------|------------|
| Manned utilization rate [%] | 65 | 60 | 32 | 68 | 62 | 60 |
| Unmanned utilization rate [%] | 28 | 0 | 4 | 18 | 0 | 22 |

Table 3. Machine utilization rate.

The analysis shows that there is potential to increase the utilization of the machines, but higher utilization of machines decreases flexibility. It should be pointed out that the analysis assumes that 8 hours/day should be used for manned production. Since many parts are processed unmanned for many hours, machines are making unmanned processing also during working time and the employees then work with other machines/tasks.

¹⁰⁹ Ljungberg; Larsson [2], p. 18, Translated from Swedish

5.1.2 Reduce Movement in Workshop

The fourth step in Hines & Rich general approach for process activity mapping is to “Consider better flow pattern, involving different flow layout or transport routing”. This will be considered in this chapter.

5.1.2.1 The Current Workshop Layout

Today the workshop has a process/function layout. The red rings in table 5 show how the situation is today. A process/function layout seems to be an appropriate layout that should be retained in the future.

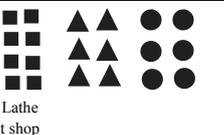
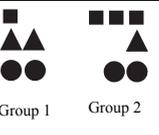
| Characteristics | Product layout | Process/function layout | Cellular layout |
|----------------------------|---|--|---|
| Type of process | Line | Jobbing/batch | Cells |
| Layout format |  Series work stations in operational sequence |  Lathe shop |  Group 1 Group 2 |
| Batch throughput time | Low | High | Medium |
| Work-in-progress inventory | Low | High | Medium |
| Disturbances sensibility | High | Low | Medium |
| Utilization of capacity | Low | High | Medium |
| Planning needs | Low | High | Medium |

Table 4. Today's process characteristics.

The empirical study showed that a lot of movement is made back and forward in the workshop.

There is a number of *constraints* that has to be taken into account when rearranging the workshop layout presented below:

- Machine 2 stands on casted foundation
- Overhead cranes cannot be used close to each other
- Machine 1, 3, 4 & 8 equipment must be placed tempered
- Machine 5 must be protected from dust
- Assembly of big tool are favorably placed close to the exit

5.1.2.2 New Workshop Layout

When making tools for brazed heat exchangers, there is a lot of material flow in and out from machines 2 and 6, those should therefore be placed close to the exist. The tool is biggest when it is assembled. In order to reduce movement of those big tools the assembly area should also be placed close to the exist as well.

Machine 2 has to stay where they are placed today because of the casted foundation. Studying the material flow chart for gasket heat exchanger it would be beneficial to place:

- Tempered machines close to each other, in one tempered room.
- Machine 7 close to both machine 1, 3, 4, 5 and 8.
- Place machine 1, 3, 4, 5 and 8 close to the exit so that the tool doesn't have to be transported through the whole workshop.

The last bullet is not compatible with the constraints, since the area close to the exit is occupied by the machine 2 and the assembly area.

A solution is to build a new door in the other end of the workshop. That would make it possible to both process and assemble tools for gasket heat exchangers, only in the right end of the building. It will also be more beneficial for production of brazed heat exchangers (and cutting tools) since they can be transported out of the workshop in that end as well.

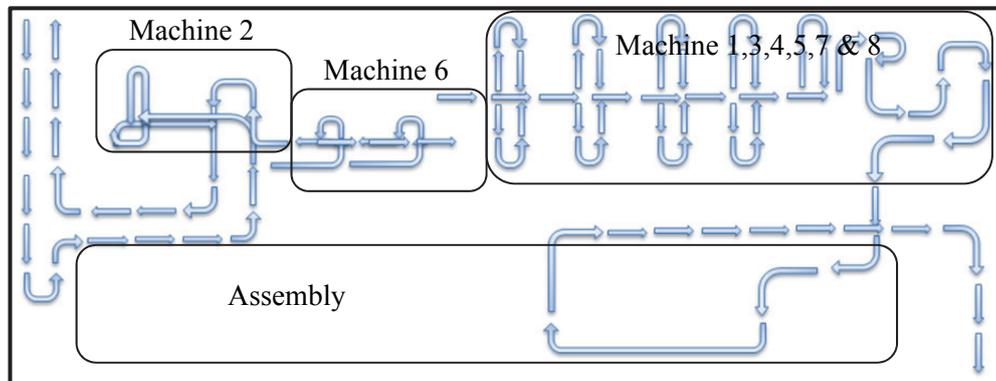


Figure 30. Material flow for producing tools for brazed heat exchangers with a new doorway.

If a new doorway is built the movement time for producing tools for brazed heat exchangers would be:

$$Movement\ time_{Brazed,new} = \frac{361.4 * 1}{60} = 6.0225\ min/tool$$

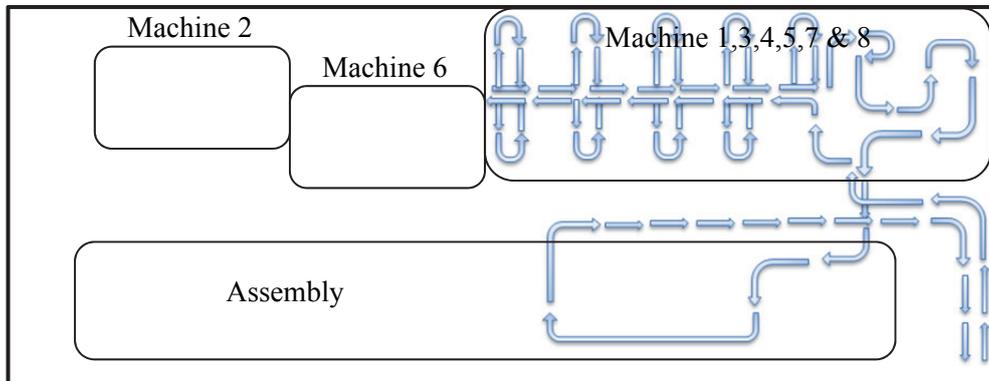


Figure 31. Material flow for producing tools for gasket heat exchangers and pillar stands with a new door way.

The movement time for producing tools for gasket heat exchangers would be:

$$Movement\ time_{Brazed,new} = \frac{619.125 * 1}{60} = 2.82\ min/tool$$

A new doorway would reduce the movement for producing tools for brazed heat exchangers from 9.26 to 6.02 minutes, and from 4.5 minutes to 2.82 minutes for a gasket heat exchanger. The cost for building a new doorway is approximately 500 000 SEK¹¹⁰, but one must also consider whether there is space enough for a gateway.

5.1.3 Production Security Matrix

The production is both manual and customized production, collecting data for a PSM therefore becomes very time consuming. Collecting data on manual work can also be sensitive¹¹¹ since specific persons' work is studied.

The department has a well-developed system for gathering deviations data, and the existing deviation reports were used as a base for the PSM, see table 6. Detailed information has been removed from the table due to confidential reasons.

¹¹⁰ Berglund [29]

¹¹¹ Ståhl [1]

| Factor group | Production losses | | | |
|---------------------------------|--------------------------------|---------------------|----------------------|----------------------|
| | Time for correcting action [h] | Material cost [SEK] | Personnel cost [SEK] | Σ Cost Factors [SEK] |
| A. Tool | | | | |
| B. Working material | | | | |
| C. Process | | | | 242 000 |
| D. Personnel and organization | | | | 290 000 |
| • Drawing mistake | | | | |
| • Dimension/tolerance deviation | | | | |
| • NC-preparation | | | | |
| E. Ware and maintenance | | | | 47 000 |
| F. Special process behavior | | | | |
| G. Peripheral equipment | | | | 20 000 |
| H. Unknown factors | | | | |
| Σ Result parameters | 551 | | | |

Table 5. PSM for OD-FTT's production year 2011.

5.2 Mapping the To-Be Process

The last step in value stream mapping with a process activity mapping approach is “Consider whether everything that is being done at each stage is really necessary and what would happen if superfluous tasks were removed”. This was taken in consideration when mapping the to-be process. The purpose with mapping to-be process is to achieve the final sub-objective:

- Develop an improved process map that can be applied to every DPT project

Three steps were followed mapping the to-be process:

1. Draft a to-be process map on basis of the as-is analysis
2. Present and communicate the drafted to-be process map
3. Workshop with process participants

5.2.1 Draft a To-Be Process Map

The main objectives with the new process map are to provide a fixed standardized process so that:

- Lead-time are reduced through:
 - Minimizing waste
 - Minimizing number of hand-overs
- Customers are always treated in the same way
- OD-FTT has a clear interface both towards other departments and within the department
- The organization supports an ongoing interaction between customer/market, design and production
- Facilitates for new recruits

First a rough map over the process was drawn, representing the different sub-processes needed, see figure 32 below.



Figure 32. Sub-processes for developing and producing tools for brazed and gasket heat exchangers.

It was found during value stream mapping that the follow-up process usually is skipped. When mapping the new process map, the follow up process mapped in the existing process map was used. In the new process map will differ between information, resources and object in/out. It is also divided since the process is interrupted by other departments.

5.2.2 Present and Communicate the Drafted To-Be Process Map

The drafted to-be process map was presented roughly at a midterm presentation in mars. In order to highlight deficiencies in the process the value analysis and the PSM was presented first. Then the to-be process map was presented next to the as-is, in order to reinforce the changes between the as-is and to-be process map. Changes that do not affect the process map (but still reduces the lead time) was also presented, for example the proposed workshop layout.

Before each session during the workshop, the main objectives with the new sub-process were presented. Every group had a paper copy of the process map and the value stream map to work with during the workshop.

5.2.3 Review and Improve the To-Be Process with Process Participants

The drafted to-be process map was reviewed and improved together with a selection of 12 process participants during a workshop. The participants were divided into three groups, i.e. four persons in each group.

5.2.3.1 Workshop Agenda

The workshop lasted for a day and was divided into five sessions plus one hour sum-up in the end. Each session contained of:

- Five minutes of introduction, where the main problems and solutions of a sub-process was presented. The lead-time of the drafted sub-process was presented as the goal lead-time. Activity lead-time was separated from waiting lead-time and the goal waiting lead-time was always zero, since waiting is waste. Eliminating waste in some cases contributes to increased activity lead-time, but the estimated reduction in waiting time justified the increased lead-time.
- 25 minutes of working on solutions to the main problems.
- 10 minutes for presentation. One group presented their solution.
- 15 minutes of discussion between the groups and finally summary.
- 10 minutes break.

The purpose of the closure session was to summarize the day and high light the top solutions. The following question was to be answered by each group:

- What is needed to update the process, based on the results of today?
- Create an action plan for implementing the solution:
 - **What** should be done?
 - **Who** is responsible?
 - **When** should it be done?

Session 1 – The “Analyzing Concept” and “Resource Planning” Sub-Process

The main objectives for this session were:

- *How to make it possible to allocated project members from the day the project starts?*
- *How to avoid that participating in a concept meeting do not ends-up with 20 hours unplanned work?*

The problem with allocating project members from the beginning of a project is that it is hard to plan the resources far ahead, so the root-cause for the problem is shortcomings in planning the workforce in the tool workshop.

The *pre-solutions* for facilitate planning were:

- Educate production planners.
- Facilitate planning by separating maintenance and producing new tool.
This can be made either by deposit different time of the day, different days or different machines and tool for maintenance and new production.
- Improve the planning system.

Tool designers are called for “Proof of concept” meetings in less than 50% of the concept projects. They want to be more involved in the concept project, and they want, in particular, to get more information about which concept projects are going on so that they can see what is coming in the future. But there are some shortcomings around how the “Proof of Concept Meetings” are distributed. One problem with the concept meeting is that the tool designer does not know how much time it will take to analyzing the concept when he goes to the meeting. Another problem is that the request is made directly to the tool designer and not through the managers of OD-FTT. The result is that the analysis of the concept project is made outside planning system.

The suggested *pre-solution* for handling this problem were:

- OD-FTT requires information about the concept before the meeting.
- If the tool technology is critical for producing the plate, a tool concept project should be started.
- Every invitation to a “Proof of concept” meeting should either be made through the manager, or the senior manager.

This would reduce the variation in lead-time from 3-20 hours, to become constant around three hours. There existed a waiting time of approximately 80 hours during the concept analyze. The reason to the waiting time is that other projects (for example production tools in use) have higher priority. If the analysis is planned for, it is can be made more concentrated.

Comments from process participants – The workshop participants agreed that a separate maintenance group can be a good idea. They suggested pre-defined groups that work either with maintenance or new tool projects. They also suggested that the project groups should contain both an experienced tool maker and one with less

experience, as a way to increase the overall competence in the workshop. They also suggested internal rotation of responsibility, so that a group both works with maintenance and new tool projects but at different times of the year. It also came to conclusion that it is better to have a tentative project group than no project group at all.

Regarding the “Analysis of Concept” process the participants agreed that all resources must be allocated through the manager. The information flow through the departments must be improved as well. They wish to get information about which concept exists and when they are ready for the next gate.

Another suggestion was to create a well-defined framework, so that the limitation frames are same for every department involved in the project.

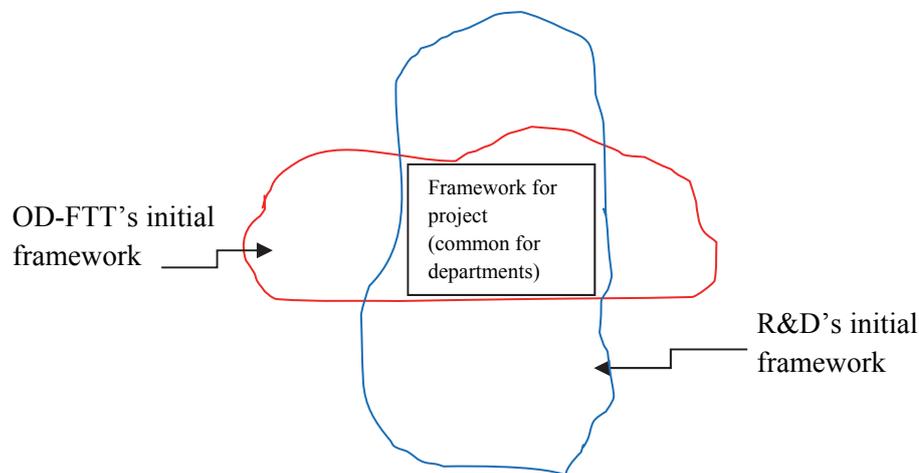


Figure 33. Common framework for projects.

The workshop participants were requested to rethink what information was needed on a checklist in this stage of the process. Since it exists a checklist today, but it is rarely used the workshop participants suggested that the existing checklist should be reviewed and used. The checklist should specify available technology and competence needed for the project.

Finally it was decided that the meeting structure must be improved. Prepared meetings with appropriate meeting frequency (day/week/month) will facilitate dissemination of information.

5.2.3.2 Session 2 – The “Pre-study” Process

The main objectives for this process were:

- *How can the pre-study process be made more efficient?*

- *How to avoid that parallel projects run in the same phase?*

Pre-solution – The VSM show that time is spent on searching for information from other departments. In order to make this part more efficient it was suggested that the tool project manager request information based on a pre-defined checklist. In the information request it shall be specified what and when the information must be delivered in order to keep the time plan. The information should only be requested one time. If there are trouble to get the information on time the tool project manager should turn to the overall project manager. It was also suggested that the pre-study should be prepared by requesting information and call for meetings in beforehand. Work can be made in parallel during the pre-study, which will reduce the lead-time.

In order to avoid parallel projects in the same phase an over-all planning on a higher level is needed.

Comments from process participants – The workshop participants wanted that a project group (at least a temporary) should be defined before starting the pre-study. During the pre-study the tool project team should have 3-4 meetings in order to capture:

- A layout that explains the principal of the tool.
- New things in the tool that does not have any best practice for how to design.
- Time, budget, risks etc.

One of the groups thought that the suggestion to have one tool project manager and another tool designer in the project was a good idea. One of the other groups suggested pair work, i.e. two designers and two tool makers in the project teams. It was suggested to create an experience/competence database from which the team leaders could choose tool project members. It was suggested to have more internal meetings within OD-FTT in order to create a common view of the technical solution. More involved people in the tool projects will probable straighten out question marks and reduce the lead-time.

It was suggested that existing checklists were complemented with requirements from OD-FTT, in order to clarify when and what information are needed. The checklist should be connected to the process map. The checklist should contain:

- Requirements on Research & Development
- Requirements on Operation Manufacturing

- Templates
- Order protocol
- Evaluation of the technology needed

The communication problems lead to a lot of administrative work in order to secure information flow in form of checklists. These checklists are non-value adding activities and should be minimized, but must be kept if needed for securing information flow.

In order to avoid that parallel projects run in the same phase it was suggested to:

- Only have one planning point. This planning point should balance the working load by planning the project with an offset and avoid batches.
- Do all activities at a time, not now and then.
- Divide the NPD pre-study into two phases, where the tool specification is made in the second phase.
- Complement the tool specification with an improvement step after delivery.

5.2.3.3 Session 3 – The “Design Tool” and “Order” Processes

The first objective of the third session was:

- *How to secure the quality of the drawings in order to prevent rework?*

Pre-solution – Add time for self-control into the process and introduce design review meetings with the tool project group.

Those changes will increase the value-adding time, but the increased quality on drawings will reduce rework and disturbances. According to the PSM showed that a lot of time was spent on rework due to drawings mistakes, and according to the general process analysis 30 % of the time is spent on correcting hasty solutions.

Comments from process participants – The final proposal from the workshop was to introduce “Design Review Meetings”, “Manufacturing Adjustment Meetings” and “Drawing Review Meetings” during the designing phase in order to get better self-control of the tool team. It was suggested to have approximately three (more or less depending of the complexity of the project) “Design Review Meetings” on regular basis. Two designer/project manager, two tool makers and one end-user (with a technical background) should attend the meetings. This requires that a project team has been appointed earlier in the process.

It was also stated that drawings of the entire tool should always be completely finished before release in order to secure the function of the design. The quality can be further improved with simulation of tool function, with every movement.

Quality could also be improved by improving usage of “Best Practice”. Proposals for improving Best Practice were:

- Continual updating of Best Practice
- List of Best Practice (facilitate findings)
- Be “faithful” to Best Practice, use concept projects for new inventions

The second objective for the session was:

- *How to reduce disturbances and waiting time?*

Pre-solutions – Disturbances seem to be approximate the same for designers/project managers during the whole process. As mentioned in chapter 5.1.1.2, the root-causes to disturbances are problems with planning, communication and quality deficiencies. The proposed solutions are:

- Run projects sequential instead of parallel
 - Reduces number of meetings with other projects
 - Reduces the risk for unplanned jobs that disturbs ongoing projects
 - Reduces drawing mistakes by self-control; the project group that is involved in the project from the beginning verifies models and drawings.
- Divide the working force in two groups: "Develop new production tools" and "Maintenance of production tools".
 - Reduces the risk for unplanned jobs that disturbs ongoing development projects.
 - Increase the competence within the department, since more persons becomes involved in the projects.
- Divide working tasks between project manager and designer.
 - Reduce the designing time and drawing mistakes, since the designer can focus on designing.
 - Increase the competence within the department, since more persons becomes involved in the projects
- Make clear when tool approval should be signed, for example after a specified number of plates have been manufactured.
 - Reduce the risk for unplanned jobs that disturbs ongoing projects.
 - Project manager doesn't have to spend time on getting the tool approval signed.

- When R&D or production make late changes, hand it over to a resource planner that reschedule the projects.
- Minimize the number of meetings and make them more efficient. Try to move meetings so that they come after each other, so that the day is not split up.

Waiting time in the order process can be reduced if the manufacturing is ordered during a design review meeting.

Comments from process participants – One group agreed that it could be beneficial to divide working tasks between project manager and designer. Another group came with an alternative idea: Work in pairs, then one designer can focus on designing and the other can answer questions etc. This division of work makes it possible to close the door, calendar and cell phone so that the designer can focus during designing.

The process participants agreed that projects will be less disturbed by having specialized maintenance groups.

Education in computer system so that more employees have the rights to check out drawings and models, was suggested.

A project team would facilitate ordering manufacturing. It would probably also improve the communication within the team. Clearer information boundaries were also suggested as a way to facilitate information flow. The importance of communicate risks for delays in an early state was also pointed out.

The last objective of the session was:

- *Define OD-FTT's core competence, what can be outsourced on consultants?*

Pre-solution – Hire consultants for project management and to draw pneumatics.

Comments from process participants –The pneumatics are too complicated to be made by consultants that have not seen the tool before. Use consultants for simpler working tasks e.g. light fixtures. Also clarify guidelines and drawing rules for consultants, and use consultants only when best practice exists.

5.2.3.4 Session 4 – The “Plan Production” and “Manufacturing” Process

The first objectives of the fourth session were:

- *How can planning be made more efficient?*

Proposals for facilitate planning was given in the first session as a way to make it possible to distribute project member to the project. In addition it should be pointed out that improved communication between project manager and team manager about the time plan would also facilitate planning.

Comments from process participants – The project team shall, as a team, produce a detailed time plan for manufacturing. A team leader must be involved in making the time plan even if he/she is not in the project group.

The process participants believe that it is important to visualize the project and the relating information flow with checklists and plans.

The second objective of the session was:

- *How can manufacturing be more efficient?*

The goal lead-time was based on case study for producing a general tool. If initial production rate could be kept throughout the manufacturing would the tool be finished within 3 months instead of 6 months, i.e. the lead-time would be reduced with 50%. According to the analysis of the case-study bench work, assembly and test pressing are the bottle-neck in the manufacturing process.

The ***pre-solutions*** for widening the manufacturing bottle-neck were:

- Draw pneumatics in drawings.
- Hire someone to help out with simpler tasks such as packing tools, ordering standard material, etc.
- Minimize movement with new gateway.
- Cell phones to tool makers in order to facilitate communication.
- Secure high quality on drawing in the “Design process” in order to reduce rework in workshop.

Comments from process participants:

- There should be a best practice for manufacture so that optimal manufacturing methods are used. Instructions for manufacturing must be clear.
- Introduce quality control of incoming components. Otherwise mistakes aren’t discovered before the components are needed.
- Use 3D-modells, only essential tolerances.

- Assembly time is 1/3 of the production time that is why the manufacturing speeds slows down in the end of the project. At most three people can work on the project at the same time.

The last objective of the session was:

- *How should late changes from R&D be handled?*

Pre-solution – If there is a great change that will affect other projects, the change should be planned as a new project.

Comments from process participants:

- Risk handling in projects.
- Both planning and late changes are a prioritizing question. Everyone agreed that it was essential that the prioritizing is clear. Two different methods for prioritizing projects were suggested:
 - FIFO – First in first out, it was suggested that this is the main principal for prioritizing.
 - SJ-principal – Named after a Swedish train company. If a train is late, it has to wait for every train that are on time. In that way less train will be late, even if the affected train will be even later. The trains are a metaphor for the projects, and the railway is the manufacturing process. Projects that aren't delayed will be prioritized.

The two prioritizing systems mentioned above can be combined. Mainly FIFO can be used, but when a project is delayed, other projects on time is prioritized.

5.2.3.5 Session 5 – The “Start-up” and “Follow-up” Processes

The first objective for this session was:

- *How to optimize start-up process?*

Pre-solutions – Improve preparations before test pressing, e.g. electrical and available material.

Comments from process participants:

The start-up on site would be more efficient if the functionality (electrical, pneumatics, hydraulic, transfer movements etc.) of the tool could be tested in beforehand.

It is also important to engage all set-up participants in time, and that everyone is participating during the set-up. That can be done by specifying in the tool specification, together with production site, whom, what, how much and when the set-up will take place.

The second objective was:

- *How can closure of projects be improved?*

Pre-solutions – Define in tool approval when a project close, e.g. after a certain number of plates.

Comments from process participants:

Separate between promised and wished date for tool approval. Clarify the consequence of making changes in the order in the end. Make guidelines for what is ok to add, and what's not and should be a separate order. Improvements should be ordered as new projects.

The last objective of the fifth session was:

- *Create a follow-up process*

Pre-solutions – The suggested follow-up process are copy-pasted from the existing process map, but include both the project team and the customer in the follow-up process.

Comments from process participants:

- A two hours long closing meeting with modifications, updating of drawings/best practice/process should be a part of the follow-up process. The process participants believe that this would save up to ten days for the next project. Alfa Laval's general project form PROMAL has a template for Project Review Meetings that can be used.
- Create a checklist for the follow-up process.
- End every project with a cake.
- Define/reserve time to have a closure phase when planning the project.
- Wait with starting the closure phase until a pre-defined date.

5.2.3.6 Closure – Create an Action Plan

In the closure phase each group summarized the day and came up with action plans for implementing improvements. The summarized action plan is presented in table 6 below. Table 6 shows that many improvements can be implemented directly when a new project starts.

| Responsible | 2012 Q3 (When next project start) | 2012 Q4 | 2012 Q1 | 2013 Q2 |
|---|---|---|---|----------------------------------|
| Team leader/Team manager | Work in pairs in the manufacturing | | | |
| | Create a competence database | | | |
| Senior Manager, Manager Tool Design and Technology, Project Manager | | Distribute resources/create a project group in an early state | | |
| Senior Manager, Manager Tool Design and Technology | Clear prioritizing between projects | | | |
| Manager Tool Design and Technology, Project manager | Standardize/create/ensure "Best Practice" for specific tool project | | | |
| OD-FTT/R&D/OM | | | | Create specification for closure |
| | | | Ensure information flow, external and internal meeting structure <i>(Senior Manager)</i> | |
| Senior Manager OD-FTT, MN PC-CHE | | | Define information flow/interfaces between departments/frames | |
| Manager Tool Design and Technology | Set up rules for communication | | | |
| | | | Create checklist with requirements towards R&D and OM | |

| | | | | |
|--|---|--|--|---|
| | | | | Investigate the opportunities for 3D-modeling |
| Senior Manager OD-FTT /Manager Tool Design and Technology | Work in pair with the design/ two representatives from design/ machine workshop/ end user | | | |
| | Create visualizing, plans and checklist (standardized) | | | |
| | More planned time in the projects | | | |
| | Introduce internal working meetings | | | |
| | Reserve time for end-control | | | |
| | Closing meeting, updating of drawings/best practice/process | | | |
| | Use "Project Review" according to Alfa Laval's general process model | | | |
| | Standard template for final report | | | |
| | Start with "Design Review Meetings" | | | |
| Team Leader/ Project Manager | Quality control of external manufacturing/ design consultants | | | |

Table 6. Summarized action plan.

6 Results

This chapter presents solutions to the key-question of this thesis: “How can lead-time be reduced for customized solutions?” The chapter presents solutions based both on the author’s analysis and the results from the workshop with the process participants. A summarization of recommended actions closes the chapter.

6.1 Understand and Improve the DPT process

The DPT process exists of eight sub-processes. The result for each sub-process is presented separately.

6.1.1 Analysis of Concept Process

The current analysis of concept process was mapped during interviews and is presented below:

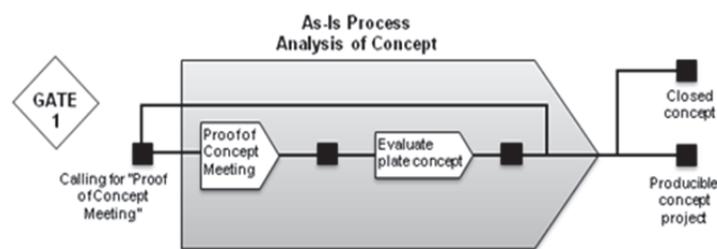


Figure 34. Current process for analyzing concepts.

Identified problems in the current concept process are:

- **Poor information about ongoing concept project:** Designers cannot prepare for upcoming projects.
- **2 hours meeting can end up with 20 hours of work:** A proof of concept loop occurs (see the process map above) that can vary from 2 hours up to 20 hours.
- **Urgent jobs and other projects with higher priority:** Projects in the feasibility phase has relative low priority compared to tools that are in use in the production, which can lead to waiting time in the feasibility study.
- **Resource request to “Proof of Concept Meeting” is not made to a central planning point:** R&D can call direct to a tool designer, therefore is not every job distributed from one planning point.

The identified root-cause to the problem is:

- **Deficiencies in the information flow:** Distribution of information about concept studies is insufficient.

The analysis and the workshop resulted in the following actions for improving the information flow:

Involve designers more during concept development

Designers can be more involved either by getting more information about ongoing projects or by attending more proof of concept meetings. If more information about the concept projects is handed-over to the tool designers before the meetings, they can prepare themselves better and the meeting can be made more efficient.

It is recommended to establishing frames for development in cooperation with R&D to create a common framework for the whole company's developments work in the same direction.

Allocating all process resources through one planning point

By allocating all process resources through the department manager will even out the working load. It makes it possible to allocate time to work focused with analyzing concept projects. This will reduce the number of ongoing projects as well as setup time between different projects.

Start a specific concept projects if the tool is critical for producing the plate

The concept study loop is avoided by starting a specific concept project if the tool is critical for producing the plate start a concept study. The concept study should be planned through the resource planning process.

The to-be process map is presented below:

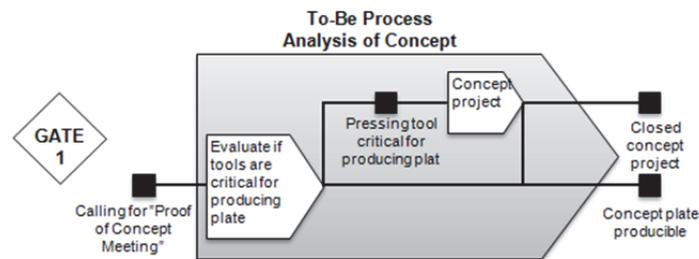


Figure 35. To-Be Analysis of Concept Process.

These improvements will reduce the lead-time from 3.08-21.58 to 3.08 h since the proof of concept loop is avoided. Waiting time is reduced by working focused with the project.

| Measure | Today [h] | Goal [h] | Potential gain [%] |
|----------------------|------------|----------|--------------------|
| Activity lead-time | 3.08-21.58 | 3.08 | 0-86 |
| Process waiting time | 80 | 0 | ∞ |

6.1.2 Resource Planning Process

Management processes controls and coordinates organizational core and support processes¹¹², and the resource planning process has been identified as a management process since it coordinates the other processes. Management processes are to be separated from core processes. The current process for resource planning is presented below:

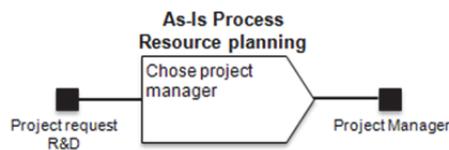


Figure 36. Current Process for Resource Planning.

Identified problems in the resource planning process are:

- **Not every project/assignment is distributed through this process, which affect resource planning/allocation.**
- **No project group is defined:** A project manager is chosen for the project, but no project team members. Since no responsible toolmaker is chosen the project manager/designer do not get feedback from production during the pre-study or designing phase.

The root-cause to this problem is:

Production planners cannot plan who will be responsible for manufacturing the tool: The production planning is complicated and is interrupted by urgent jobs and problems with other projects. Furthermore, the department has four different planning systems which require manual conversion between systems.

¹¹² Chapter 3.2.1 What is a process?

In order to solve the root-cause, planning must be improved. Suggestions for improving the planning are:

Improve planning system

OD-FTT is investigating opportunities for simpler planning systems at the moment, and has therefore not been investigated further in this study. It is though recommended to use the PERT for planning (since the technique can deal with deterministic problems) and to reschedule non critical activities within the available slack if possible and if not possible delay them. Finally it is recommended to educate team leaders in production planning, since they are responsible for planning the production.

Separate manufacturing into different production flows

By separating production flow between MPT and DPT, it becomes more natural to divide responsible and build teams according to processes boundaries rather than to function boundaries. It should though be pointed out that there are other alternatives for dividing the production flow, for example between time-consuming and quick units.

It is also suggested to have pre-defined groups that work either within the MPT or DPT process. The project groups should contain both an experienced toolmaker and one with less experience as a way to increase the overall competence in the workshop. It is possible to have internal rotation of responsibility so that teams work with both in the MPT and the DPT process, but at different times of the year. Internal rotation of responsibility develops the personnel's competence.

Four different ways to physically separate flows are suggested:

- Perform maintenance and new production during different times of the day.
- Perform maintenance and new production during different days of the week.
- Assign specific groups of machines and employees to either maintenance or new production.
- Two shifts with one shift working with maintenance and the other shift working with new production.

The improved process map, with the new checklist is presented below:

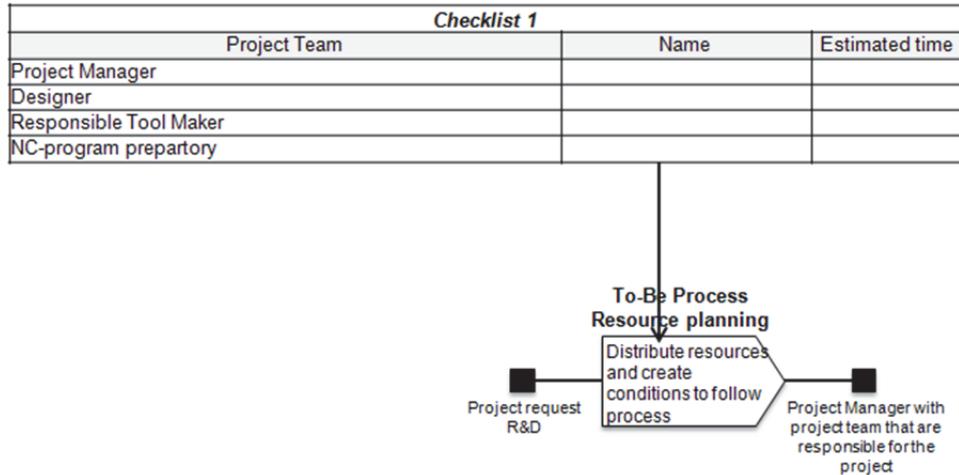


Figure 37. To-Be Resources Planning Process.

These changes will not reduce the lead-time for this specific process but they will reduce lead-time for the core processes.

6.1.3 Pre-Study Process

The current Pre-Study process is presented below:

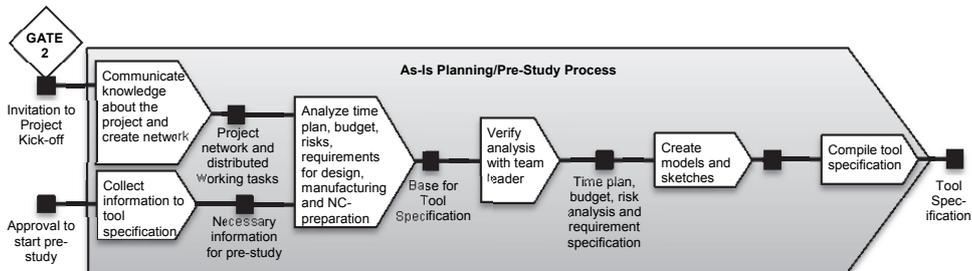


Figure 38. Current Pre-Study Process.

The identified problems in the pre-study process are:

- **No tool project team is defined in this phase:** Tool project managers do not get sufficient feedback from other functions within the department.
- **Tool project managers do not receive required information on time:** Collecting information becomes time consuming.

- **Tool specification is worked on intermittently:** Increase the number of ongoing projects.
- **Demands differ between R&D and production site:** R&D wants inexpensive tools and the production site wants a sustainable tools. The tool project leader must compromise between these two demands.

The identified root-cause to the problems is again:

Deficiencies in the information flow: Since no tool project team is defined in this phase, communications are made between managers and not within a project team. When a tool project manager has to wait for required information they work on other projects and the number of ongoing projects increases.

In order to improve the pre-study the following actions are recommended:

Define project team before the pre-study process start

It is recommended to allocate team members to the project in the resource planning process. An experience/competence database can be created to help the team manager (how is responsible for the resource planning process) to find appropriate team members. It is suggested to work in pairs of two designers and two toolmakers in a project team.

A defined project group from the beginning of the project enables ongoing communication between team members which reduces misunderstandings and creates a common view of the technical solution. Questions will be addressed and that will reduce lead-time downstream. This will also involve more people in the project at an earlier state which will reduce the dependency of individuals.

In order to nurture the dialogue within the group it is recommended to have three to four meetings during pre-study. The purpose of these meeting is to capture:

- A layout that explains the principal of the tool.
- New things in the tool that does not have any best practice.
- Time, budget, risks etc.

Complement existing checklists with requirements from OD-FTT

A checklist for information flow in NPD project exists today, but during the workshop it was suggested that this checklist should be complemented with requirements from OD-FTT. The improved checklist should clarify when and what information is needed for the project. The checklist should contain:

1. Requirements on Research & Development
2. Requirements on Operation Manufacturing
3. Templates
4. Order Protocol
5. Evaluation of the technology needed

If required information is not received on time the tool project manager are recommended to turn to the overall project manager in order. Information should only be required once otherwise it is rework which is equal to waste.

Another way to avoid waiting for information from other departments is to divide the pre-study into two phases. The tool specification is made in the second phase, when required information already has been gathered.

Prepare pre-study

It is recommended that some time is spent on preparing the pre-study in terms of requiring information and call for necessary meetings. These preparations are made with the purpose to avoid waiting time during pre-study.

The to-be pre-study process map is presented below:

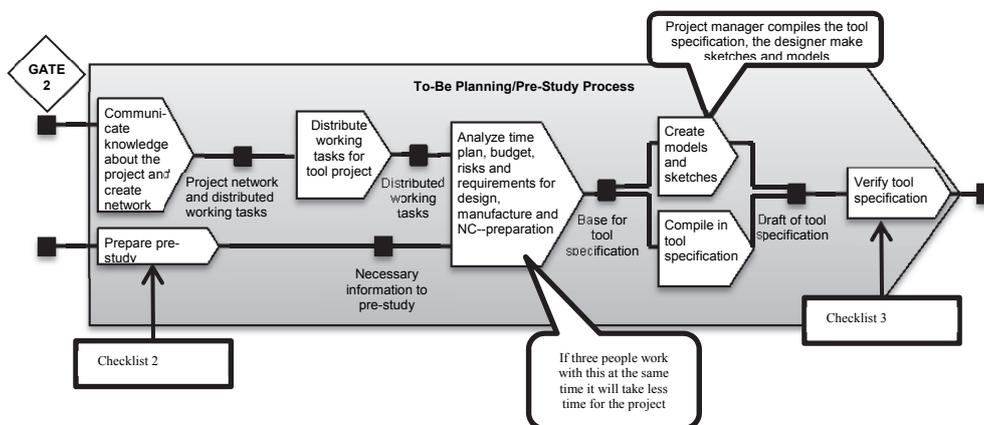


Figure 39. To-Be Pre-Study Process.

The suggested checklists are presented below:

| <i>Checklist 2 - Prepare pre-study</i> | | |
|---|---------------|----------------|
| Meetings | Booked date: | |
| Tool kick-off | | |
| Meeting with responsible person on site | | |
| Meeting with R&D | | |
| Information | Require date: | Delivery date: |
| <i>Operation</i> | | |
| Press machine | | |
| Cutting machine | | |
| Welding machine | | |
| Peripheral equipment | | |
| Fixtures | | |
| Production flow | | |
| <i>Market</i> | | |
| Plate material | | |
| Thickness | | |
| Volumes | | |
| Sheet combinations | | |
| <i>R&D Plate</i> | | |
| Carrying bar cut | | |
| Corner | | |
| Width | | |
| Length | | |
| Channel depth | | |
| Thicknesses | | |
| Material | | |
| Volumes | | |
| Plate pattern | | |
| Multi pass (single hole cutting tool) | | |
| Double wall, Gemini, semi welded | | |
| Hanger or collar | | |
| Corner steering | | |
| Expected pressing forces | | |
| Update project | | |
| Operation Development Database | | |
| Project Portfolio Board | | |
| Order system | | |

| Checklist 3 - Verify tool specification | | |
|---|-------------------|--------------|
| Information | OK/ Not OK | Notes |
| Deliverables | | |
| Time plan | | |
| Budget | | |
| Offer | | |
| Risk analysis | | |
| Cash flow | | |
| Project list | | |
| Organization | | |
| Tool approval | | |
| Guide lines | | |
| Information flow | | |
| Project planned in capacity planning program | | |

These suggested improvements have been estimated to reduce lead-time from 47-367.03 hours to 45.39-154.79.

| Measure | Today [h] | Goal [h] | Potential gain [%] |
|-----------------------------|------------------|-----------------|---------------------------|
| Activity lead-time | 47-367.03 | 45.39-154.79 | 3-58 |
| Process waiting time | 0-720 | 0 | ∞ |

6.1.4 Design Tools and Order Process

The Design Tools and Order processes are advantageously presented together since the interface between the processes are recommended to be changed.

The as-is design and order processes:

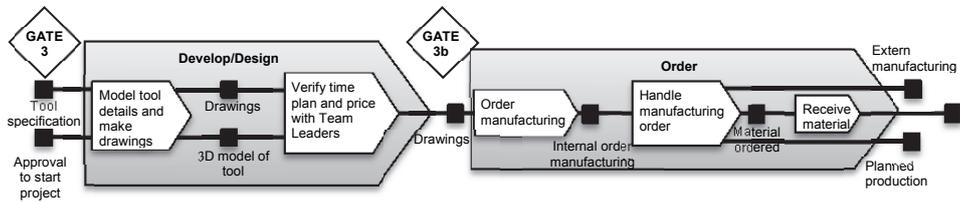


Figure 40. Current Design and Order Process

The main problem during the design stage is disturbances. Disturbances increase the risk for mistakes and extend lead-time. Tool designers estimate that they can work effectively three hours per day with a given project. Disturbances occur in every sub-process, and are often created by parallel projects. Designers always have at least three projects running in parallel.

Identified disturbances are:

- **Questions from other functions:** Most of the questions come from R&D or the production site.
- **Meetings:** Regarding other projects, regularly meetings and meetings with the department.
- **Late changes from R&D:** Late changes might cause re-work in the form of re-designing the tool design.
- **Urgent old projects that must be fixed:** Especially when tool approval has not yet been signed off on.
- **Unplanned work.**
- **Print drawings:** It can take up to one day to print drawings. Sometimes drawings are thrown away which can lead to re-work.
- **Review and correct deviation reports:** If a deviation have been corrected that should be registered on the deviation report. Sometimes that is not registered, then the drawing has to be opened and analyzed just to see that the deviation has already have been corrected.

Other issues during designing are:

- **Tool project team is not defined:** Designer does not get feed-back from the tool workshop.
- **Quality problems when hiring consultants:** Checking drawings is time-consuming and it is difficult to find mistakes.

The order process contains many hand-overs. This is illustrated best in the value stream map. The lightning (⚡) represent electronically hand-over of information. As one can see in the value stream map every hand-over that is followed by waiting time¹¹³, i.e. waste.

¹¹³ Waiting time is illustrated by the triangles.

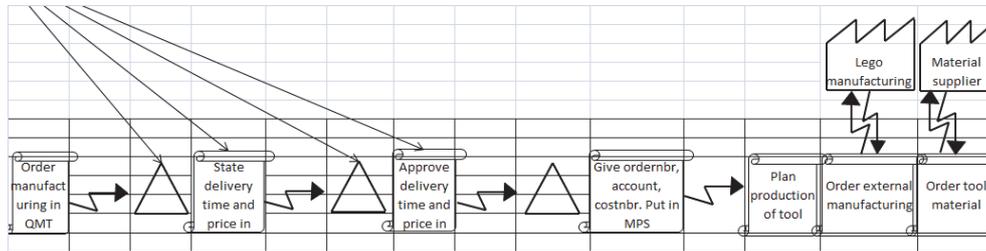


Figure 41. Value Stream Map for Oder Process.

The identified root-causes to problems in the design and the order process are:

Deficiencies in planning, communication and quality deficiencies: The identified root-cause to problems in the design process is disturbances. The root-causes to disturbances are deficiencies in planning, communication and quality as stated in chapter 5.1.1.2.

Too many hands-overs: Each hand-over result in waiting time which can be removed if the hand-overs are removed.

Some of the recommendations made for the previous processes are relevant for improving the design process as well. To divide the production flow and working force between DPT and MPT process will reduce the risk for unplanned jobs disturbing ongoing DPT projects. It is also beneficial to have two designer (or even one designer and one tool project manager) in the process teams. By dividing working tasks between tool project manager and designer, the designer can focus on designing and waiting time during drawing and drawing mistakes are avoided.

Design Review Meetings and Manufacturing Adjustment Meetings with the project group

It is advantageously to have Design Review Meetings and Manufacturing Adjustment Meetings during the designing phase with the pre-defined project team, since the project group that is involved in the project from the beginning verifies models and drawings. It involves the people who will work with the project later and they can impact the design with their expertise in manufacturing.

It is suggested to have approximately three (more or less depending of the complexity of the project) Design Review Meetings on a regular basis. The purposes of these meetings are to reduce drawing mistakes by self-control of the team. It is also important to add time for the designers to self-control their own drawings.

These changes will increase the value-adding time, but the increased quality of drawings will reduce rework and disturbances. According to the PSM ~280 weeks are spent on rework due to drawings mistakes and according to the general process analysis 30 % of the time is spent on correcting hasty solutions.

Do not allow drawing to be released before the complete tool is finished

To not start manufacturing before the design is finished secures the function of the design. Otherwise it is a risk that manufactured part has to be changed which lead to re-work. The quality can be further improved with simulation of tool function with every movement.

Always use and update Best Practices

1. Continual update Best Practices.
2. Create list of Best Practices with the purpose to facilitating searching for existing Best Practices.
3. Be faithful to Best Practices, i.e. always use Best Practice if it exists. Use concept projects for new inventions.

Gain control over the workload by rescheduling late changes and make clearer boundaries for closure

If an internal or external customer make late changes, hand it over to a resource planner that reschedule the projects. The purpose is to gain control over the workload in order to create a smooth flow of projects and assignments through the process. It is recommended to reschedule late changes in every sub-process.

Make clear when tool approval should be signed, for example after a specified number of plates have been manufactured. This will reduces the risk for unplanned jobs that disturbs ongoing projects and the project manager does not have to spend time on getting the tool approval signed.

Communicate risks for delays in an early state

Escalate problems to the tool project manager and the tool project manger escalates them to the department manager or senior manager.

Reduce hand-overs in the ordering process

One way to reduce hand-overs in the ordering process is to order manufacturing during the drawing review meeting. That would reduce hand-overs since both the tool project manager and team leaders are attending the meeting.

The recommendations mentioned above handles the root-causes to waste in the existing process. It is important to focus on solving the root-causes to problems, but some actions for just avoiding disturbances can be made. By closing the door and calendar and turn off cell phones when designing might help to reduce unnecessary disturbances.

Minimize the number of meetings and make them as efficient as possible. Also, if possible, move meetings so that they come after each other, in that way is not the day split up.

Run projects sequentially instead of parallel will reduce number of meetings with other projects and unplanned jobs.

The last recommendation for avoiding disturbances is to education in computer systems. That will give more employees the right to check out drawings and models will reduce dependency on other persons.

The suggested checklists are presented below:

| <i>Checklist 4 - 3D modeling</i> | | |
|---|-------------------|--------------|
| Information | OK/ Not OK | Notes |
| 3D-model verified and approved | | |
| Price updated | | |
| Time plan updated | | |

| <i>Checklist 5 - Verification of drawings</i> | | |
|--|-------------------|--------------|
| Information | OK/ Not OK | Notes |
| Drawings verified by project team | | |
| Price and time plan verified by project team | | |

The to-be design and order process:

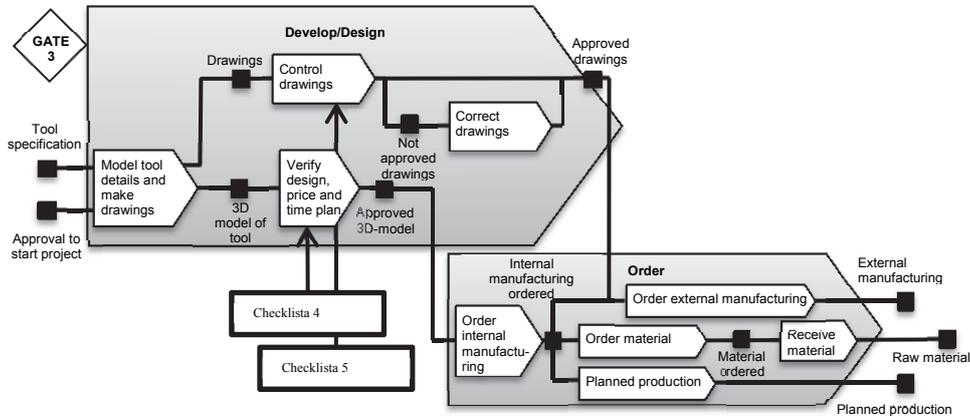


Figure 42. To-Be Design and Order Process

These changes are estimated to reduce the lead-time with:

| Measure | Today [h] | Goal [h] | Potential gain [%] |
|----------------------|-----------|----------|--------------------|
| Activity lead-time | 202-790 | 206-614 | (-)-23 |
| Process waiting time | 41-1088 | 0 | ∞ |

The minimum activity lead-time increases due to the changes but the extra hours aims to reduce quality deficiencies and hence disturbances in the future.

6.1.5 Manufacturing Process

The case study showed that the manufacturing speed slows down in the end of the project. The project report shows that the activities made in the end are mostly bench work, assembly and test pressing. The result of this analysis shows that improvement of the efficiency in the workshop should focus on easing assembly, bench work and test pressing.

Identified problems in the manufacturing process are:

- **65% utilization rate of machines:** According to the analysis, there is potential to utilize the machines more. It must be considered that *higher utilization* of machines *causes lower flexibility* in the production.
- **Assembly, bench work and test pressing are bottlenecks.**

The identified root-cause is:

Planning and quality deficiencies: Quality deficiencies up-stream in the process reviles during manufacturing and assembly. The up-stream deviations lead to re-work in the production. Deficiencies in the planning lead to more setup time and low utilization of machines.

The as-is process is presented below:

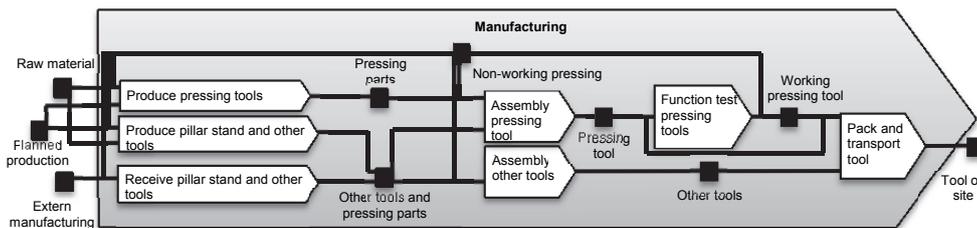


Figure 43. Current Manufacturing Process.

Recommended actions in order to improve the manufacturing process are presented below:

Mark where pneumatics can be drawn on drawings

Marking areas to draw pneumatics on drawings will reduce thinking time for the toolmaker when he assembles the tool. To draw pneumatics will take some extra time but it is estimated to be worthwhile it since it facilitate assembly, which has been identified to be a bottle-neck in the production. The action will also reduce disturbances for tool designer because toolmaker does not have to ask questions about the pneumatics.

Hire someone to help out with simpler tasks like packing, order standard components, etc.

This recommendation was suggested by tool makers. The toolmaker will have more time to work on tasks for which he is most qualified for. The tool makers have also suggested that personal cell phones and e-mail would facilitate communication.

Minimize movement in workshop with a new gateway

Analysis shows that a new gateway will reduce movement of gasket heat exchangers from 4.5 min/tool to 2.82 min/tool. Movement for brazed heat exchangers will be reduced from 9,258 min/tool to 6.0225 min/tool.

Distinct, standardized prioritizing between projects

Today OD-FTT prioritize project according to the FIFO principal. Today the department is not authorized to do any other prioritizing. During the workshop prioritizing was discussed and result was:

- FIFO – First in first out, is and must remain to be the main principal for prioritizing. The FIFO-principal is constantly challenged by urgent and unplanned job, and also by loops in DPT projects. It was suggested that projects that are not delayed will be prioritized, but OD-FTT is not authorized to do this kind of prioritizing.

Whether FIFO is the optimal method for prioritizing project have not been studied in this master thesis but it is recommend to do further studies in this area.

Other recommendations for making the manufacturing process more efficient are:

- Order packing material beforehand so no waiting for packing material occurs.
- Update checklists for this process as well.
- Visualize project plans on process map.
- Be faithful to Best Practice in manufacturing as well as in designing. That will secure that the optimal manufacturing methods are used.
- Discovers errors before the components are needed by implementing quality control of incoming components.
- Use 3D-models with only essential tolerances.

If current capacity is not enough after changes – implement two shifts

If the current capacity is not enough to meet the current demand after the other recommendation has been implemented it is recommended to start with two shifts in the workshop. Two shifts will increase through put time for assembly and bench work. It would also increase the utilization of the machines.

These changes will not change the current process. The goal with the improvements is to keep up the same manufacturing speed throughout the projects. That gives the lead-time reduction presented in the table below:

| Measure | Today [h] | Goal [h] | Potential gain [%] |
|-----------------------------|------------------|-----------------|---------------------------|
| Activity lead-time | 907 | 371 | 59 |
| Process waiting time | ? | 0 | ∞ |

6.1.6 Setup Process

Identified problems during setup are:

- Missing sheets
- Electricity does not work
- Disturbances in peripheral equipment

Identified root-cause:

Poor communication with production site and planning of the setup.

The current setup process is defined below:

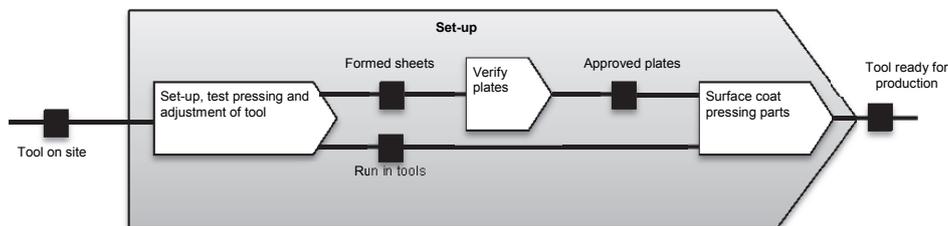


Figure 44. Current Set-Up Process.

Involve personnel concerned by the test pressing early in the process. One can also put higher demand on production to prepare for test pressing and to control that sheets are not missing. The to-be process map the same as the as-is process map.

Recommended actions for facilitating set-up are:

Test the functionality (electrical, pneumatics, hydraulic, transfer movements etc) of the tool before delivery in order to make the setup on site more efficient.

Specify in the tool specification what, how much and when setup will take place and who will do what in order to engage all setup participants in time.

6.1.1 Follow-Up Process

A follow-up process is defined in the existing process map, but the main problem with the follow-up process is that it is often skipped. The point of having a follow-up process is to improve the existing process and to improve the process for coming projects. By spending extra time on follow-up, the future process will be more efficient.

The identified problems with the follow-up process are:

- **Not defined when tool approval will be signed:** Tool project managers might have to spend time on getting the tool approval signed, which is wasteful.
- **Customers add requests at the end of the project:** Customers sometimes requests improvements of the delivered tool. The problem is that time for improvements is not planned for and other projects can be delayed as a consequence.

The identified root-cause is:

Communication: Boundaries for when to closure projects are diffuse.

The follow-up process is often skipped.

To start follow-out the follow-up process is essential for success. It is important to make follow-up in order to improve and up-date the process after each project. A new improved follow-up process has been designed and some recommendations for improving communication and clarify project guidelines are presented below.

Make guidelines for what is acceptable to add to a project

Be clear about what is a part of the project. Improvements of an ordered tool should be ordered as new projects. It is recommended that the tool specification is complemented with an “improvement after delivery” section as a way to clarify boundaries in the closure phase.

Closing meeting with modifications, updating of drawings/best practice/process

A 2-hour long meeting is sufficient. The meeting should be a part of the follow-up process. The process participants believe that this would save up to ten days for the next project. Alfa Laval’s general project form PROMAL has a template for “Project review meetings” that can be used.

The follow-up process is designed on basis of the existing process. The main difference is that the customer should attend the project review meeting.

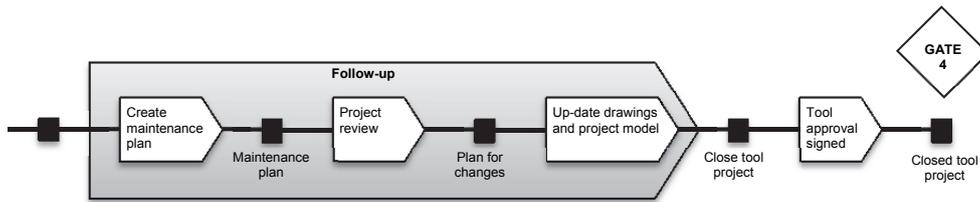


Figure 45. Current Follow-Up Process.

When implementing the new process it is important to reserve time for a closure phase already when planning the project. It is also recommended to wait with starting the closure phase until a pre-defined date after the running-in period. The project can then be put on-hold at OD-FTT during the running-in period.

No new checklists for the follow-up process have been made in this master thesis, but it is still recommended that the department creates a checklist for the follow-up process.

The changes in the set-up and follow-up process will increase the lead-time with:

| Measure | Today [h] | Goal [h] | Potential gain [%] |
|----------------------|-----------|----------|--------------------|
| Activity lead-time | 160-280 | 162-302 | (-1)-(-8) |
| Process waiting time | 42-96 | 0 | ∞ |

Processes reflect customers' need, which are dynamic and so are processes dynamic. The purpose of the follow-up process is to constantly improve and adjust the existing DPT process for the future. The increased lead-time for performing the follow-up process is therefore justified, since it will help to improve the future process and avoid waste.

6.2 Recommended Actions

Since most waste is in waiting time, it is crucial to act to reduce waiting time. Waiting time mainly consist of disturbances. Root-causes to disturbances are:

1. Information flow deficiencies
2. Planning deficiencies
3. Quality deficiencies

6.2.1 Actions for Improving Information Flow

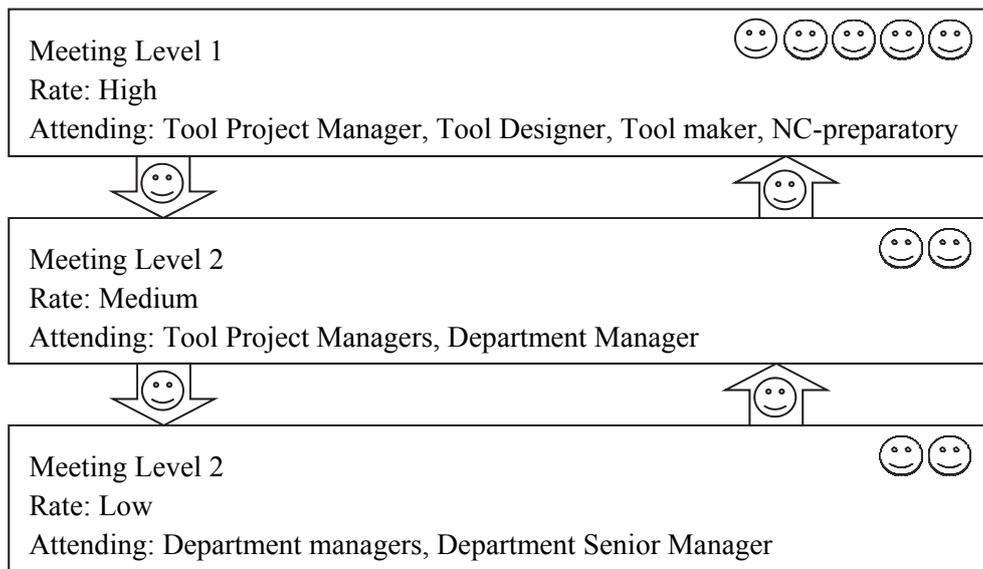
1. Improve the meeting structure

In order to improve the information flow, the department can improve their meeting structure. It is recommended to have meetings on different levels with different frequency. Three levels are recommended:

Level 1: Meeting with the process team. These are held with the shortest interval. If the problems cannot be solved on the base level, the process team leader escalates them up to the next level.

Level 2: The next level can be a meeting with the process manager. If the problems cannot be solved on this level, the process manager escalates them to the next level.

Level 3: The third level is a meeting with the process owner. If the problems cannot be solved, the process owner escalates them up to the next level.



2. Work in process teams

In order to improve interaction between product development and production, project teams are recommended to be defined as early as possible in the process.

Information flow will probably be improved, since communication can be made on team level instead of manager level. Teams are recommended to work together throughout the process. In the meeting structure, it is important to have regular level 1 meetings with the process team.

A process team is recommended to consist of the following members:

- 1 Designer/Team leader (corresponding to a tool project manager)
- 1 Designer
- 2 Toolmakers
- 1 NC-preparatory

The tool designers and the toolmakers work with the project in pairs. It is recommended that one toolmaker have more and one toolmaker have less experience. This way, the working relationship becomes educational as well.

It is important to have good communication within the team. For example, everyday process team meetings are effective. If they cannot be held, the process team leader should at least have everyday check-up meetings with the team members. The team manager should also have regularly check-up meetings with every process team leader to know how the projects are progressing.

3. Implement checklists

Checklists can be used to secure the information flow within the department. The purpose of the checklist is to support the process participants in their everyday work. The checklist also helps document the project. It can also be used as level 1 meeting protocols.

6.2.2 Actions for Improved Planning

1. Plan every project through the resource planning process

All distribution of work should be made through one planning point, e.g. the process manager, optionally two planning points, one planning point for human resources and one for machines resources. Although this solution requires that there is always one operator free that can operate the machine. The planning point should balance the workload by planning the projects with an offset.

The production planning can be improved with simpler planning systems and by educating production planners in both production planning and the computer system.

2. Separate resources between MPT and DPT process

The planning will be more accurate if special resources are assigned to maintenance work and also if different teams (maintenance and new project teams) are pre-defined.

3. Visualizing the process and how ongoing projects progress in the process map

Information about the projects progress through the process is recommended to be visualized on the process map. The process map is preferably posted in the same room where the regularly process team meetings are held. The project progress can be documented by taking pictures of the process map. It will also be easier to understand if and how schedules are followed with a visualized process.

4. More distinctive boundaries for closure

Having more distinctive boundaries for closure that also has been pre-defined earlier in the process will also facilitate planning since it will be easier to predict when the project will close.

6.2.3 Actions for Improved Quality

1. Always have Design Review Meetings, Manufacturing Adjustment Meetings and Drawing Review Meetings

These meetings aim to increase the quality of the drawings. As stated in the illustration of the ongoing interaction between customer/market, product development and production¹¹⁴, it is important to work in a way so that you constantly get feedback from other departments. These meeting will support such a way of working.

By having these meetings toolmakers become more involved in the project in an early state and hopefully questions can be effectively addressed early in the process - a positive side effect.

2. Do not start manufacturing until the drawings are finished

Design errors are easier to see when the total design is finished. The risk for re-work is therefore reduced if manufacturing do not start before the total design is finished. If one chooses to start manufacturing before the design is finished, the risks for re-work and how those risks can affect every other project in the process should be carefully taken into consideration as part of a cost-benefit analysis.

¹¹⁴ Ståhl [24]

6.2.4 Actions for Improved Efficiency in the Workshop

1. Improve planning and prioritizing

This is an area that is interesting both from a company and research point of view. The situation at OD-FTT is complex since many projects are prioritized on a higher level, which makes it harder to plan and prioritize in order to promote efficient production.

2. Facilitate assembly

Assembly is facilitated if it is marked in drawings where pneumatics can be drawn. Regular meetings with the process team during through the development process will help tool makers to understand the thinking and rationale of the design earlier in the process.

3. Introduce two work shifts in order to increase utilization of machines and increase assembly rate

By improving quality, planning and communication deviations and disturbances are reduced as well as loops of malfunctioning tool. In the best case are enough resources released so that the current workshop capacity is enough to meet the future demand. Otherwise it might be needed to introduce a second shift. Since assembly is a bottle-neck, more machines might not be enough to increase capacity. A postulate for introducing one more shift is to have enough with personnel; resources are a limitation for such solution. One possibility is to only have 2 shifts when there is a great need to reduce lead time for a specific project. But other projects/jobs will suffer since the workforce will be reduced during the regular shift.

6.2.5 Implementing the To-Be Process

This empirical study showed that no standardized process was followed for DPT projects. During the study a to-be process map was developed, still the greatest challenge remains: to implement the new process. The process map must first be communicated. It is recommended that the process map is posted in the corridors and in the process team's meeting rooms. Subsequently stakeholders should be informed about where the process map is posted. The goal is that everyone should know the design of the process, why it looks like it does, and who does what in the process. When the map is available, the next step is to use the map.

OD-FTT has many tools to pursue improvement such as deviation reports and product portfolio board meetings, etc., but is challenged to improve their improvement and process culture.

The to-be process is not very different from the as-is process. The greatest change that must be made is to effectively use the existing tools available. The process owner, process manager, process leader and process team must all be committed to following and improving the process as well as being actively involved in the culture accompanying a process-orientated organization.

7 Discussion

This chapter will consider how well the results met the objectives and the possibilities to generalize the results. Ideas for further studies are presented and finally some personal reflections about the study and its results are discussed.

The predefined objectives of the project were to:

- Propose changes in order to create a more efficient value flow in the current process
- Identify value and waste of different types in the current process
- Make improvements in the form of templates, routines, systems, and checklists
- Study the interaction between customer/market, product development/design and production

The results showed that templates, routines, systems and checklists exist but are not updated or always used. A well designed process also exists but is not always followed. The possibility to deviate from the standardized processes contributes to a very flexible department, which is a great strength and very advantageously for producing customized solutions. Identified areas that can be improved are:

- Quality
- Organization
 - Project/process teams
 - Production flow
- Planning
- Timing/Involvement/Communication

Some of the suggested improvements might though reduce flexibility. Flexibility and standardization has to be weight towards each other, as well as prioritizing between DPT projects and maintenance.

A deeper understanding of the as-is process was gained through interviews with the process participants at Alfa Laval. The interviews provide a true picture about how the process participants experience the current process. Interviews also revealed deviations from the process map. Data gathered from the interviews are however subjective. Moreover, the participants' answers could potentially have been tailored to influence the preferred results. In addition, the experienced time for executing a task might not correspond to the actual time spent on a given task.

The estimated activity cycle times showed to be very useful in the value analysis since there showed to be a large difference in time between activities and waiting time. In the value analysis different activities were marked with green for value-adding, yellow for non-value adding, red for waste and grey triangles for representing waiting time. The analysis shows that most of the activities are classified as non-value adding activities. The distribution of time between value-adding, non-value-adding, waste and waiting time shows that most time is spent in a waiting state. The waiting time has been divided into internal and external categories. The external waiting time is when OD-FTT waits for information from other departments. This waiting time is not necessarily considered a waste because it is unknown what is happening to the project at other departments. The internal waiting time can on the other hand be classified as waste and should be eliminated or at least minimized whenever and wherever possible.

The project reports provide increased understanding of some of the main characteristics of the manufacturing process even if the exact time for each activity of the process could not be precisely identified. Furthermore, the study also provides concrete suggestions for improving the current process.

7.1 Further studies

This study concluded that the maintenance process should be separated from the development of the production tools process. Further studies regarding how to focus factories in addition to how to prioritize projects are recommended.

The importance of an ongoing interaction between customer/market, product development and production has been pointed out in this study. It would be worthwhile to also study the actual effects of increased interaction after implementation.

7.2 Personal reflections

This study has showed that tools like templates, routines, systems, checklists and process maps are not enough to create changes. Even when tools for improvement exist in a mature business, it is nonetheless imperative that communication, planning and quality are key and ongoing focal points in order to achieve process excellence.

8 References

- [1] Ståhl, J.-E. *Industriella tillverkningssystem del II – Länken mellan teknik och ekonomi*, Lund 2009.
- [2] Ljungberg, A; Larsson, E. *Processbaserad verksamhetsutveckling*, Lund 2001.
- [3] Bergman.B.;Klefsjö.B, *Kvalitet från behov till användning*, Lund 2007.
- [4] Hill, A&Hill, T. *Manufacturing operation strategy*, Palgrave Macmillan (STAD) 2009
- [5] Nahmias,S. *Production and Operation Analysis*. McGraw-Hill Companies.6.New York 2009.
- [6] Becker.J;Kugeler.M;Rosemann.M. *Process Management A Guide for the Design of Business Processes*. Berlin 2003.
- [7] Höst,M;Regnell,B;Runeson,P.*Att genomföra ett examensarbete*, Lund 2006.
- [8] Ackoff, R. *Vetenskaplig metodik*, Stockholm 1972.
- [9] Wilkinson,D; Brimingham,P. *Using Research Instruments*
- [10] Hines, P; Rich, N; Esain, A. *Value stream mapping: A distribution industry application*, Benchmarking: An International Journal, Vol. 6 Iss: 1 pp. 60 – 77, 1999
- [11] S.Gazdziak. *Measuring operations through OEE*. National Provisioner, 224(3), p28-31, 2010
- [12] P.J, Keller; J.M, Jacka. *Process mapping*, Internal Auditor; Vol. 56 Issue 5, p60-64, 1999
- [13] Ekman,D; Jacobsson,D. *Production development with TESSPA – applied on gearwheel manufacturing*, Lund 2007
- [14] Chen, D. *Information management for the factory planning process*. Lic.-avh. The royal institute of Technology, Stockholm 2009.
- [15] Alfa Laval. United States. Key Technologies, received 2012-04-05, <http://local.alfalaval.com/en-us/key-technologies/pages/default.aspx>
- [16] Alfa Laval. United States. About us, received 2012-04-05, <http://local.alfalaval.com/en-us/about-us/pages/default.aspx>
- [17] Alfa Laval. Sweden. Om oss, received 2012-04-05, <http://local.alfalaval.com/sv-se/about-us/kvalitet/pages/default.aspx>
- [18] Alfa Laval. Internal. Organization, received 2012-04-05, <http://share.alfalaval.org/organizations/operationsdevelopmentformingandtooltechnology/Pages/default.aspx>

- [19] Alfa Laval. Internal. How we work, received 2012-04-05, <http://share.alfalaval.org/processes/howwework/Pages/default.aspx>
- [20] Alfa Laval. Internal. NPD Project Manual, 2010.
- [21] A.Ljungberg, Lecture at Lund University Faculty of Engineering, 2011.
- [22] Hines,P; Rich,N. *The seven value stream mapping tools*. International Journal of Operations & Production Management, Vol. 17, Issue 1, p. 46 – 64, 1997
- [23] Alfa Laval. Internal, 2011.
- [24] Ståhl, J.-E. *Industriella tillverkningssystem del II – Länken mellan teknik och ekonomi*, Lund 2012.
- [25] Alfa Laval. Internal. Tool specification template.
- [26] Alfa Laval. Internal. Deviation report 12-02-10. 2012
- [27] Alfa Laval. Internal. Project report, order 2251. 2010
- [28] Jeffrey K. Liker, *The Toyota Way Lean för världsklass*, Malmö 2009
- [29] Berglund, F. Supervisor Alfa Laval. Communication
- [30] Hagberg,L; Henriksson,T. Lecture, *Underhåll i världsklass*. OEE Consultants AB. Lund Univesity Faculty of Engineering. 2011
- [31] Sthål, J-E. Supervisor Lund University Faculty of Engineering. Communication

8.1 Interviews

- 4 Project Manager/Designer OD-FTT
- 2 Team Leader OD-FTT
- 1 Designer OD-FTT

Appendix 1

Interview Guide

The interview purpose is to gain knowledge about process flow, waiting, activity cycle time and also pick up problem areas.

1. How, when and by whom do you find out that a project are about to start?
2. What do you do first?
3. How long time? What do you based the estimation of time on?
4. Do you do anything before?
5. How long time? What do you based the estimation of time on?
6. Can the activity be divided into sub-activities?
7. What do you do when you have finished the activity?
8. To whom do you hand-over?
9. What is the next activity?
10. Is there a clear relation between the activities? (Is object in object out to the next activity?)
11. Does all project start with this activity? Is it at any time skipped?
12. If yes, why?
13. Does the activity name describe the purpose of the activity? Does the name describe how value is created?
14. How does the activity create value for? Is the activity necessary for coming activities?
15. Do you know how the customer is?
16. What do you think would have happened if the activity is skipped?
17. Does documentary exists for how to pursue the activity?
18. If yes, do you follow these instructions?
19. If no, do you think you would have followed the instruction of the existed?

