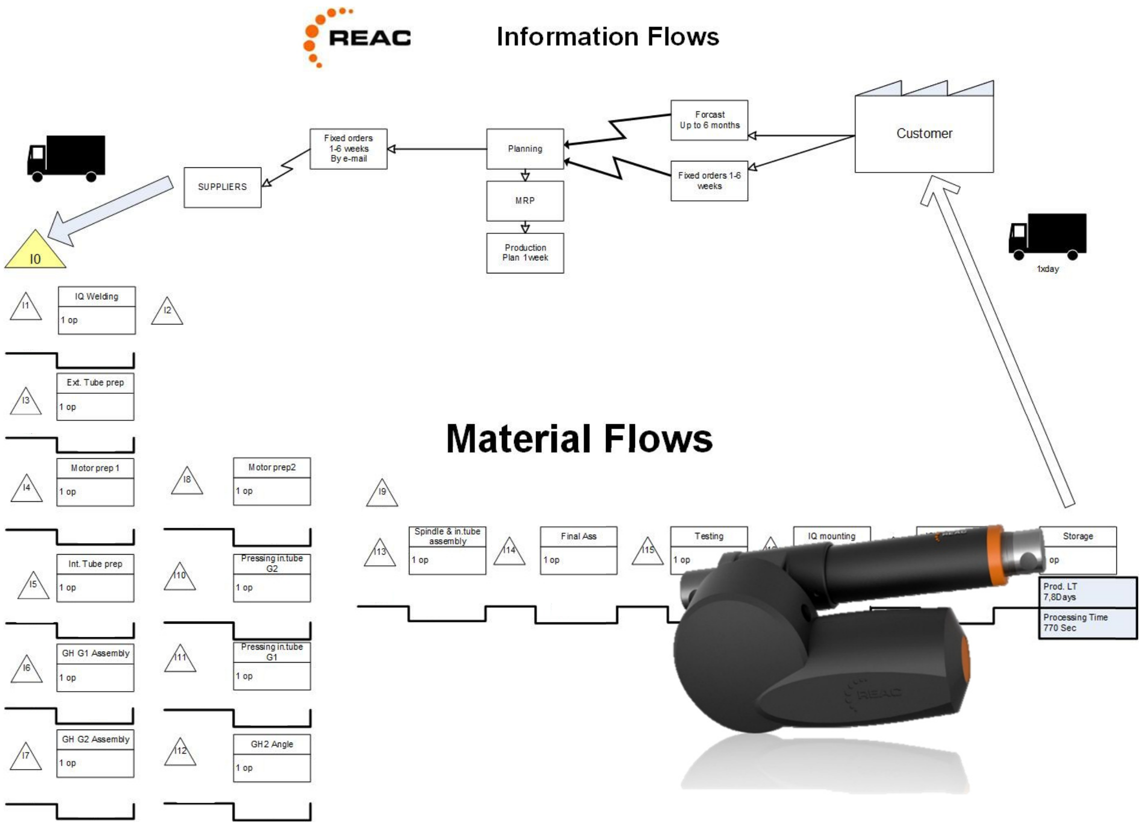

Analyse and increase production through Value Stream Mapping

A case-study in REACs production plant in Åmål

Master of Science Thesis in Production Engineering

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Gothenburg, Sweden 2015

Analyse and increase production through Value Stream Mapping
- A case-study in REACs production plant in Åmål

Karl-Robin Grönberg, 2015

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Cover:
An example of Value Stream Mapping and an RE25 Actuator

Department Product and Production Development
Göteborg, Sweden June 2015

Abstract

REAC is a motion solution system provider of different electrical actuators, hoists and other innovative electro-mechanical motion, which is owned by Latour Industries. Their aim is to offer their clients an excellent service, backed up by experience in the application of advanced motion components. Their production is located in Åmål and consists of four production lines were RE25 is the one that will be investigated.

Due to more and more variants, more workstations have been included in the current facility. This also means that more material handling has to be carried out in less available space. The addition of variants has caused a high production mix with a lot of crossing production flows and difficult to balance the flow. Currently the solution used is several small storage points in between the work stations, this consumes even more floor space and binds a lot of capital in work in progress.

This thesis work scientifically analyses the production system by conducting a SAM analysis to use as basic data for a Value Stream Mapping. Workshops are conducted to utilize in-house knowledge and to generate new ideas. Based on this analysis improvement suggestions are developed that considers the context and finds a good trade-off between lead time, flexibility, and area utilization.

This thesis work proposes a new production layout focusing on shorter lead times while maintaining high flexibility and staying within current shop floor area constraints. Furthermore, a production planning strategy for products in the RE25 product line, based on the proposed new production layout, is presented.

Before the Value Stream Mapping the Production Lead time was 7,8 days and the Process time was 770 sec. In the future scenario the Production Lead time is calculated to be 2,8 days and the Process time 440 sec. Estimates for the savings in production of high volume goods based on the new layout is a reduction of the lead time with 65% and reduction of process time with 43%.

The Future State, which represents an ideal state in a future production, includes a change in both production layout and production planning. The layout proposal achieves straighter production flow, which makes it possible to have a one piece flow when it is more suited for the production, where standard parts go in and out from a “Supermarket”. The supermarket acts as a warehouse in the production line that holds the parts used in the most common products. With the layout change and the Supermarket comes a change in the Production Planning, this change strives to produce standard part towards forecast while low volume products will be produced towards order.

Acknowledgements

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Last but not least, Captain Hindsight for all his valuable information and input sadly he was always too late.

Karl-Robin Grönberg, Sweden June 2015

Table of contents

1. Introduction

In this chapter the background, regarding REAC, the problem definition, where a problem in their production system will be described, and the purpose for this master thesis will be introduced.

1.1 Background

REAC is a motion solution system provider of different electrical actuators, hoists and other innovative electro-mechanical motion, which is owned by Latour Industries. Their aim is to offer their clients an excellent service, backed up by experience in the application of advanced motion components.

Since REAC started their production they gained more and more customers and because their business model have been to always correct themselves after customer demands they also increased their number of variants.

Nowadays most are familiar with Lean thinking, from the Toyota Way. Lean is most often associated with different ways to eliminate muda (waste or non-value adding actions). Instead of only looking and identifying muda a tool called Value Stream Mapping (VSM) or Material and Information Flow Mapping will be used. Value Stream Mapping is a tool that helps visualize and understand the flow of material and information as the product makes its way through the production line. In the pre-study/data collection phase VSM is a manual tool to collect data, where the data later on will be digital analysed and optimized depending on different future scenarios.

1.2 Problem definition

Due to more and more variants, more workstations have been included in the current facility. This also means that more material handling has to be carried out in less available space.

The addition of variants has caused a high production mix with a lot of crossing production flows and difficult to balance the flow. Currently the solution used is several small storage points in between the work stations, this consumes even more floor space and binds a lot of capital in work in progress.

There are tentative plans for re-locating to a new facility. REAC considers this as a chance to implement a new shop floor layout that is better suited for the current product mix. Even without the re-location there is a need to adapt the shop floor layout in the current facility to improve the production operations.

1.3 Purpose

The purpose of this master thesis is to:

- Scientifically analyse the production by conducting a SAM analysis to use as basic data for a Value Stream Mapping.

- Develop improvement suggestions based on the analysis that considers the context described in problem definition and find a good trade-off between lead time, flexibility, and area utilization.

1.4 Goals and deliverables

Based on scientific analysis of the current production value flow of actuators at REAC this thesis work will propose:

- A new production layout focusing on shorter lead times while maintaining high flexibility and staying within current shop floor area constraints.
- A production planning strategy for products in the RE25 product line, based on the proposed new production layout.

1.5 Delimitations

Only RE25 product line – Reac's plant in Åmål consist of four production lines and according to the companies needs it is the RE25 line that is in focus. Therefore it will now represent the product family.

Shop floor level – this thesis investigates the operations of the company from a shop floor and production flow perspective. Therefore R&D and Sales operation activities are excluded from the study (Sales volumes are considered).

Product design is not considered in this study, although some thoughts regarding the product design's implications in the production system can be found in the discussion.

1.6 Thesis outline

The thesis starts with the theoretical frameworks which are supposed to aid the reader to better understand the different topics that are included in this master thesis. Then follows the method chapter which aims to give readers an understanding about how the project research is performed. This includes a description of the research study and the data collection as well as how the study was performed. The Case Study was conducted on Reac's producion site in Åmål, the result from the case study will be presented in the results chapter. First the Current State Map and the Future State Map will be presented, then the results will show how the Future State evolved and how it's motivated by above mentioned tools. Finally the Discussion and Conclusions chapter will include a brief résumé of the result followed by some discussion regarding good and bad decisions and their impact on the result

1.7 Glossary

List of abbreviations and technical terms

FIFO	First In First Out
Kanban	A method for managing to schedule work in production
KPI	Key Performance Indicator
MTM	Methods-Time Measurement
Pitch	The pitch describes the rise for each revolution
SAM	A method to analyse Sequence based Activity Measurement
Spaghetti Diagram	A line diagram that shoves the flow of a product
Stroke	The length of the piston that moves in and out by the motor on the actuator
VSM	Value Stream Mapping, a tool to map Material and Information flow through the Value chain

2. Theoretical framework

The theoretical frameworks are supposed to aid the reader to better understand the different topics that are included in this master thesis.

2.1 Production systems

Production systems or also often referred to as Toyota Production systems (TPS) and maybe even more known as Lean manufacturing, describes how a product is produced from raw material to a finished product in the hand of a costumer. All since 1990, when Womac Jones and Roos wrote about Lean in *The Machine That Changed the World,* it has been every production manager goal to implement the Lean foundations into their own production.
Even though Toyota have been very open and helpful regarding their production system most of the attempts to fully understand it have failed. When companies tries to implement the new tools they often use it on separate stations and forgets to see the company as one system.
One thing that is well known in every company is that the more unnecessary or waste work that is done to a product gets ten times more expensive to correct for each step in the value chain.

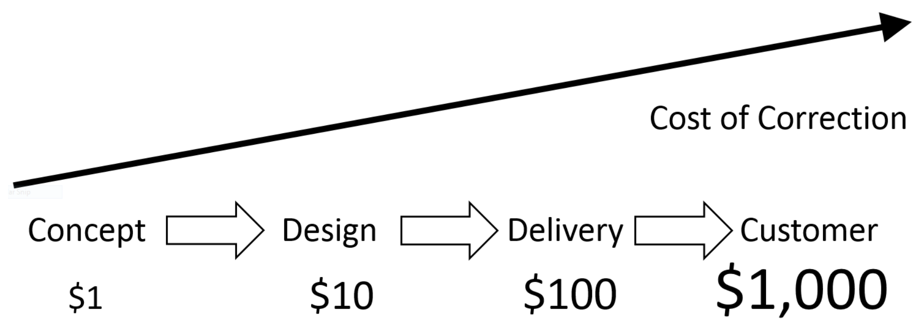


Figure 1 Increasing cost of error correction in value chains (P Marksberry, 2012)

2.2 MTM Method-Time Measurement

MTM is a shortening of Method-Time Measurement and it is defined by the time it takes to perform a specific task. It is used to describe work instructions, product design and to plan the production. Today it’s the most common standardized predetermined time system (Kuhlang, P. 2011).

2.3 VSM Value Stream Mapping

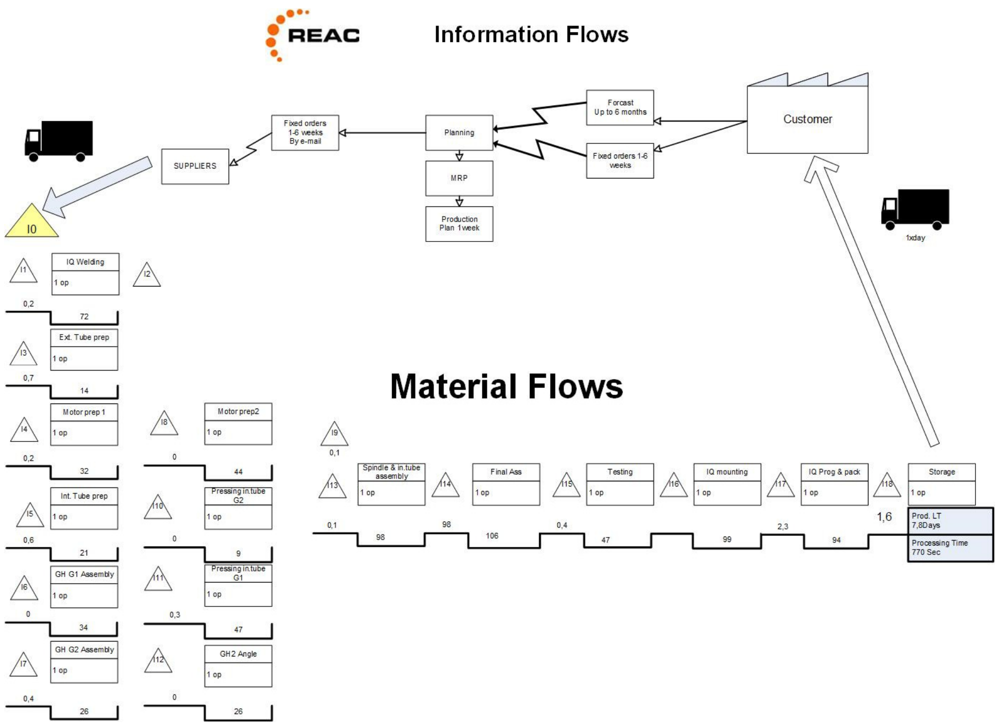


Figure 2 Current State Map VSM

2.3.1 What is Value Stream Mapping?

Value Stream Mapping (VSM) is a rather simple tool since most of the work is done by pen and paper. The true power with VSM is that it maps both the production flow and the information flow, it can there by distinguish the true value for the costumer. The mapping is done in three stages: identifying the value stream, draw the Current State Map and draw the Future State Map. To draw the Future State Map the information from the current state, future visions and goals and some simple lean tools are used such as Continues Flow, Kanban and Muda.

By mapping the so called value stream both value adding, non-value adding and activities, from raw material to delivered product to the costumer, are taken into consideration (Drew A. Locher, 2011).

2.3.2 Combining VSM and MTM

To find and design proper work methods will have a big influence on the productivity. To achieve this MTM can be a good approach, but this can often lead to the need of new investments because it most of the need a process change for ex. a new machine. One thing to strive for is high employee utilization, this however does not practically require new tools or machines. By using VSM is it possible to anticipate fluctuations in order-frequency and deliveries or any delay from suppliers. Trough production planning and flexible employee assignments is it then possible to adapt the work and gain a high utilization factor. They both complement each other so good because they make it possible to look at the production on three different dimensions, (Method/process design, Performance and utilization), which is shown in Table 1 (Kuhlang, 2011).

Table 1 Comparison between Value Stream Mapping and Method-Time-Measurements on different production levels

Method/process design	
"Single processes" (indiv. task-orientation) – MTM	**"Overall processes" (flow-orientation) – VSM**
Layout – workplace design (tools, fixtures, machines, etc.)	Process organisation/work organisation
Added value, complimentary work, waste	Production systems
Handling expenditures	Layout – workplace alignment layout (factory, floor, assembly line, cell, etc.)
Expenditures for controlling and supervision	Material flow
Ease of assembly/disassembly	
Ease of grasp/operability	
Manual material handling	
Information flow and control VSM + MTM	
Production planning and control	
Control principles	
Product design	
Design of information flow	
Performance	**Utilization**
MTM	**VSM + MTM**
Performance standards (performance rate, actual/target-time ratio, standard time, normal performance, etc.)	Net man-hours worked, total amount of hours available
Personal performance	Fluctuations in order-frequency and work content
Labour standards	Balancing (static, dynamic)
Training, routine	Work in progress/inventory
Motivation/disposition	Stock (amount)
Target orientation/monitoring	Idle times/breakdowns
Competences, skills, education	Scrap (quality of work)
Support/instructions, coaching	Set-up times/change over efficiency
	Maintenance
	Machine utilisation
	Material utilisation
	Area utilisatio

MTM is a good thing to use in all the phases of the VSM and especially when new or redefined work methods are being used, also in the line balancing and for ergonomic aspects.

2.3.3 Value stream in a product production planning

A value stream includes all activities from the order, of the product and raw material, to delivered goods such as operational processes, flow of material, steering activities and the information flow.

Material flow

To improve the production material handling is often one area that needs to be deeper investigated and because VSM is not only focusing on the processes it can be a suitable tool.

Since there are no general strategy on how to plan the material flow from supplier to end costumer is it important to choose critical key factors that suits the company. These factors can be flexibility, number of variant and/or inventory volume. Since these factors also is seen as none value adding for the customer it is considered waste.

Spaghetti diagram can be used to track necessary and non-necessary movement in house, which can give an indicator of waste connected to lay-out.

Information flow

In production it is not only the material flow that is important but also the information flow. Information flow describe what task to do next, what is included in the task and also who will perform the task. This does not only include the production but also the suppliers and the entire way through the chain to the costumer.

Value adding activities

An activity that increases the value of a product at a given stage in a production cycle or supply chain.

Table 2 Aspects of Value in different production related activities (Mc Manus, 2005)

Aspects of Value	
Definition of End Product with desired Functional Performance	The task affects the definition and/or functionality of the end product delivered to the customer. It contributes directly to either the function or the form that affects the function. For example, requirements specification, design decisions, material/part/subsystem specification, geometry specification, etc.
Definition of Processes to Deliver Product	The task directly affects the processes necessary to deliver the end product to the customer. It includes the design or procurement of the tools and processes necessary for manufacturing, testing, certification and/or other downstream processes, such as the creation of manufacturing and assembly procedures.
Forming Final Output	The task directly contributes to the final documentation given to the customer or manufacturer. This typically includes the documentation of the materials, parts, subsystems, and systems, and documentation to meet legal and contractual constraints.
Facilitating Communication	The task aids necessary communication. Typically includes reviews, meetings, and discussions with other company or industry personnel.
Meeting or Reducing Cost and/or Schedule	The task emphasizes maintaining or improving cost and/or schedule, e.g., many management and process improvement tasks.

None value adding activities

Which are defined by the seven different waste types in Lean manufacturing:

- **Overproduction**
  Completing products that are not needed for the moment and thereby take space and utilize personal.
  "Over-engineering", functions not needed for the costumer or it's more complicated than other existing versions.
- **Waiting**
  The gods are ready to be shipped but waiting for the last confirmation from either the system or a superior.
  Starved processes, waiting for work in progress or material from the process before in the stream.
- **Transportation**
  Digital information (e-mail)
  Paperwork waiting for signature
  Each time the product is moved it stands the chance of being lost, damaged or cause delay. Neither does transportation do any transformation on the end product.
- **Excess Inventory**
  This is related to WIP, work in progress, where all sorts of resources just "sits" idle this also includes machines and workers.
  Too much information on the product, if perhaps the products that the costumer did not wish for.
- **Defects**
  Human error which is hard to get rid of but the design can be better to try to minimize the chance of things going wrong.
  Bad design this can be connected to human errors but it can also just be a bad or out dated design.
  Information does not make sense for the user, because of a hard or bad user manual.
- **Excessive processing**
  Lack of standardization, there are a lot of similar products which could be formed after on and a same standard to make it easier or less resource demanding to produce.
  Lack of understanding of the users' needs so perhaps functions are missed or included which require rework.
  Poor output design, lack of understanding the processing capabilities
- **Excess Motion**
  This is not the same as transportation. It refers more to defects that will be inflicted on the process while processing the product. Such as wear over time and strain injuries because repetitive work.

(Hugh L, 2005)

2.3.4 The Current-State Map

- ***Identify main processes (in order):***

  The first thing to do is to decide how detailed the Current State Map is supposed to be, or how many boxes that should be included. Where should a box end and where should the next start. The most importing factor here is the time and especially the lead time. The goal is to be able to identify stations where the flow stops and the queues begin, it's preferable to make as detailed as possible. However it is not necessary to map every little stoppage just the important ones. So when is a stoppage important? It will be defined by the lead time. The same goes for mapping the processes. If there is more than one small stoppage or process in row they can be combined. (McManus, 2005)

- ***Follow the work:***

  Take a tour around the factory and try to follow the product flow up and down the value stream, to identify the true value stream. Try to understand where the information transforms the product to the costumer's description. If time gives the possibility is it even a good idea to try the different work steps. But it will probably be easier and faster to follow an existing part. (McManus, 2005)

- ***Collect the information yourself:***

  If time and possibility is given try to talk to the different participants and try to include them as much as possible in your work. If it is not possible to do in person even try by phone and by mail. Always try to get the tasks described rather than document them. If there exists any standardized forms to get the information needed can it be good to use them as help. (McManus, 2005)

- ***Exploit existing process information resources, cautiously:***

  It is important to get good understanding for the process and it is easiest to do this by collecting data yourself. But this does not mean that you should disregard information that other people already have collected.

- ***Map "in pencil"***

  Rother &Shook's uses an 11x17 inch sheet as a templet but everything that works best for the user should be preferred. But a standard A3 paper works just fine. Resist the temptation of using a computer for the drawing phase. (Rother M, 1999)

- ***Map the whole value stream:***

  For the start have the whole team map the entire value stream together instead of divide it. The goal is to make everyone see the overall picture.

2.3.5 The Future-State Map

The purpose of the Future State is to eliminate waste in all steps along the value chain. Then the goal is to create a production with either continues or a pull flow. This can be achieved by the help of these seven guideline questions:

(Lochter, 2011)

- *What does the customer really need?*

  This question describes the purpose of the whole Value Stream Mapping and there cannot be an existing Future State where the costumer's needs are not taken under consideration. This could be answered by asking the question: "What service level does the costumer need?" where service level includes lead time, quality and cost. Where in most cases price is the biggest factor. It is therefore important to include a cost model in the Future State Map.

- *How often will we check our performance to customer needs?*

  How often a company update this is often referred to as pitch. This is a question directed towards the design and sails personal, but that's doesn't mean that they are the only one that have to come up with new ideas. One way to utilize knowledge within the company is to have a short session once a week, where you just freely ask if anyone have any improvement ideas. Then you also need to have in mind that even bad ideas can generate good once further on.

- *Which steps create value and which steps create waste?*

  This question is directly connected to the seven types of muda in Lean production, which are being described in 2.3.3 Value stream in a product production planning.
  The waste should easily be recognized from the Current State Map.
  What creates value in a product is harder to pinpoint but there are some definitions that have been proposed by academics and industry experts, which are shown in table 3

Table 3 Definitions of value from Chase 2011

Source	Value Definition
Miles, 1961	**Value is the appropriate performance and cost.**
Kaufman, 1985	**Value is function divided by cost.**
Shillito&DeMarle, 1992	**Value is the potential energy function representing the desire between people and products.**
Womack & Jones, 1996	**Value is a capability provided to a customer at the right time at an appropriate price, as defined in each case by the customer.**

Slack, 1998	**Value is a measurement of the worth of a specific product or service by a customer and is a function of: (1) Product's usefulness in satisfying customer needs (2) The relative importance of the need being satisfied (3) Availability of the product relative to when it is needed (4) Cost of ownership to the customer**
LAI, 1998	**Value is anything that directly contributes to the "form, fit, or function" of the build-to package or the buy-to Package · Form: Information must be in concrete format, explicitly stored · Fit: Information must be (seamlessly) useful to downstream processes · Function: Information must satisfy end-user and downstream process needs with an Acceptable probability of working (risk)**
Browning, 1998	**[Value is] balancing performance, cost, and schedule appropriately through planning and control.**
Deyst, 2001	**Value is the amount by which risk is reduced per resource expended.**
Stanke, 2001	**[Value is] a system introduced at the right time and right price which delivers best value in mission effectiveness, performance, affordability and sustainability and retains these advantages throughout its life.**

- *Will you build to a finished goods Supermarket or directly to shipping?*

This depends on a lot of different factors, such as reliability of the process and customers buying pattern. For example, if the demand does not fluctuate and the forecast is correct there is no need to use a Supermarket. On the other hand, if there is a high level of mixed products it can be better to find an optimal batch size and build to a middle inventory, called a Supermarket.

- *How do we control work between interruptions, and how will work be triggered and prioritized?*

It is often possible to identify spots in the value chain where continues flow is not possible, maybe because:

- o Some processes are designed to work on a fast or slow cycle and have long changeover time
- o Some processes have long delivery time when you or material
- o Some processes are very unreliable, regarding break down

(Rother M, 1999)

To manage the queues that will occur is it possible to implement one of three basic production pull system:

- o Supermarket Pull Systems, where an amount of each material is stored.

- Sequential Pull Systems (FIFO) where products are made-to-order. Such systems are used when there are too many part numbers to hold inventory of each in a Supermarket.
- Mixed Systems, which use a combination of the first two

The implementation the Supermarket is by far the most time and resource consuming and even not always the most suited choice. Which one to choose depends on how much work or resources that is required to achieve the goal, the answer to this can be motivated by: as little as possible as long as the demand and the lead time is met.
(Locher,2011)

- *How will we level the workload and/or different activities?*

There are many different factors that can influent the workload, such as economy, season and break downs. Some companies attend to yearly exhibitions and must maybe the plan to have new models to show, while others like clothes companies have new seasonal cloth collection.
Because of this some of the methods only work parts of the year.
The mix development can take many forms mostly because most it varies from company to company.
"To summarize, a robust development system can be designed with particular features to meet unique needs, if these needs are identified and discussed as part of the Future State design."(Locher,2011)

- *What process improvements will be necessary?*

There will probably already come up ideas while discussing the previous questions, these should be marked on the Future State Map, however some improvements may have been overseen. A lot of ideas are good during brainstorming but remember that it's not quantity that's important but quality.

2.3.6 Achieving the Future-State

Because of a lot of differences between companies is it almost impossible to find an implementation strategy that fits everyone, but there are some guidelines. The focus should be regarding waste that was found in the Current State Map. While reducing waste in the system a lot of recourses are freed up which can continue work on improvements during the Future State design.
It is also possible that the VSM team decides to postpone some project to make it easier to push the transition on some projects. When the waste has been reduced from the process focus once again turns to define and renew design and manufacturing standards. The easiest way is to use existing knowledge from key-personal. This design and work standards are easily documented trough checklist, templates and guidelines.
When the waste has been reduced in the organization the focus should turn to improving the flow. When this is achieved its time to continue improving the efficiency by trying to find new development tools and continues training programs. (Locher,2011)

2.4 Workshops

A workshop is a method where a group of people with the same or different pack ground and roles work together to achieve a specific outcome. There are three important purposes when conduction a workshop, *the facilitators*, *the participants* and *other interested parties*. To make it easier the purpose should be summarized in as few sentences as possible before the workshop.

The facilitator has to be clear about how the workshop will contribute to the goal and that there is a plan on how to design it to be most effective. If it's demanded from someone else is it important to discuss who will be present and where it will take place.
The participants need to be informed and clear of the purpose of the workshop so that they can prepare if needed.
As preparation the facilitator should try to be able to answer the following questions:

- Is there a good reason for each participant to attend the workshop?
- Do you know what you are expecting each participant to contribute?
- Do you know what you want the participants to go away with?
- Do you know what will happen to the information generated by the workshop?
- Will the participants be making any firm decisions during the workshop, and if so, how will these decisions be made?
- Do you know what the expected outcomes are? (Decisions, preferences, a list of key issues, suggestions for solutions to a problem, creative ideas?)
- Are you well-informed about the subject matter under discussion? (If not, address this before the workshop.)
- Are the participants well-informed about the subject matter under discussion? (If not, this could be addressed before or during the workshop.)
- Do you have the right technical equipment (eg for demonstrations)?
- Do you know how to handle actions arising during the workshop?

Other interested parties, such as higher up managers or external advisors, so that they don't feel like they get excluded from or that someone takes control over the project.
"The beauty of a facilitated workshop is that everyone is encouraged to contribute, everyone gets a feeling of involvement and there are real, demonstrable outcomes".
(Camerorn E, 2005)

3. Method

The method chapter aims to give readers an understanding about how the project research is performed. This includes a description of the research study and the data collection as well as how the study was performed.

3.1 Research Strategy and Design

"The research strategy is supposed to be a guideline for the researcher, to follow while trying to find the answers to the research question. The research can be divided in to Qualitative or Quantitative analysis"

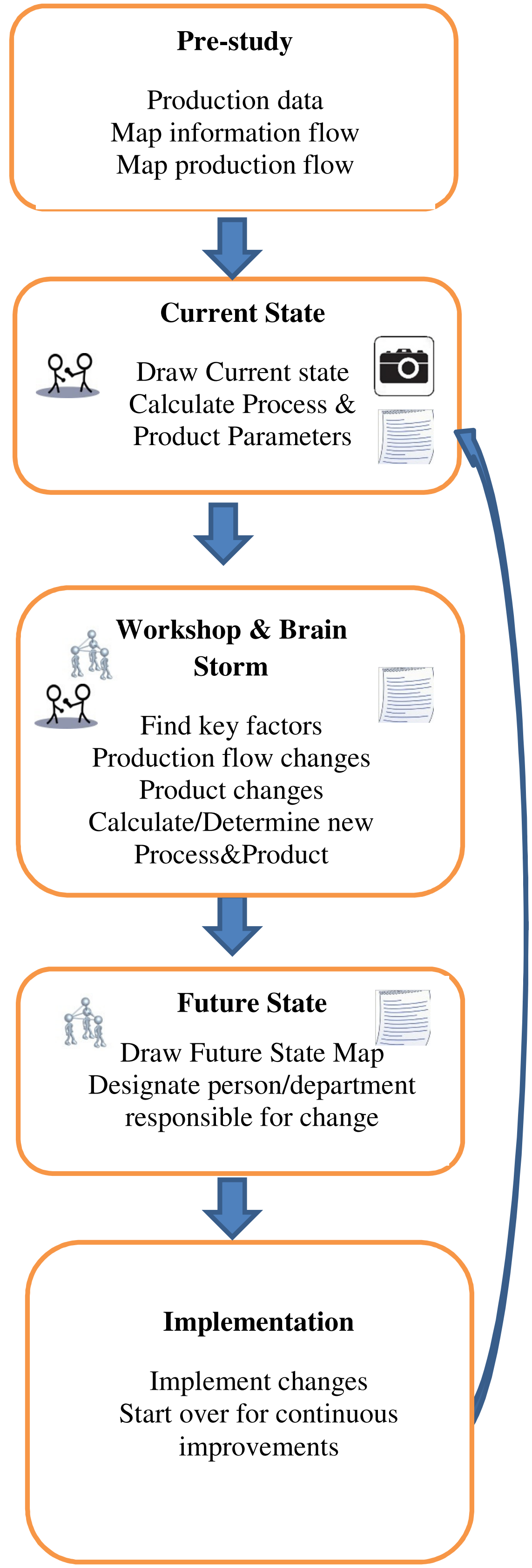
Literature study

The purpose with the literature study was to conclude relevant sources regarding the fields of Value Stream Mapping (VSM), Methods-Time Measurements (MTM) and production systems as well as combinations of them. This was done by searches on several databases (e.g. ScienceDirect, ProQuest, Scopus, etc.), to find scientific articles, and also by reading "Learning to see", a book on VSM written by Rother, Mike and John Shook

Qualitative

The qualitative analysis was made to gain a deeper knowledge in the product, production and managing flow. The following activities were conducted:

- Observe and record the processes and the complete flow
- Interviews with workers
- Case study
- Pre-study, to gain deeper knowledge
- Workshops



Quantitative analysis

The purpose of the quantitative analysis is to analyse data that was found in the qualitative analysis and from existing production data.

- Production data
- Analysis of video recordings to find process and production cycle times.

Research category by production method

This table shows suitable research category, and the relationship between MTM and VSM, depending on process operation and observation level. The methods and processes applied in this study for creating the Current State and later the Future State Map are highlighted.

Table 4 Method/process design

"Single processes" (indiv. task-orientation) – MTM	"Overall processes" (flow-orientation) – VSM
Layout – workplace design (tools, fixtures, machines, etc.)	Process organisation/work organisation
Added value, complimentary work, waste	Production systems
Handling expenditures	Layout – workplace alignment layout (factory, floor, assembly line, cell, etc.)
Expenditures for controlling and supervision	Material flow
Ease of assembly/disassembly	
Ease of grasp/operability	
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Information flow and control VSM + MTM	
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Performance	**Utilization**
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Performance standards (performance rate, actual/target-time ratio, standard time, normal performance, etc.)	Net man-hours worked, total amount of hours available
Personal performance	Fluctuations in order-frequency and work content
Labour standards	Balancing (static, dynamic)
Training, routine	Work in progress/inventory
Motivation/disposition	Stock (amount)
Target orientation/monitoring	Idle times/breakdowns
Competences, skills, education	Scrap (quality of work)
Support/instructions, coaching	Set-up times/change over efficiency
	Maintenance
	Machine utilisation
	Material utilisation
	Area utilisation

3.2 Pre-study

The pre-study phase is used to gather information and gain deeper knowledge about the theory of VSM, the company and the production including the products. This will be achieved by a thorough literature study, interviews with working personal and an analysis of the existing production flow through observations.

3.2.1 Literature study

Since Value Stream Mapping isn't a new subject, started as a tool in Toyotas Lean manufacturing, and because of that there are a lot of existing researches regarding the subject. There by the actual project started by conducting a literature study. Where information was gathered from articles books and internet searches regarding: Value Stream Mapping, lead time, quality, value, work space design and MTM.

3.3 Case study

To be able to conduct a scientific study of a production and the production flow with low or/and limited knowledge is hard. One thing that needs to be in mind is that there exist a lot of experience and knowledge in the operators. They also have a big influence on the work environment and there for it's important to take their advice and suggestions under consideration. In this thesis such a study is conducted on REACs plant in Åmål. The following chapters will describe how the different steps of the Value Stream Mapping were implemented. Before the project started the Production Managing Director had decided that it was the line that produced RE25, which is categorized by the motor type, which was the object for the VSM.

3.3.1 Analysis of exciting production flow

In this thesis a bottom up research strategy was used to gather data information, where the RE25 production line was analysed.
The researchers started the initial phase on the material- handling and processing plane to generate a bigger understanding of the material flow. This was done through visual overview, video recordings and work instruction, spaghetti diagram and interviews with workers.
When the material flow was mapped a small team started to map the information flow and these two analyse where then the backbone of theory to create the Current State Map.

3.3.2 SAM-analysis

”The purpose of conducting a SAM-analysis, which is a method to analyse sequence based activities, is to create a common language operators/work team, R&D whit out have to go through any major education. While the operators are performing their usual processing tasks a researcher is recording every step of the way, so that the recordings later can be analysed in a program called Avix.
“Avix is a digital production tool which is used to enhance the competitiveness by creating a better understanding of the product and the production. This was done in one afternoon and with three iterations on each product step. It was chosen to be done in three iterations to eliminate the chance of one time errors.
In Avix is it possible to categorize every task as value adding, non-value adding and necessary non-value adding tasks.

3.3.2 Work instructions

Work instructions are detailed to do lists, which are made to aid production personal with parts, assembly order and which tools to be used.

The work instructions were made to get a deeper knowledge about the product and the production in real time and at the same time help REAC in future education or aid for their personal.

3.3.3 Sch*e*matic overview and spaghetti diagram

Schematic overviews can be seen as guidance in all types of organizations and Spaghetti diagrams shows on a drawing or CAD drawing how the material flows between the processes and inventories.

The schematic overview was done by visually follow the material flow making its way through the production, starting from the warehouse to finished goods, this was later reviewed by the production manager to check that the version was correct.

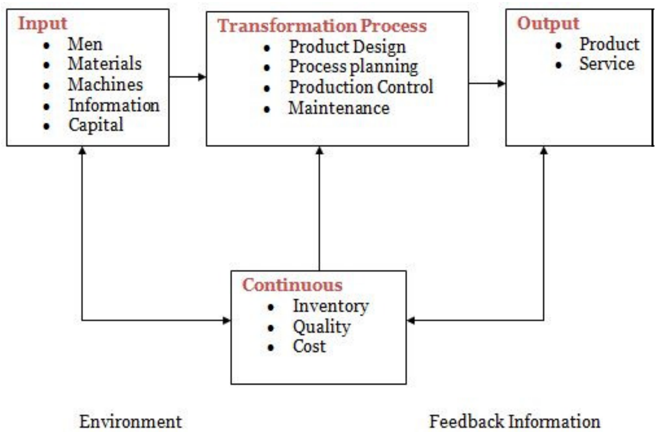

Figure 3 schematic overview over typical process chain

When this was done the next step was to draw the spaghetti diagram. To do this a drawing of the shop floor was used, where the material flow are resembled by arrows and inventory between stations as triangles. Each colour corresponds to a sub assembly material flow.

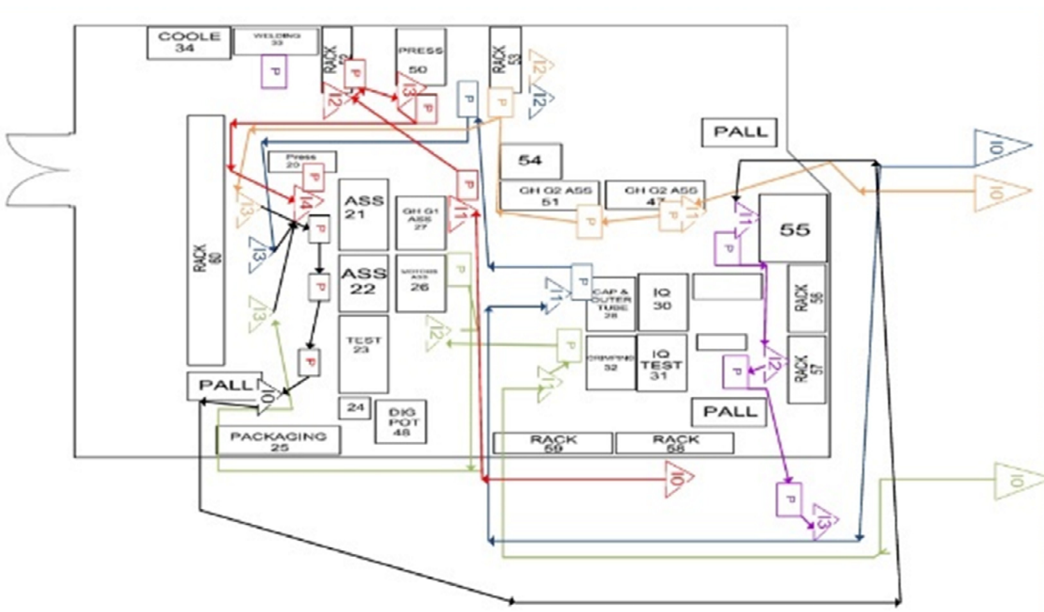

Figure 4 Spaghetti diagram

3.4 Creating the Current State Map

All data that was needed to create The Current State Map comes from the case study, pre study and discussions with experts such as production manager and assembler personal.

- ***Identify current customer needs.***

By discussing REACs KPIs with the chief of production, the production manager and sales personal was it possible to identify their expected costumer's needs such as;

- *On time delivery*
- *Quality*
- *Cost*
- *Right product when the costumer wants it*

- ***Identify main processes (in order).***

This step was already done in the analysis of existing production flow and can be found under Schematic overview and Spaghetti diagram.
Most of the processes until step 9, except from 3&4 and 7&8 can be done without the need of the previous step to be finished, are possible to produce parallel to each other.
There are 9 – 10 workers simultaneously occupying different workstations along the line.

- ***Select process metrics (or data attributes).***

Available work time each week, At the plant in Åmål they mostly work in one shift and 8 hours a day Monday-Thursday while 5,5h on Friday.
Lead time, this is the time it takes from that the costumer puts it order until he or she get the finished product.
Process time, represents the time any work effort is made on the product.
Tack time, will describe how fast the system need to produce a product to meet the costumers demand. $Takt\ time\ = \frac{Available\ \ work\ time\ per\ week}{Customer\ demand\ per\ week}$
So the Tack time decides the slowest possible phase while still meeting the demand.
Pacemaker process this is the process that control upstream processes, most often the process with longest process time or longest change over time. The most important thing with the pacemaker process is that: $PT_{pace} < Tt$
Activity ration, this reflects to the effectiveness of the value stream. Where $Activity\ ratio\ = \frac{Total\ Process\ Time}{Total\ Lead\ Time} \times 100$, it is most common to see production lines to be between 2-5%. Even thou the production personal are working for almost 100% of their time, the products most often have an idle time of 95-98%. (Martin K, 2013)

- *Establish how each process prioritizes work.*

For the moment the over all, weekly production plan, is decided by the production manager. But the operator that works on the first station, motor preparation 1, picks an order from the order board. That order will be worked on until all the motors, the whole batch, are prepared for the next work station.

- *Calculate value stream summary metrics such as lead time, process time, first pass yield, cost, and other measures that the mapping team deems important.*

These parameters are important to calculate, because they will be the measurement that decides where and how much to improve.
Work time each week = *number of available work hours each week in seconds.*

Lead time = *the time it takes for one part to travel through the shop floor, starting at raw material and ending at shipping to costumer.*
Takt time = *total time / number of units from costumer* demand = *number of units comes from an average from 2013*

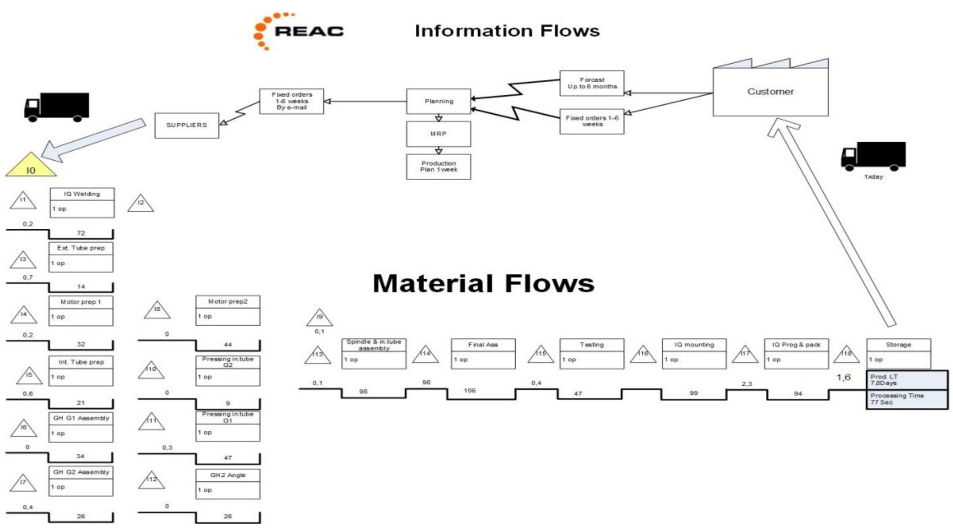

Figure 5 Current State Map

3.5 Creating the Future State Map

When creating the Future State Map the biggest goal is to work towards customer needs and mostly to reduce waste. There is one important rule ”the 70% update rule”, (Locher A, 2008), which means as long as there is a 70% chance of implementation you should keep working on the idea. When the team thinks that it’s no longer reachable you should stop or start with a new idea. The facilitator must also have in mind that the implementations must be done in a reasonable timeframe. Such a timeframe can be up to one year but real changes should start earlier than that.

- ***What does the customer really need?***

Have the needs changed since the Current State Map, if they have are they achievable to reach by change in product or production? If they haven’t change are we reaching them today or is there a need for change? What time frame; now, six months or a year? What division in the company will have to overall responsibility?

- ***How often will we check our performance to customer needs****?*

How often should there be check if the demands are met? Who should check for it? There must be an easy way to see ”the warning sign” if there is something wrong. Is it possible to have a meeting with everybody to update the awareness? If there is, how often?

- ***Which steps create value and which steps are waste?***

This question leads back to the seven “Mudas” in Lean manufacturing, Defects, Overproduction, Inventories, Unnecessary over-processing, Unnecessary motion of employees, Unnecessary transport and handling of goods and Waiting. It should be fairly easy to identify most of the sources from the Current State Map. Trying to implement standard work such as standard parts and standard assembly routines should also be brought up here.

- ***How can we flow work with fewer interruptions?***

This question will focus a lot on information flow, here it's important to involve people from different parts of the processing to help identifying the interrupts. Is it possible to reduce inventories between operations or should the production split up to partly implement continues flow? What happens with "starved" processes when interrupt occurs when using a "one piece flow"?

- ***How do we control work between interruptions, and how will work be triggered and prioritized?***

The way to always assure work between interrupts is to work with queues. The most important to keep in mind is that the bigger the queue the longer the lead time will be.
How do you control the size of the queues? Can you combine operation with low break down and interrupt ratio? Which can be seen in Figure 6.

Figure 6 Partial single piece flow

Is a pull system achievable?
There are three types of pull systems: Supermarket, FIFO and Mixed. Here a Kanban system is suitable to control the size of the queue.

- ***How will we level the workload and/or different activities*?**

With fluctuating demand in order size and variants is it hard to work towards a takt time. The first thing that needs to be done is to identify the root cause of the fluctuation, for example the total demand can be seasonal and variants due to many costumers. Is it possible to standardize parts to minimize changeover times?

- ***What process improvements will be necessary?***

Is there any need for new tools, machines, product changes or educations to reach the Future State Map? Will there be any need for change in the process flow to meet the changes in machine up-time, waste reduction and batch sizes?

3.6 Workshop

Workshops are a great way to get input from a lot of experts with the same or different backgrounds and make them all feel included in the project.
Before the workshop the facilitator needs to have a vision on how the workshop will contribute to the goal. Then he needs to decide on suitable participants, such as Sales, R&D, Production Manager or product assembly personal. There needs to be a motivation for everyone that attends to the workshop else their resource could be more needed elsewhere.
When participants have been chosen is it time to decide on the level of the workshop: how much information will the participants get before the session, what will happen with the information generated from the workshop and how much the discussions should be steered by the facilitator.

When the hard decisions have been made you just need to make sure that all practical things are dealt with before the workshop starts, such as pens, paper and anything else that comes to mind. (Cameron,E 2005)

4. Results

This Case Study was conducted on Reac's producion site in Åmål, Sweden, where they are producing actuators. The production consists of four production lines which are categorized by the size of the motor, in this thesis the RE25 line will be in focus.

The result from the case study will be presented in this chapter. These results are based on observations, interviews, Lean production tools and some statistical analysis.

First the Current State Map and the Future State Map will be presented, then the results will show how the Future State evolved and how it's motivated by above mentioned tools.

4.1 Current State Map

This is the result from the creation of the Current State Map

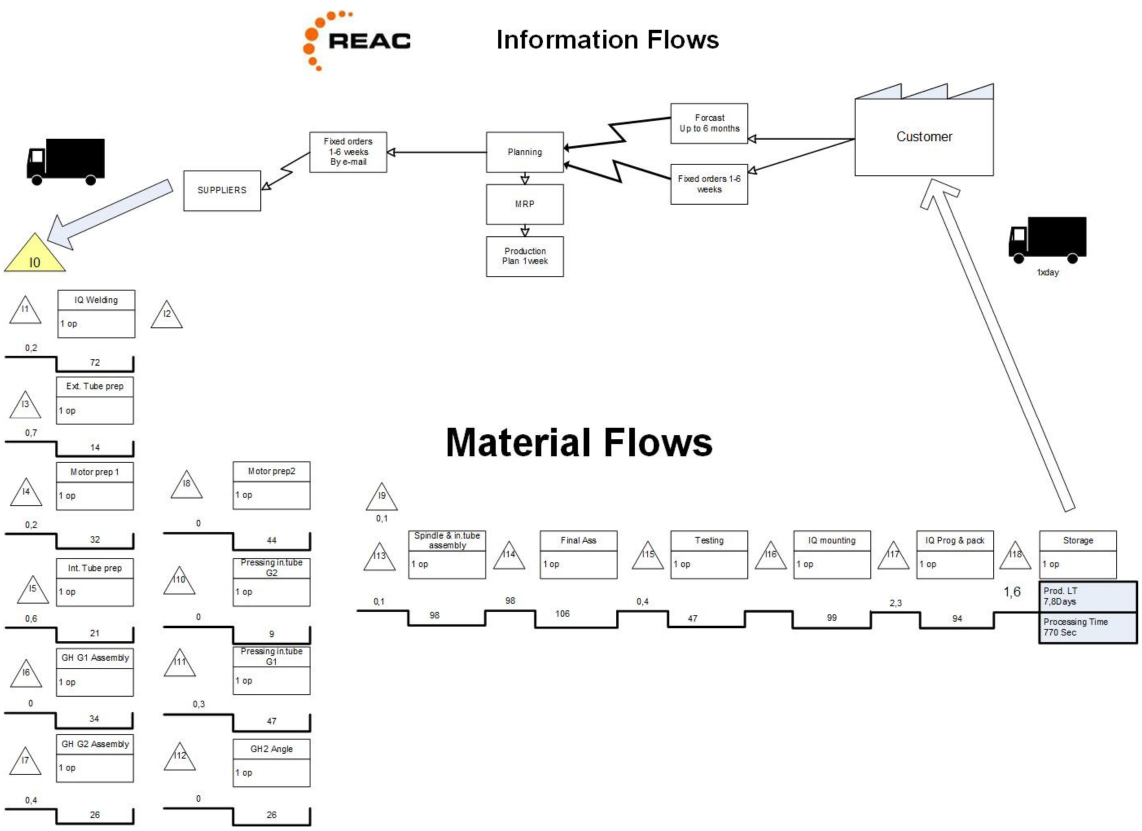

Figure 7 Current State Map

The Current State Map is drawn and it caracterize a split second in an average work day including both information and material flow.

4.2 Future State Map

This is the result from the creation of the Current State Map with a Supermarket implemented

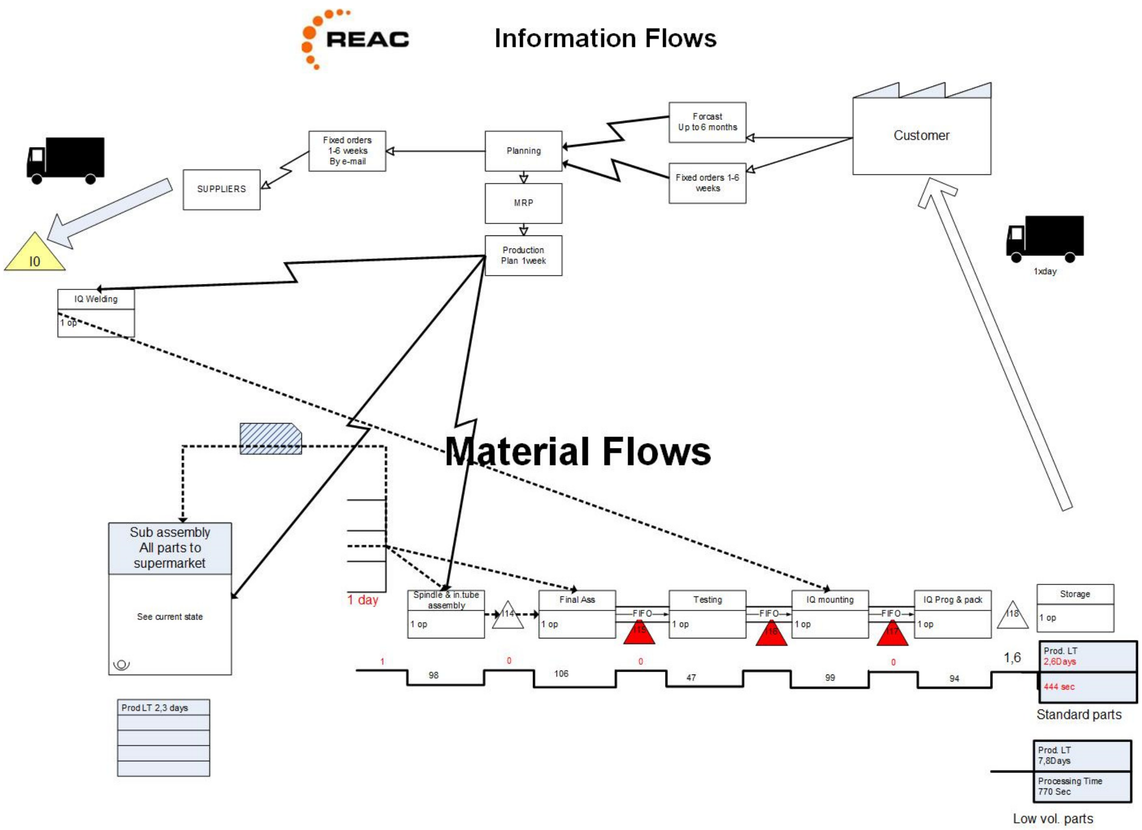

Figure 8 Future State Map

The Future State Map shows the changes from the current state Map, where a supermarket is implemented and the change in information flow shown, all the processes leading to the supermarket are represented by a sub-assembly process because they are unchanged. The supermarket implementation leads to changes in production and material flow. Based on demand the products are split into low and high volume product categories. Production planning and information flow is also affected. This also leads to a change in lead time which will be discussed more in the information flow chapter.

4.3 Creating the Current State Map

Choosing product

Reac's plant in Åmål consist of four production lanes and before this thesis started was it already decided that it was the RE25 line that was in focus, that will now represent the product family. That made it easy to identify production personnel that were interesting for interviews, observations and recording subjects.

Literature study,

Before creating the Current State Map there was a need for deeper knowledge, from the production manager a book called Learning to see from Mike Rother and John Shook was recommended and it was used as a guide through the entire thesis.

(Follow the work, Collect the information yourself)
The first step regarding the production floor level was to understand and create the material and the production flow. This was done through interviews with production personal, follow the material flow both upstream and downstream and simultaneously record the processes to make it easier to later go back and analyse it deeper. From this a schematic overview of the processes and a spaghetti diagram over the material flow was created.

Main process,
This schematic overview represents all the processes from start to end process.

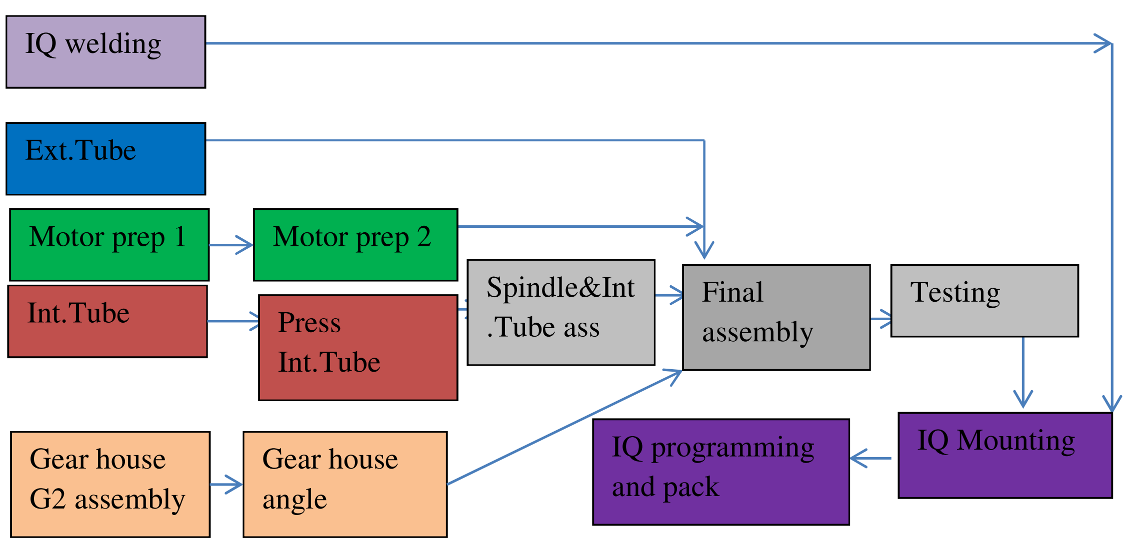

Figure 9, Schematic overveiw

In this spaghetti diagram the material flow is represented by the different arrows and the triangles represent the inventory between the stations.

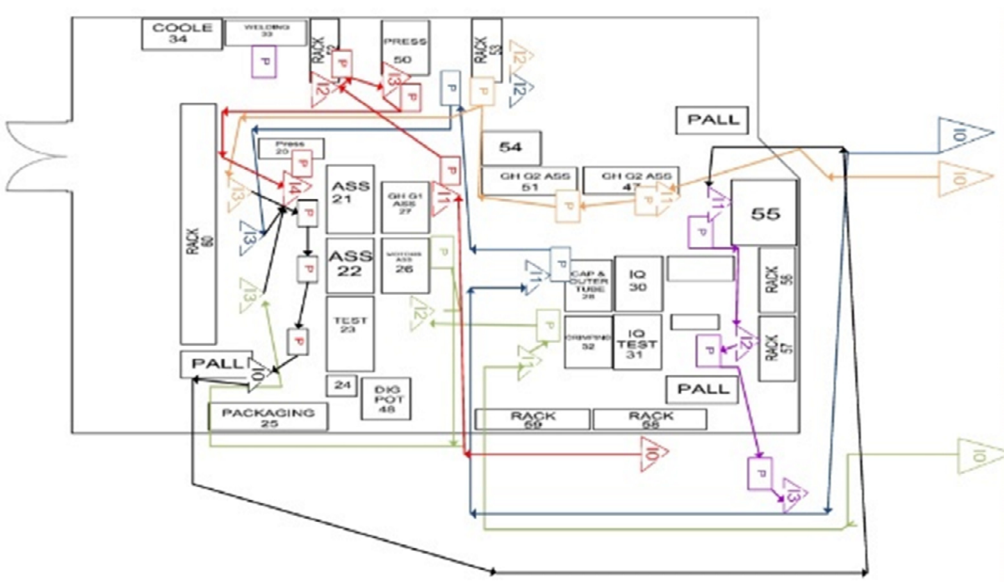

Figure 10, Spaghetti diagram

Exploit existing process information resources, cautiously:
To find value added time from each station the video recordings was analysed in Avix and for broader understanding work instruction was created for each step of the process.

1. IQ welding – *welding of the IQ-card*
   Cycle time 72s

2. Ext.Tube – *external cup and seal are mounted on the external tube*
   Cycle time 14s

3. Motor prep 1 – *cuts the motor cables an mounts a cable connector*
   Cycle time 32s

4. Motor prep 2 – *brackets and cog wheel are mounted on the motor and greased*
   Cycle time 44s

5. Int.Tube – *the front bracket is assembled on the internal tube*
   Cycle time 21s

6. Press Int.Tube – *the internal tube is pressed together*
   Cycle time 9s

7. Gear house G2 assembly – *all the parts that are included in the gear house, cog wheels, bearings and bricks are mounted together*
   Cycle time 26s

8. Gear house angle – *the angle between the motor and the gear house is being fixated*
   Cycle time 26s

9. Spindle&Int.Tube ass – *the spindle is placed inside the internal tube*
   Cycle time 98s

10. Final assembly – *spindle package, motor and gear house are being put together*
    Cycle time 106s

11. Testing – *the complete actuator is beings tested to see if there are any problems with the motion*
    Cycle time 47s
    Change over time (only for new models)

12. IQ Mounting – *the welded IQ-card is being mounted on the actuator*
    Cycle time 99s

13. IQ programming and pack – *the IQ-card is being programed and the complete actuator is being packed and ready for shipping*
    Cycle time 94s

14. Storage –
    Daily shipping to customer

Map "in pencil" Map the whole value stream:
To map the information flow a workshop was needed.

Workshop 1
To conduct the workshop two experts, the chief of production manager and the plant manager was gathered. The purpose was to calculate lead time, available work time each week, process time, takt time and activity ratio.

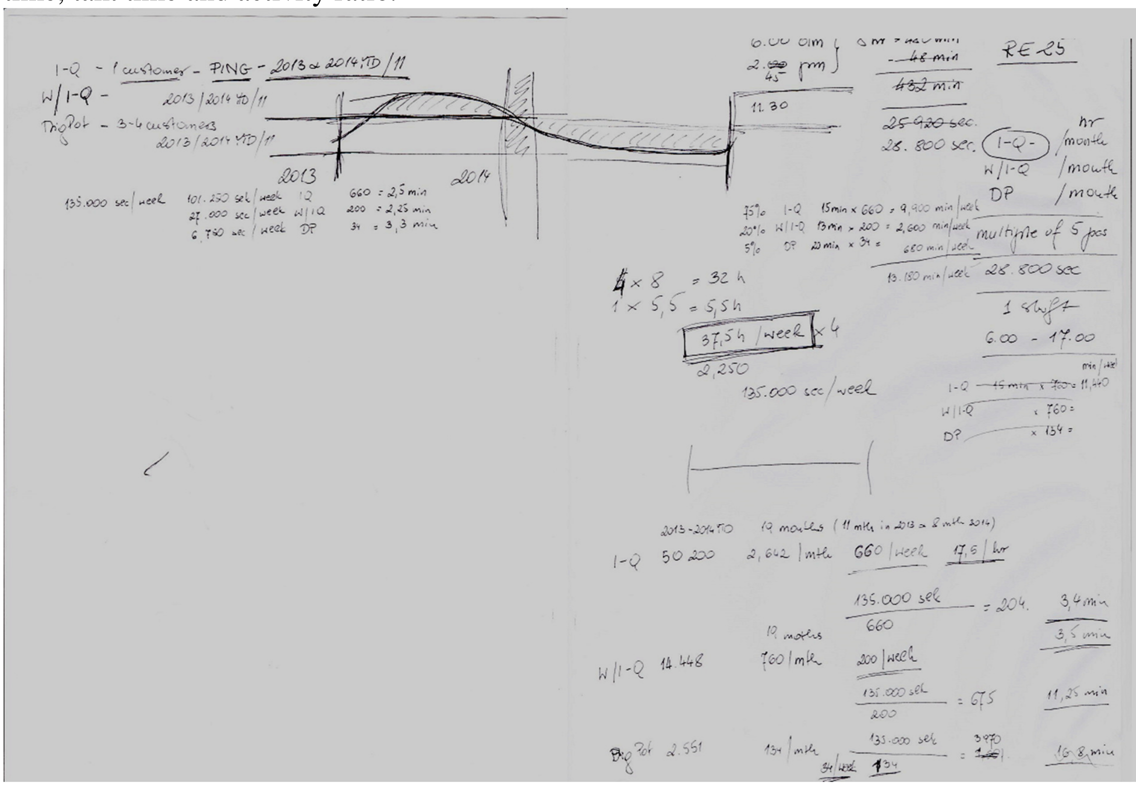

Figure 11 Current stream information flow calculations

Available work time each week, at the plant in Åmål they mostly work in one shift and 8 hours a day Monday- Friday but they have the choice to utilize flex time, the possibility to start later by compensate it by work longer in the afternoon.

$$Available\ work\ time\ each\ week\ = 4 \times 8\text{h} + 5{,}5\text{h}\ =\ 135.000\text{s}\ /\text{w}$$

The takt time comes from the total processing time, the sum of each process operation time, divided by number of units produced, which is an approximation that comes from an average of 2013 year's sales.

$$Takt\ time\ = \frac{Total\ Available\ time}{number\ of\ units}$$
$$= \{number\ of\ units\ comes\ from\ an\ average\ from\ 2013\} = \frac{135000}{860}$$
$$= 2{,}62min = 2min\ 37sec$$

The Pacemaker process in this case is the final assembly station with a processing time of 106 sec = 1min 46 sec. the most important thing to notice is that $PT_{pace} < Tt$ which in this case is true.

To be able to find the total lead time an inventory investigation was needed, where "the most important" part in every inventory between processes was counted. The total lead time then became the sum of all "process inventory" divided by the average daily demand.

$$Total\ lead\ time = \sum \frac{process\ inventory}{daily\ demand} = 7{,}8\ days$$

$$Activity\ ratio\ \equiv \frac{Total\ Process\ Time}{Total\ Lead\ Time} \times 100 = \frac{770sec}{7{,}8\ days} \times 100 = \frac{770}{673920} \times 100 = 0.114\%$$

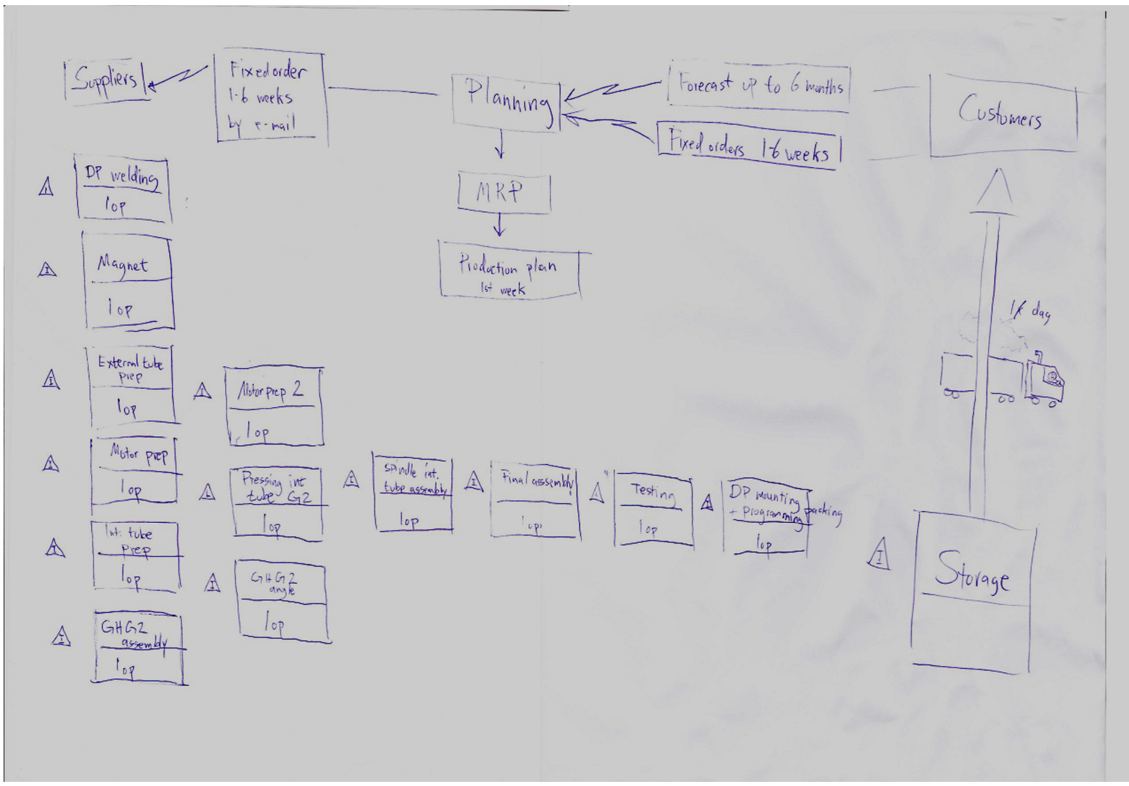

Figure 12 Current State Map drawn by hand

4.4 Creating the Future State Map

Creating the Future State chapter will describe step by step how the questions flaws found in the Current State map were handled with to create a better Future State Map. Changes that were changed from the Current State Map to the Future State Map can be categorized as information flow and material flow changes. The way it was tackled was to create a workshop.

Workshop 2

In this workshop the chief of production manager, the plant manager and two product assemblers, where one was union representative and the other one was better on product and production flow. The goal was to hear their input on what they thought was the biggest problem, on the shop floor level, without any influence from the management department.

There were three major things they could both agree on:

1. Lack of space, to narrow (material flow)
2. Right material at the right time or even lack of products (information flow)
3. Defect products (material/information flow)

After the workshop these three problems were investigated deeper:
Since a change of facility was not an option a change in the Product flow and rearrangements on the production floor became interesting. When studying the spaghetti diagram we can clearly see that it gets messy, crowded and tight in a bunch of areas. There for a second workshop was conducted, Lay out (theoretical).
Before that workshop the second problem, the one regarding lack of materials and products, was investigated. This was done by looking at sold models during 2014, categorized by motors, pitch, strokes and model.

4.4.1 Data analysis

All sales data from previous year was sorted into different categories, Motor, Pitch, Stroke and model. Then in each category the data was sorted into types and then clumped together for each week

Motor

There are five different types of motors that power the actuators on the RE25-lane. The differences between the motors are top speed (rpm) and voltage on the power supply (12V or 25V)

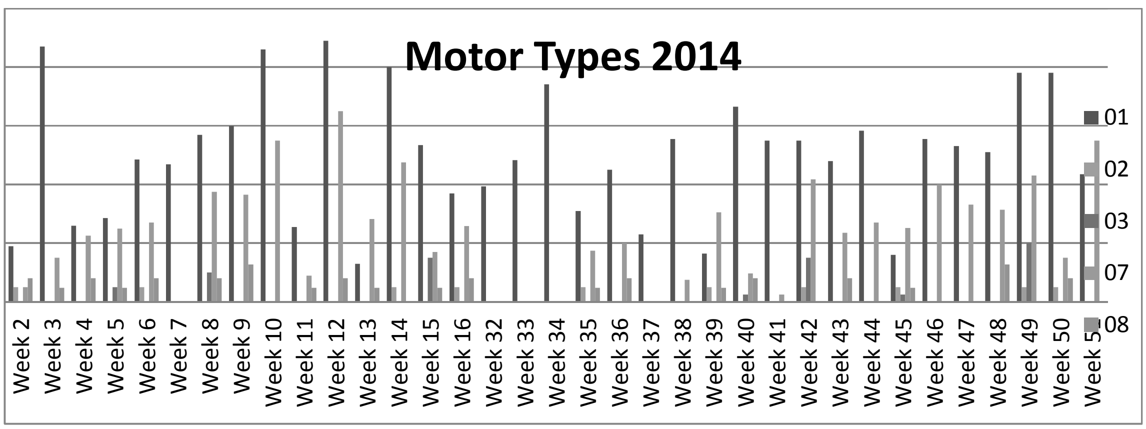

Figure 113, Motor types

Each line on the y-axis represents an increase of 100 motors. As can be seen in the diagram type one and seven stands for a majority of what has been produced each week, together they stands for 90,1% of the weekly production $\frac{\sum type1+type7}{totaly\ produced} = 0{,}613 + 0{,}294 = 0{,}907$.

Pitch

There are five different types of pitches produced where the pitch describes the rise for each revolution. Each type differs from the others by rise and diameter.

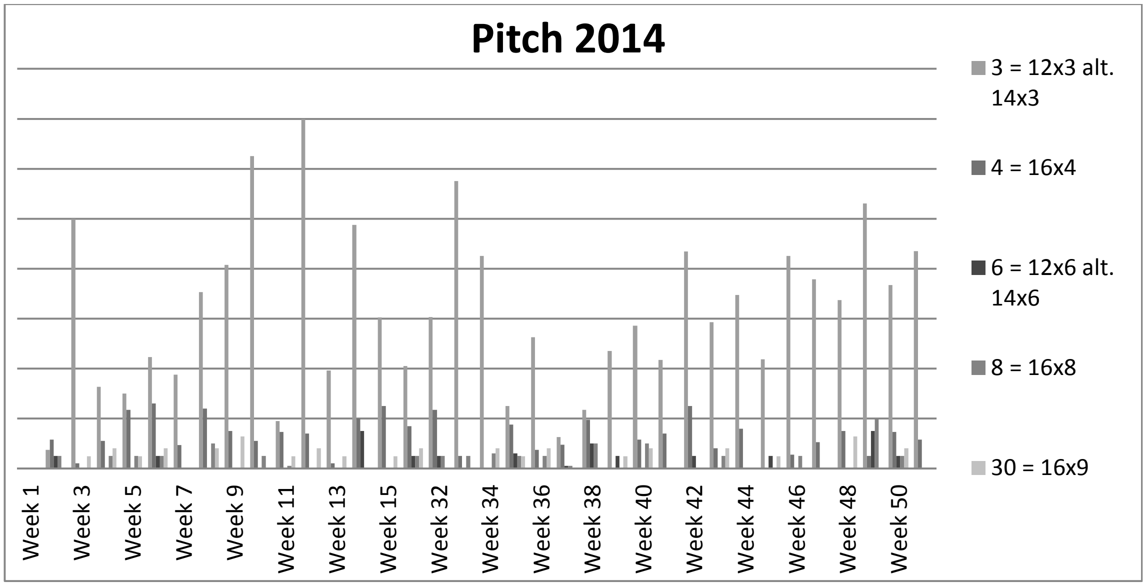

Figure 124, Pitch

Each line on the y-axis is an increase of 200. The most commonly produced one is the type 3 that stands for 73,3% of the weekly production and the second most common is type 4 with 14,8% together they stands for 88,1% of the pitches.

Stroke

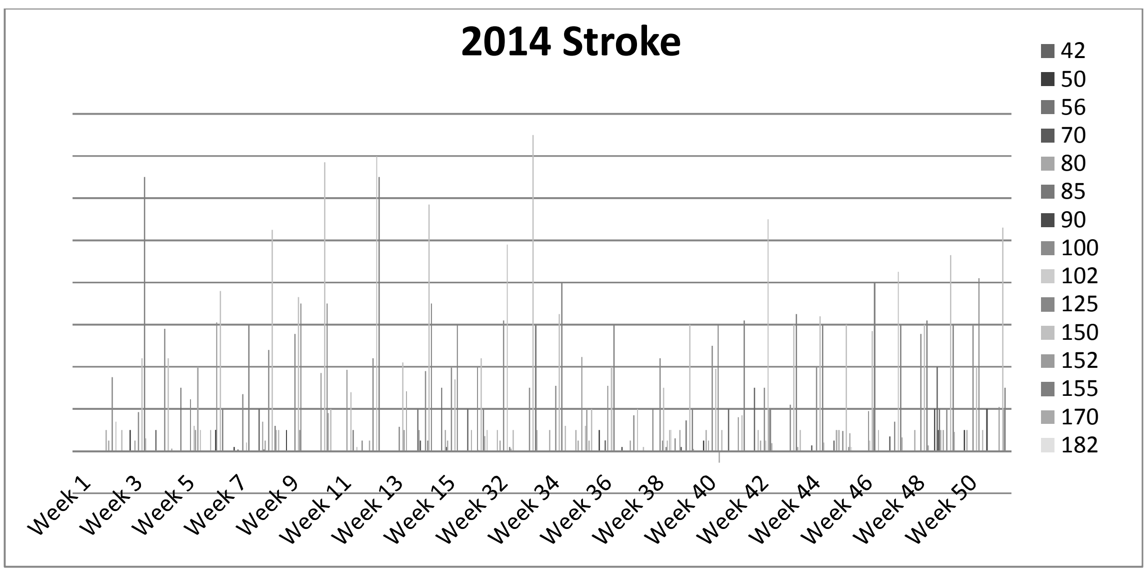

Figure 135, Stroke

The stroke describes the length of the piston that moves in and out by the motor on the actuator. There are 20 different types of Strokes and the difference between them is the length.

Each line on the y-axis is an increase of 100. This one is more even than the other two but there are still three types that are more common than the other ones and its type 100, type 150 and type 155. The distribution is type 100 stands for 20,1% type 150 stands for 36,2% and type 155 stands for 25,2% together they stand for 81,6% of the strokes.

Model

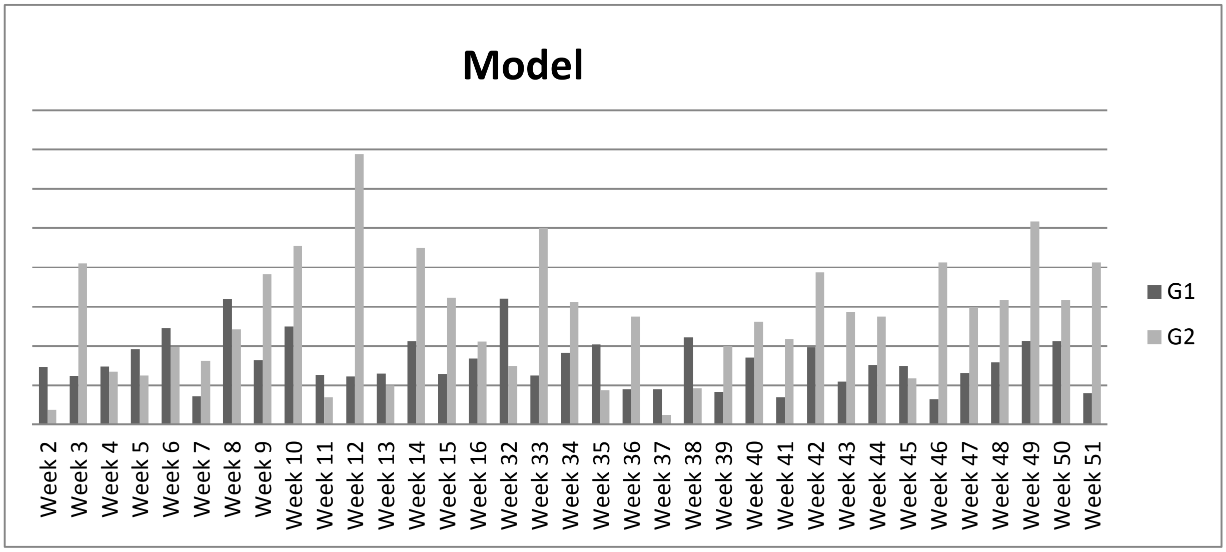

Figure 146, Model

Each line on the y-axis is an increase of 200. In this case the distribution is 37% for G1 and 63% for G2, but if trend lines are added is it possible to see that G1 were decreasing and G2 increasing over the year.

After the data analysis was it obvious that it was mostly the same products that was produced each week. So then a discussion regarding a Supermarket started. Why Supermarket then? The purpose of implementing a Supermarket between processes is to create a downstream pull system and to easier control upstream processes. This suits well for productions with a mix of high and low quantity products.

Supermarket inventory size
The Supermarket inventory size will be calculated by most common weekly produced amount * 1/5, this will provide one day safety stock. To be able to regulate this a Kanban system will be implemented, when a lower limit is reach will a signal be given to start produce new products of that kind. The signal will just be a piece of red paper that will say how many pieces that are left in stock and work as a visual signal.

Weekly distribution
To decide the lower limit an investigation started with purpose of finding the most common weekly amount delivered products for each cathegory. This was done by looking at last years, 2014, sales numbers and sort dem into 25 brackets, 1-25 and 26-50 etc.the bracket size was chosen to 50 because of the boxes in the weare house contained multiples of 25.

Motor type
Since it was motor type 1 and 7 that were the once with high quantity they will be included in the Supermarket.

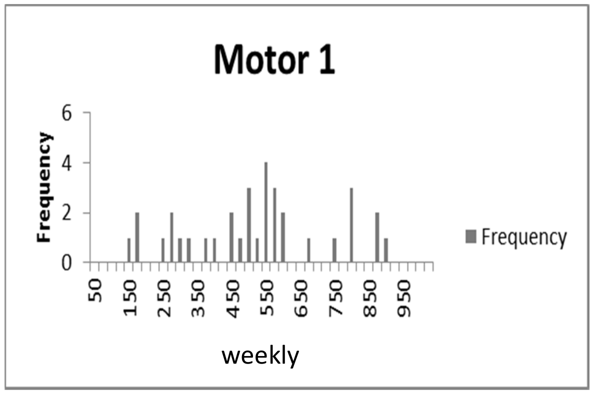

Figure 157, Motor type 1

By looking at Figure 17, can we see that a weekly sale of 550 motor type 1 is the most common. There for will we asume that this will be the daily demand.

$$s_{m1} = \frac{550}{5} = 110$$

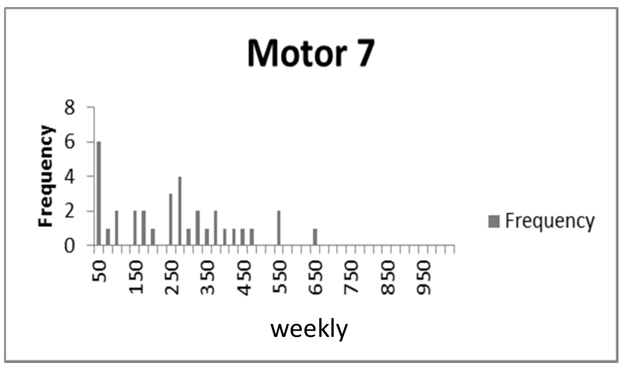

Figure 18, Motor type 7

In difference from type 1 is that it is more common that the weekly demand is either 225 or 250 pieces.

$$s_{m7} = \frac{225 + 250}{2 * 5} \approx 50$$

Pitch

Since it was pitch type 3 and 4 that was the once with high quantity they will be included in the Supermarket.

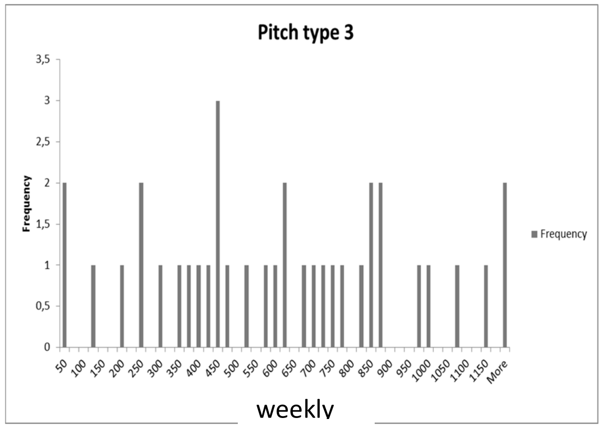

Figure 19, Pitch type 3

By looking at Figure 19 makes it possible to identify that the most common weekly quantity is 450 pieces.

$$s_{pe3} = \frac{450}{5} = 90$$

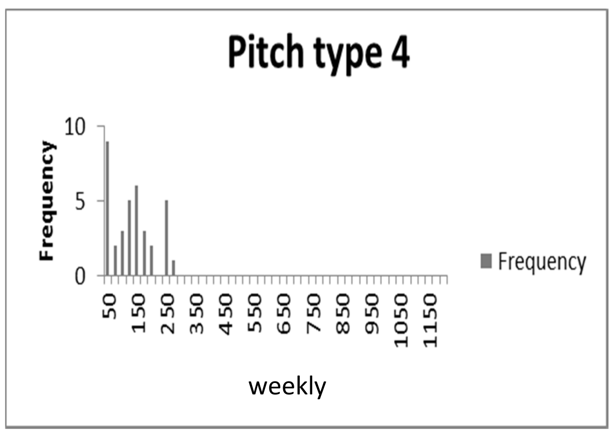

Figure 20, Pitch type 4

When looking at Figure 20 for pitch type 4 is it more likely that either 125 or 150 pieces will be ordered each week than 50 and it's more suitable regarding order sizes and inventory batch size.

$$s_{p3} = \frac{125 + 150}{105} \approx 30$$

Stroke
Since it was stroke type 100,150 and155 that was the once with high quantity they will be included in the Supermarket.

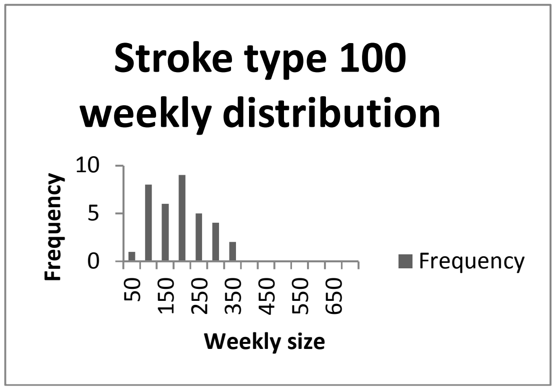

Figure 21, Stroke type 100

When looking at the distribution for the type 100 it's more or less normalized around 200 pieces each week.

$$s_{s100} = \frac{200}{5} = 40$$

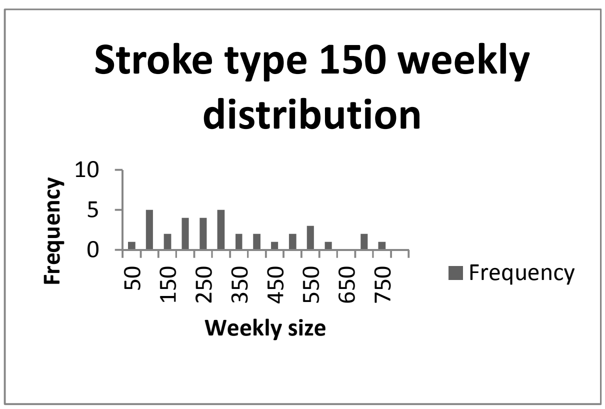

Figure 22, Stroke type 150

While the type 150 have a more even distribution but statistically will either 250 or 300 be sold each week.

$$s_{s150} = \frac{250 + 300}{2 * 5} = 55$$

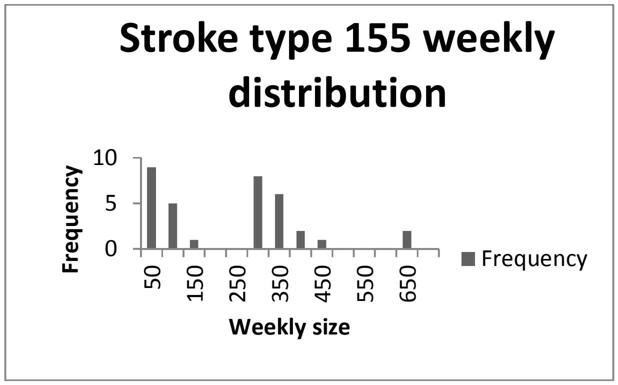

Figure 23, Stroke type 155

For the last type it's either, from a statistical point of view, a combination of 50 and 100 pieces or 300 and 350. Since there is enough space to have 65 pieces in the Supermarket, the later one will be chosen.

$$s_{s155} = \frac{300 + 350}{2 * 5} = 65$$

Model
Since these are the only two models and they are fairly equal will they both be included.

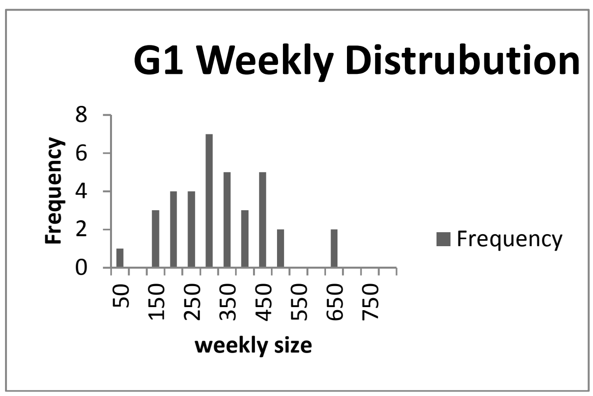

Figure 24, model G1

The G1 model is sort of normalized around 250 pieces each week.

$$s_{g1} = \frac{250}{5} = 50$$

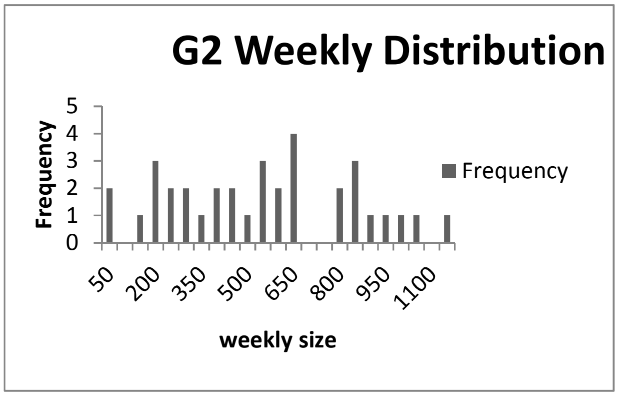

Figure 25, model G2

For the G2 model the demand was a bit more spread but to be on the ”safe side” 650 pieces each week was chosen.

$$s_{g2} = \frac{650}{5} = 150$$

Kanban

When studying the Future State map you find that the process with the longest process time is the Final Assembly station. While all stations, counting all linear stations that lead towards the final assembly as a single station with their process time as one, leading there are parallel, this result into that it is faster to fill the Supermarket then emptying it. There for was it decided that the Kanban threshold should half of the Supermarket level and that the order would queue after the current order for the processes leading to the Supermarket.

4.4.2 Information flow

When the information flow was discussed any outside customers and suppliers were ignored and it was only in house questions that were taken into account. The focus was now to create a Kanban system for the Supermarket and decide work levelling to make sure that even the low demand products were produced.

For the Kanban system a lower limit or safety stock for the different products in the Supermarket has been set, it can be found in the data analysis chapter. For the work levelling in product mix the idea was to mimic the demand. This means that the percentage of work hours spent each day on producing a certain product should correspond to the production volume percentage of that product.

Lead time

In Value Stream Mapping Lead Time is one of the most interesting measurements to look into. One of the biggest changes in the Future State Map is the implementation of the Supermarket. Because of the Supermarket the Lead Time can be split up into two different times, this is only from the costumer’s view, where one is the Lead Time for standard parts $LT_{std} = 2{,}6\ days$ and one for low volume parts$LT_{low} = 7{,}8\ days$. The LT_{low} is equal to the Production Lead Time since those products will be built to order. While the standard parts will be built towards a forecast and picked in the final assembly.

Lay out (theoretical)

To create a new lay out for the shop floor, a third work shop was conducted.
For the third work shop the same group as for the second one was assembled. The work shop started with some brain storming with help of Simplified Systematic Layout Planning, which is a method used to weight different criteria against each other. Examples of these criteria are:

- Finished gods should be as close to the shipping dock as possible
- It must be as quiet as possible at the IQ assembly station
- It should be easy to re-fill the assembly station inventories
- The workers should not work with their backs towards the forklift lane
- There should be a designated space for a future lane, RE60

The final layout can be found in the next chapter, Lay out (practical), while the three suggestion layouts that were created can be found in Appendix A.

Lay out (practical)

To gather more opinions and ideas a physical demonstration of the theoretical lay out was conducted.

To demonstrate the theoretical suggestion an empty facility was borrowed and on the floor all stations were marked with duct tape. This was done to see so that it was possible to move around between the stations with pallets and check that it wasn't to narrow. At the same time some new suggestions and quest were brought up:

- Is it possible to remove the G1 press for inner tubes and replace it for the G2 press? Since the G1 model is supposed to be phased out and should there by not have a center position. This was a good and easy implemented idea.
- In the current lay-out they need to enter the RE35 line if they need to create special cables, and it's more likely that the cable machine is used in the RE25 flow than in the RE35. So why not move it to the RE25 line. This suggestion was also easy to implement in the future Lay-out.
- Then there were some concerns regarding free space in the line to make it possible to store empty trolleys.

4.5 Before and after, in the Layout

In this chapter will the changes from the current Lay-out to the future Lay-out be highlighted and described.

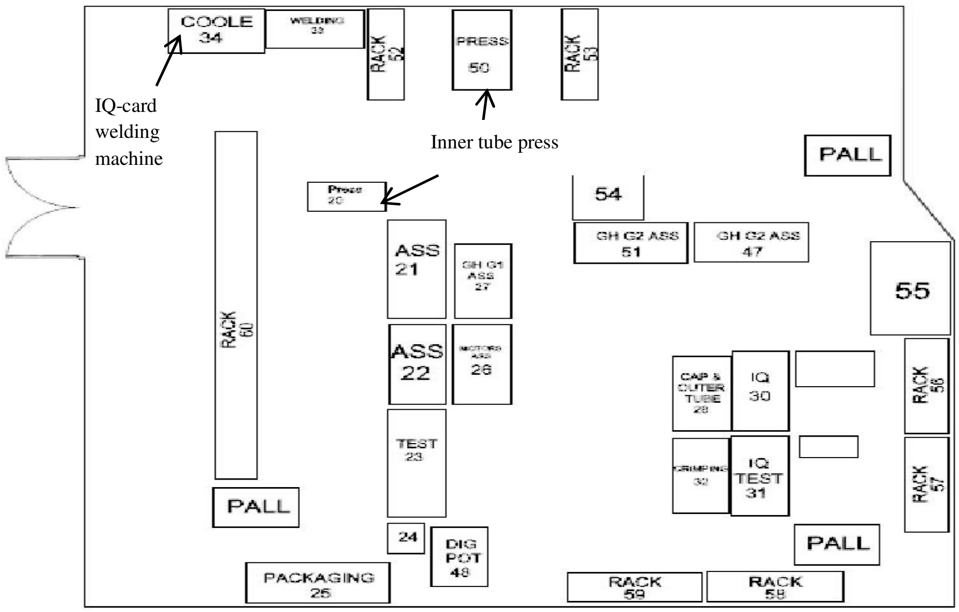

Figure 26, Current Layout

After the practical work shop the Lay-out suggestion were finalized. The final suggestion is based on former criteria:

- Lack of space, too narrow
- As quiet as possible at the IQ-assembly, far from the welding machine and the inner tube press
- Right material at the right time or even lack of products
- Straighter production flow
- The press for the G2 model in a better position than the G1 model
- The cabel machine has been included in the line
- New design of the Cap and outher tube assembly

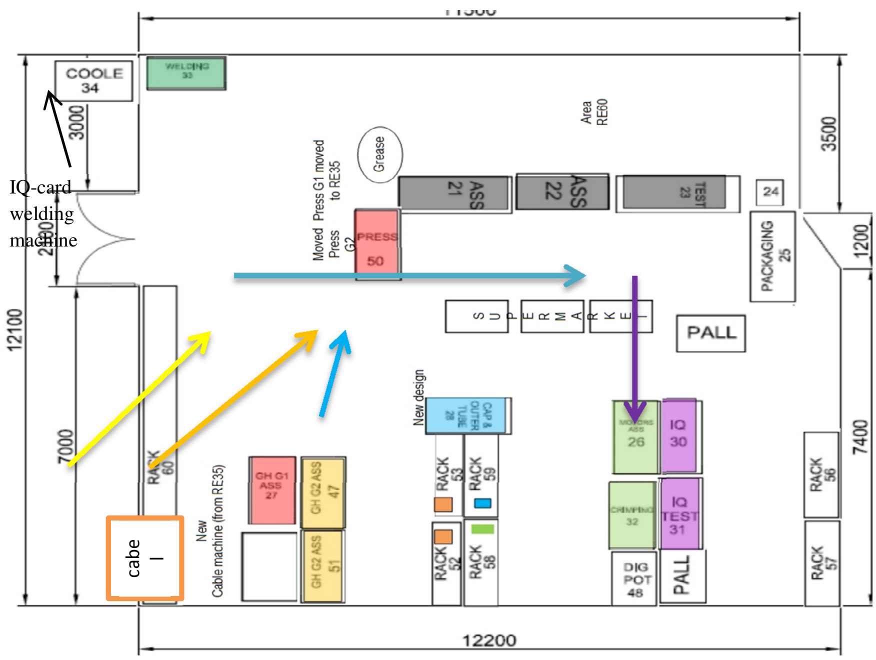

Figure 27, Future Lay Out

All the suggestions differ from the current lay out, but as much as possible was kept the same. The IQ assembly stations did already match all the criteria and there for a lot of the decisions that were taken strived to keep that part as it was.
In the final solution all material flow strives to be as straight as possible to not only make the flow to the supermarket more convenient but it also make a one piece flow easier to obtain when wanted. Because of the implementation of the supermarket the whole production line strives to build towards forecast and the process stations can there by work parallel against each other as long as they are producing the standard parts. From the data analysis chapter we find that the standard parts stand for 74%-90% of the sold products. There for this will make an impact on the production planning. This will lead to more controlled work levelling, because the production will correspond to the product distribution, with some modification for forecast.

5 Conclusions and discussion

This chapter will include a brief résumé of the result followed by some discussion regarding good and bad decisions and their impact on the result

The purpose of this master thesis was to:

- *Scientifically analyse the production by conducting a SAM analysis to use as basic data for a Value Stream Mapping.*

This was done in combination with using Avix, which gave a great depth and understanding how to perform the different processing tasks to complete the actuators. Then when the work instructions were made they became some sort of confirmation that every task was understood. But was it essential for the thesis to make it so thorough? Maybe not, because there were no changes on the processes so the processing times could have been enough. But it was a gain in that way that the shop floor workers appreciated when I know what they were talking about. I believe that it created a more mutual understanding.

- *Develop improvement suggestions based on the analysis that considers the context described in problem definition and find a good trade-off between lead time, flexibility and area utilization.*

All the improvements are based on the criteria that were decided during the workshops, they were regarding material and information flow as well as area utilization/lay-out. For the material and information flow a supermarket was implemented and in combination with it a data analysis over produced product type distribution was conducted. The data analysis resulted in a new production planning.

The goals for this maser thesis

- *A new production layout focusing on shorter lead times while maintaining high flexibility and staying within current shop floor area constraints.*

During this thesis there have been a lot of changes regarding new facilities, so for the layout that was presented some assumptions were made; the facilities will remain the same or if changed the area should look similar, and in the end we had to plan for a second smaller line in the same space. The new layout makes it possible to obtain a one piece flow even though it's only partially planned for it. With the new supermarket will it be more flexible if needed, at the cost of more unfinished goods. Even though they will have a lot of unfinished goods they will, judging from the data analysis, finalize the products within the week. With the supermarket the production can be divided into standard parts and low volume parts, the ratio can be found in the result chapter under data analysis, and for the standard part there will be a reduction .of 65% in lead time from the customers' point of view.

- *A production planning strategy for products in the RE25 product line, based on the proposed new production layout.*

The data analysis gives us a possible production plan where we can combine most common weekly orders with the forecast. When combining this with the supermarket a Kanban system can be implemented. This result in the possibility to build up a stock on pieces that will, with high possibility, be sold in the near future. The production changes will make impacts on:
Available work time – the workers will have the same work hours as before but since there will be parts in the supermarket and from there it can be a one piece flow.

Takt time – Production can be increased by , $\frac{\text{Takt time – processtime for the pacemaker}}{\text{takt time}} * 100 = \frac{157-106}{157} * 100 = 32{,}5\%$. It should be noted that with a shorter takt time, the system is more vulnerable to disturbances from setups and breakdowns.
Lead time – This key factor have two points of view, the production and the customers, where the costumers is the most interesting one. In this case all the processes before the supermarket will be ignored, because the order will be picked up at the final assembly station.

Takt time discussion – Through this thesis the takt time is based on an average yearly demand. It is seldom that this correspond with the reality, the demand often fluctuate not only from week to week but also the year. Depending on season and maybe also events such as exhibitions or introduction of a new model. The variation in sold actuator for 2014 can be found in Figure 28 below.

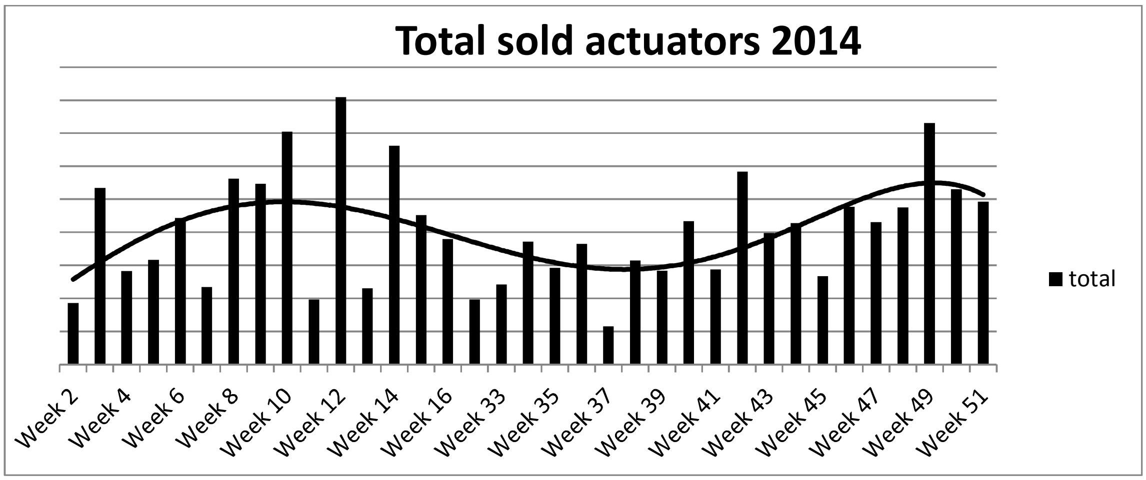

Figure 28, Total sold actuators 2014, weeks 17-31 are excluded from the data set

The figure verifies the statement in changes in demand over a year. For future improvements which should be achieve able would be to take these variations into consideration. First step should be to utilize the six weeks forecast period the second step should be to identify seasonal variations by analyse data from previous years to find any trends.

Value Stream Mapping has been an excellent tool. Because it was easy to understand and to get started with, it also has the possibility to combine with other lean tools to make deeper analysis. So this does not mean that VSM is a simple tool, Just that it can be easy to use but hard to master.

If I would have been more prepared from the start and if I've had more knowledge in Discrete Event Simulation, I would have combined the methods to create better line balance and to simulate the new production flow.

This study considers the entire system and gives an overview, potential next steps would be to go deeper into the different system components. Reduction of product variants seems to be a high return option due to:

- Reduced storage

- Reduced number of setups
- Easier to predict demand

Product variant reduction can be achieved by having more similar internal parts shared between variants. This will not have any impact for the customer, as long as the products perform the same before. This could lead to either lower prices or higher sales margin. An alternative way to reduce variants is to remove the low volume products entirely. This could potentially result in loss of customers.

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Appendix A

Figure A1:

A layout where a big inventory rack is placed in the centre of the line to hold all in line material and at the same time is easy to fill. This layout will fail if the empty area will be used for the RE60 production line, because it will be impossible to easy fill the inventory.

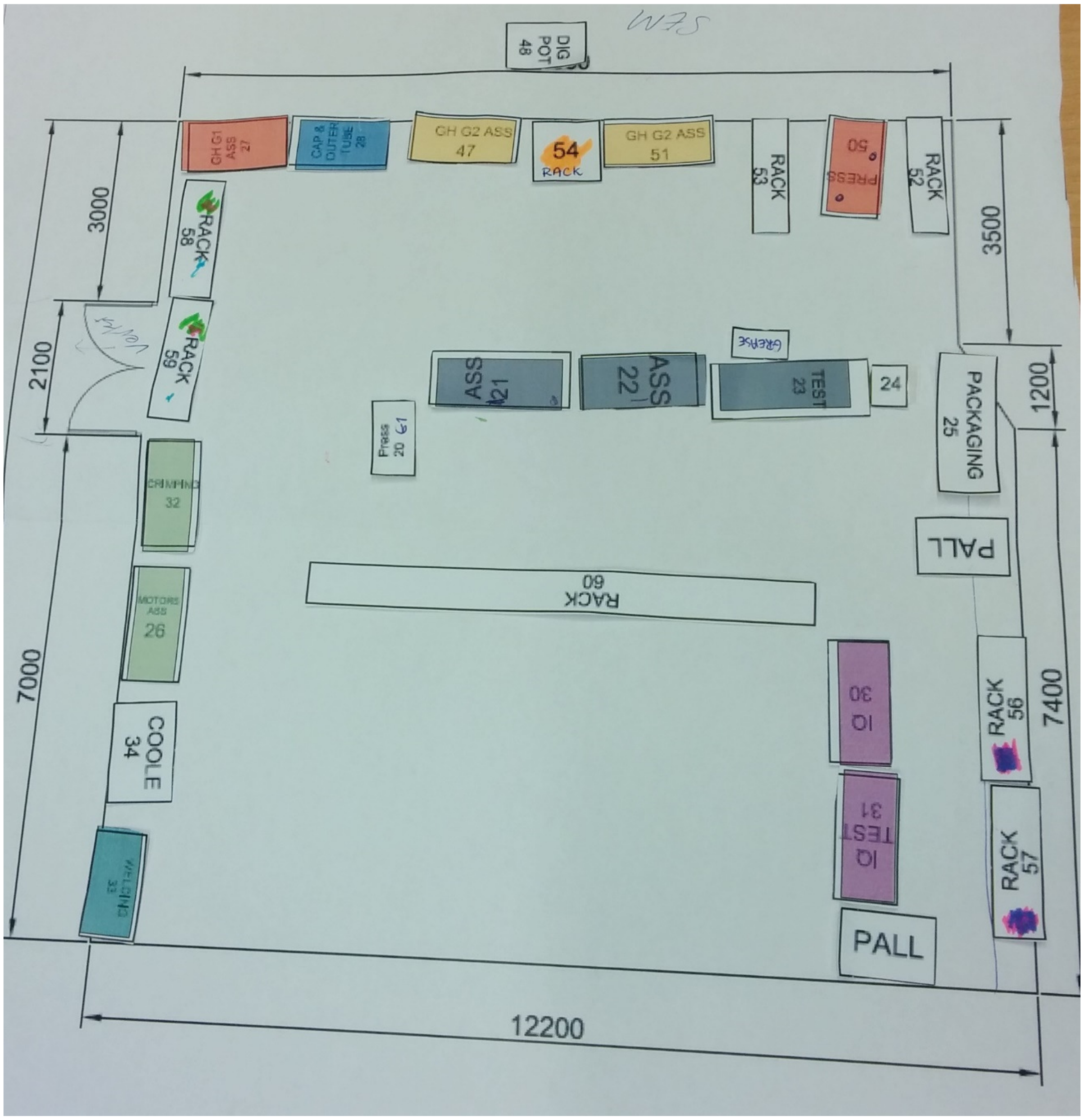

Figure A2:

This layout places all processes at the edges of the shop floor to create as free space as possible and have the final assembly line in the middle of the room. This layout will fail if the empty area will be used for the RE60 production line, because it will be impossible to easy fill the inventory.

Figure A3:

This layout focus on a one piece flow where the parallel production processes ends as near as possible where they will be used in the final assembly line and use as much area as possible. This layout will fail if the empty area will be used for the RE60 production line, because it will be impossible to easy fill the inventory.