DEGREE PROJECT

Mapping and improving the after sales flow in a high-tech assembly plant

a case study of the aftermarket at Saab Järfälla

Viktor Toftberger
Gustaf Jörnelius

Industrial Design Engineering, master's level
2018

Luleå University of Technology
Department of Business Administration, Technology and Social Sciences

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- A case study of the aftermarket at Saab Järfälla

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2017

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MSc in INDUSTRIAL DESIGN ENGINEERING
Department of Business Administration, Technology and Social Sciences
Luleå University of Technology

CIVILINGENJÖR I TEKNISK DESIGN
Master of Science Thesis in Industrial Design Engineering

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Published and distributed by
Luleå University of Technology
SE-971 87 Luleå, Sweden
Telephone: + 46 (0) 920 49 00 00

Printed in Luleå Sweden by
Luleå University of Technology Reproservice
Luleå, 2017

Acknowledgement

VIKTOR TOFTBERGER

With this thesis completed, I have finally fulfilled my dream of becoming an educated engineer. Coming to Luleå with nothing but an address, a bag and a nervous and excited mind to grow into the person I am today These five years have taught me not only that studying pays off but to grow into a person with a working life balance between everything around. To be a good person, help others and spread joy in stressing situations and for this I am truly grateful. This would not have been possible without the support and love of my family, friends and teachers at the university. I would like to thank you all.

The thesis and the work behind it would not have been possible without my friend, classmate, lacrosse teammate and thesis partner, Gustaf Jörnelius who I would like to thank for great collaboration and support during this project and our whole journey through the education. I thank you for these awesome years!

I would also like to thank everyone involved in our thesis project. Our supervisor Magnus Stenberg at Luleå University of Technology for fast and constructive feedback whenever needed. Everyone at Saab Järfälla guiding us through their work, especially the “Key Initiatives”; Peter Flodin, Alexander Murby and Niklas Malmelöv for being great supervisors, always helping and letting us be a part of their project.

Stockholm, August 17, 2017
Viktor Toftberger

GUSTAF JÖRNELIUS

Five years ago I arrived to Luleå with just my backpack, a suitcase and a note with an address on. Now five year later I can for sure say that moving to Luleå and starting at LTU is the best choice of my life so far. I have learning to play lacrosse, become a member of StiL Alpina planning ski trips and events for all students, skiing around 50 days a year, meeting new lifelong friends and much more.

Writing this master thesis it sort of summers all the hard work that I have done to fulfill my dream of becoming an educated Industrial Design Engineer. Completing this thesis would not have been possible without first of all Viktor Toftberger, my partner, friend and lacrosse teammate. I also want to thank Magnus Stenberg, our supervisor at LTU for all the help he have giving us under this thesis. From Saab I want to specially thank “the key initiatives” Peter Flodin, Niklas Malmelöv and Alexander Murby for always being helpful when needed and also all other personnel from Saab that have in some way helped us completing this thesis.

Last of all I just want to thank friends and family for all support during these five years, you know how you are and make sure to take credit for it! Now it is time to take on new challenges.

Stockholm, August 17, 2017
Gustaf Jörnelius

Abstract

This thesis report is the final element of the Master of Science degree in Industrial Design Engineering at Luleå University of Technology, conducted between January and September 2017 at Saab AB Surveillance in Järfälla, Sweden. The purpose of this thesis project was to analyze the current situation inside production of aftermarket products with an aim to create an extensive mapping of the current situation. Resulting in suggestions for improvements to stabilize the production and creating integration between the aftermarket and new production.

Products produced at Saab Järfälla are used in military defense applications where the larger systems in electronic warfare (EW) and countermeasure systems have very long life cycles, i.e. up to 40 years, and are being used in harsh environments. The products have to be maintained through various service agreements to include support with repairs, maintenance, supplies and transports between Saab and the client. One of these service agreements has a demanded net average lead time of N+12 days between Saab's facilities and the client whereas N days inside the Järfälla production site. Mapping the situation and handling all the product information in a production with high-mix, low-volume characteristics have not been easy. The aftermarket processes inside Järfälla include diagnosing, reparation, assembling and testing to ensure the performance of the products. The aftermarket shares resources with the production of newly manufactured products which is one of the reasons creating a vast difference in the lead times standard deviation. Other reasons such as information handling, priority inference, flexibility issues and bad visual management has been the effect of causing delays in the production.

The thesis project has been conducted through a development process using various methods for mapping the current situation and to come up with new ideas to improve the situation. Starting with a search in available literature and research about HMLV production, aftermarket situations and lean principles, onto using well-known methods for analyzing such as value stream mapping, Ishikawa diagrams and data collection to form a requirement specification for the upcoming solutions.

As a result, in the analysis of the current state, the fact that the processes itself works almost flawlessly shows that causes for delays and lack of stability lies between the operations. Thereby through ideation, evaluation and further development towards the conducted requirement specification, a solution to start with is to make sure the visual management works. A solution creating a complete overview of the production between all operations integrating new products with aftermarket using a new kind of visual production control boards. These visual production control boards will help prioritizing using FIFO queues and daily meetings, seeing capacity demands and troubles easy by stacking station- or areawise and also create an altogether working flow together with the current layout of the production site.

Further recommendations include further development of these visual production control boards together with implementing a CONWIP planning and control principle using wagons, standardize communications and continuously become more transparent inside the company. The proposed solutions might not guarantee N days inside the Järfälla production site but it will help operators, planners and management to easier locate problems and allocate capacity to increase the flexibility of the production.

KEYWORDS: Aftermarket, After Sales Services, High-Mix Low-Volume Production, Production Planning, Visual management

Sammanfattning

Detta examensarbete är det sista delen på civilingenjörsprogrammet Teknisk Design vid Luleå tekniska universitet, ett arbete som genomfördes mellan januari och september 2017 hos Saab AB Surveillance i Järfälla, Sverige. Syftet med examensarbete var att utföra en nulägesanalys över eftermarknadsproduktionen för att senare kunna ge förslag på förbättringar och kunna hjälpa till att skapa integration mellan eftermarknadsproduktion och produktionen av nya produkter.

Produkter som produceras av Saab i Järfälla används i militära försvarssammanhang där de större systemen inom elektronisk krigsföring (EW) och motåtgärder har mycket långa livscykler, t.ex. upp till 40 år och används i mycket krävande miljöer. Därmed har produkterna olika omfattande serviceavtal för inkludera support med reparationer, underhåll, leverans och transporter mellan Saab och kund. Ett av dessa serviceavtal kräver en genomsnittlig netto ledtid på N+12 dagar mellan kund och Saab för reparation varav N dagar maximalt hos produktionen i Saab Järfälla. Kartläggningen av situationen och hanteringen av all produktinformation i en produktion med hög variation och låg volym har inte varit lätt. Eftermarknadsprocesserna inom Järfälla inkluderar diagnostisering, reparation, montering och testning för att säkerställa produktens prestanda. Eftermarknaden delar även resurser med produktion av nyframställda produkter vilket är en av anledningarna till att skapa en stor skillnad i ledtidens standardavvikelse. Andra orsaker som informationshantering, prioritetsinferens, flexibilitetsproblem och dålig visuell hantering har medfört förseningar i produktionen.

Projektet har genomförts genom en utvecklingsprocess med olika metoder för att kartlägga den nuvarande situationen och att komma med nya idéer för att förbättra situationen. Det startade med en sökning i tillgänglig litteratur och forskning om HMLV-produktion, eftermarknadssituationer och lean principer, på att använda välkända metoder för att analysera som value stream mapping, Ishikawa diagram och datainsamling för att skapa en kravspecifikation för kommande lösningar.

Som ett resultat visar det faktum att processerna själva fungerar nästan felfritt och att orsakerna till förseningar och bristen på stabilitet ligger istället mellan operationerna. Därigenom genom idégenerering, utvärdering och vidareutveckling mot den genomförda kravspecifikationen, är en lösning till att börja med att se till att den visuella hanteringen fungerar. En framställd lösning som skapar en fullständig översikt över produktionen mellan alla verksamheter som integrerar nya produkter med eftermarknaden med hjälp av en ny typ av visuella produktionsstyrningstavlor. Dessa visuella produktionsstyrningstavlorna kommer att bidra till att hjälpa prioritera genom att använda sig av FIFO-köer och dagliga möten, eftersom kapacitetsbehov och problem är enkla genom att istället stapla station- eller områdesvis och skapa ett helt arbetsflöde tillsammans med produktionsplatsens nuvarande layout.

Ytterligare rekommendationer inkluderar vidareutveckling av dessa visuella produktionsstyrningstavlorna tillsammans med implementering av en CONWIP planerings- och kontrollprincip med hjälp av vagnar, standardisering av kommunikationer och att kontinuerligt bli mer transparenta inom företaget. Lösningarna kan inte helt garantera N dagar på Järfällas produktionsplats, men det kommer att hjälpa operatörer, planerare och ledare att lättare hitta problem och fördela kapacitet för att öka produktionens flexibilitet.

NYCKELORD: Eftermarknad, Hög-variation låg-volym produktion, Produktionsplanering, Visuell styrning, Produktionsvisualisering

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1 Introduction

This thesis is the last step to complete a Master of Science degree within Industrial Design Engineering towards Production Design, at Luleå University of Technology (LTU). It consists of 30 credits (hp) and is conducted through January to September 2017 in cooperation with Saab Surveillance in Järfälla, Sweden. The aim of the project is to define and map the current situation of the aftermarket production flow to provide sufficient information for having a turn-around inside the factory at Saab Järfälla consisting of a maximum N days. This chapter introduces the project through its incentives, stakeholders, objectives and aims, along with the project's scope and the outline of the thesis.

1.1 Project incentives

The Sourcing and Production division at Saab Surveillance in Järfälla and Gothenburg are in synchronization with each other in form of how the production operates. With orders from the top of Saabs organization, they have started a change in focus on what to improve on a production level at both Järfälla and Gothenburg. Recently Saab begun placing resources to formulate a new production flow for both new and after sales products inside the factory in Järfälla. A team consisting of three persons has the key initiative to make suggestions on how the production flow for new products should fit inside the organization. The aftermarket production is not a part of their assignment but this is where the majority of this project comes in.

The aftermarket is driven by In Service Support (ISS)-agreements and supports for services on all of Saabs products. Saab is constantly working to become more efficient and evolve in every aspect of their business and services. The aftermarket is a major key for the success of Saab and has a great need to become faster and more efficient, since the high cost of binding capital and penalty fees when they are not able to resolve product defects on a short basis. Most of the products produced have a very long lifespan, i.e. up to 30-40 years, and thereby have long service agreements. This makes it extremely important to keep close contact with subcontractors and great knowledge of possible lead-times of material and information inside the factory.

In the current situation at Saab Järfälla, an operator or planner together with the project management can apply a disruption clause in service agreement meaning that they can set a product to stop and days won't be counted as the product went out of production. Using accepted interruptions in the disruption clause has led to problems, since it's easier to set a product to stop and load up units than addressing the root of the problem. However, new agreement negotiations will demand the product to be moving inside the production system and that the disruption clause can only be used in specific cases and in a minimal amount or penalty fees will be applied.

A frequent problem in the after sales production flow is misdiagnoses when swapping personnel between the test persons and the technical design authority (TDA), in charge of product structure. The TDA is located outside the production unit and the diagnosis could sometimes mean that the person brings the product to their seat. The products at Saab are for the most part ESD-classed and should not leave the specific production area since it provides an additional chance for new errors. Also, this may contribute to that the product is hard to locate or lost entirely for the production planners.

The products from Saab Surveillance in Järfälla are used in harsh environments on military aircraft and equipment for national defense and must be produced with special care. With products ranging from a small circuit board to a full scale unit, Saab Järfälla has to conform to a high-mix/low-volume production system to reduce lead times and improve organizational structure. Most methods for improving production systems, such as lean, are adapted for manufacturers who creates new product, high product volume and has low variation in their product mix. This means that a key element during the thesis project is to find and adapt methods for optimal after sales services with high-mix/low-volume characteristics. Where it can be integrated with current development of the production flow of new products.

1.2 Project stakeholders

This master thesis project is made for Saab Surveillance in Järfälla, Sweden, our main stakeholder. Our project employer Sven Pettersson, Manager of Production Planning, together with the group that works with production flow of new products will use this thesis to develop the after sales production and combine these two production flows to create a better production flow in the whole factory. Combined with project supervisors, examiner and other involved personnel at Saab are considered as *supervisory stakeholders.* These stakeholders have influenced the project and hold certain expectations in form of execution, content and result of this project.

Hopefully this thesis will help the after sales production to have a turn-around time consisting of a maximum N days. This will lead to no delayed payment penalties and more satisfied customers. The thesis will also help to ensure a basis for the all the operators and managers to ensure a better working environment through better understanding of the after sales production and a less stressful through a more continuous production flow. These are considered the *user stakeholders* of this project.

1.3 Objectives and aims

The objective of the project is to study Saab Järfälla's current after sales production flow by mapping and analyzing to be able to give Saab suggestions for improvements. How the after sales flow could be integrated into production flow of new products and stabilize the turn-around time inside the factory.

The aim of the project is to create an extensive analysis over the current situation in the after sales production flow, and suggest solutions to ensure the time frames of N days are kept. To fulfill the objectives and aims of the project with optimal result, one main research question with three sub questions will be answered:

Main RQ1. How can the after sales service production flow with HMLV characteristics be improved to manage an N days turn-around through the factory?

Sub RQ1. Which principles or methods should be used to stabilize the after sales service flow?

Sub RQ2. How should an after sales services flow be designed and developed to be integrated with the production flow of new products?

Sub RQ3. Where and what variables affect and create delays in the after sales service flow?

1.4 Project scope

At the aftermarket production there are many products that go through the production flow therefore in this project in order to produce a prominent result within the project aims and objectives, we do not have enough time to include all of them. And have focused our data on a few products and product families with characteristics that defines the after sales services in flow and system relevant to the thesis project. The largest focus of the project has been on defining the current state, finding deficiencies and improving the production flow of a few products of the after sales services.

The following delimitations were made to keep within the boundaries of the project resources:

- The project will not take account for the changes made in the production flow of new product, but use the changes to integrate the aftermarket flow into the flow of new products.
- The project will not include any calculations for eventual investments.
- The report will give suggestions for improvements and recommendations how they can be implemented or further developed but implementation will only be tested if time allows.

This master thesis concludes 30 credits of studies, which corresponds to 20 full work weeks or 800 hours per person between January to September 2017. The thesis work includes two presentations; a midterm presentation and a final presentation, which is both examined by project supervisor, examiner and an opponent.

1.5 Thesis outline

The master thesis report consists of the following information in the chronological order it was performed in the project.

Chapter 1 presents the project's incentives, stakeholders, scope, objectives and aims. Chapter 2 describes the case company, Saab AB Järfälla and the background of the involved parts of the thesis projects. Chapter 3 creates a theoretical foundation for the discussions, analyzes and conclusions drawn in the project. How the project was conducted is explained in Chapter 4, answering in stages what, why and how each step was taken. In Chapter 5 to 6, the current state of Saab AB Järfälla's production is mapped and analyzed in order to conduct a requirement specification for further developed solutions. Further in Chapter 7 is the ideation, evaluation and development of many solutions and concepts explained to choose a final concept for additional development. Chapter 8 describes the chosen concept in ways of change to current situation, what principles is used in order to make it work and how it supposed to work physically. The project's execution, results, relevance and conclusions is critically discussed in Chapter 9 with regards to the objectives, aims and company goals with specified in the scope of the project. In Chapter 10, the final results are summarized with easy read recommendations for future development of the whole production of Saab Järfälla.

1.6 Abbreviations

ALT	Average lead time
AT	Acceptance test
CONWIP	CONstant Work In Progress
ESD	ElectroStatic Discharge
FD	Fault Diagnosis
FIFO	First-In-First-Out
HMLV	High Mix/Low Volume
HVLV	High Volume/Low Variation
IFS	Industrial and Finance System
LRU	Line Replaceable Unit
OEM	Original Equipment Manufacturer
SB	SpringBok
SPM	Sub-project Manager
SRU	Shop Replaceable Unit
S&S	Support & Services (Business Area in Saab AB)
TDA	Technical Design Advisor
TPS	Toyota Production System
VSM	Value Stream Mapping
WIP	Work In Progress

2 Contextual framework

In this section a description of the history of the company is explained, to understand the bigger picture and the surroundings of this thesis. Followed by a production process description of the analyzed parts of the production and the future goals of the production. This will help to understand why this thesis is made and how it will affect the company later. The information in this section is based on discussions with employees, our tours around the production and complementary information taken from the company website. Because of all the visual and verbal information, this company description is described from the employee's point of view.

2.1 Company Introduction

Saab AB, originally called Svenska Aeroplan Aktiebolaget, is a Swedish company with a long history in military defense industry solutions. Founded 1937 in Trollhättan with the aim to prepare for the worst in the ongoing conflict in Europe by providing the nation with military aircraft. The company has ventured through different strings of moving mechanical solutions from aircrafts to cars. Today Saab focuses on wide array of high-tech products, solutions and services with everything from military defense and aerospace to civil security. (Saab AB, 2017a)

Saab is divided into seven business areas (Figure 1) providing products, services and solutions in their respective field. The production site in Järfälla belongs to the business area Surveillance, previously named Electronic Defense Systems that provides and produces airborne, ground-based and naval radar solutions, electronic warfare self-production-, combat- and traffic management systems. (Saab AB, 2017a)

Sourcing and Production is a division of Surveillance where all of their sourcing and manufacturing activities in Sweden are gathered. It consists of four major departments; Global Sourcing, Operational Excellence & Quality Management and the two production sites in Järfälla and Gothenburg. In Järfälla the main products manufactured are electronic warfare-, combat- and countermeasure systems. These are assembled through various kinds of process steps in a high-mix low-volume production environment where Saab manufactures most of the inherent components inside the products

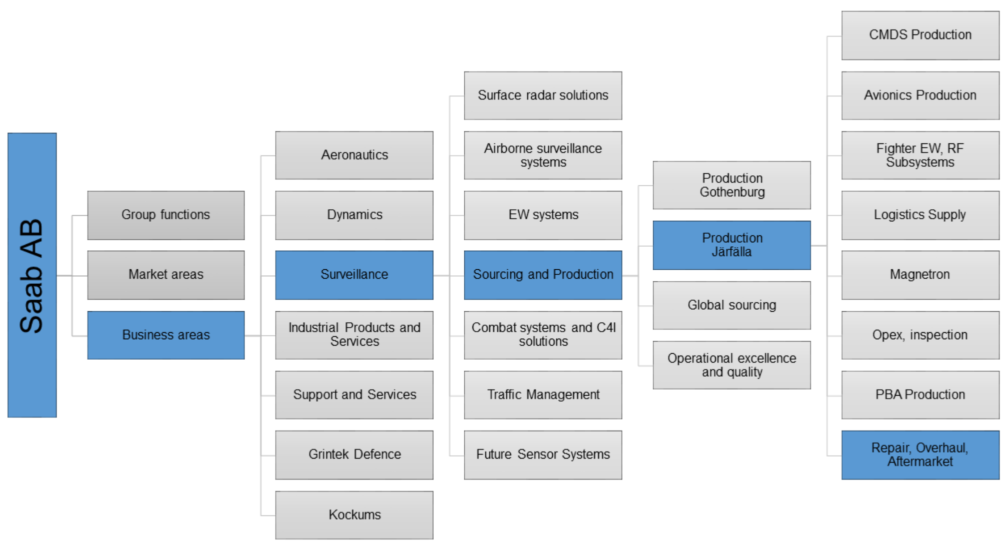

Figure 1: Structure of the organization through the outline of this thesis project.

themselves. Production activities at Järfälla include assembly, test, planning, procurement, production engineering, material handling, receiving inspection, maintenance and storage. Roughly 380 people are employed in the Sourcing and Production division whereas 170 of them in production at the Järfälla site.

2.2 Repair, Overhaul and Aftermarket

Most of Saab AB's products are made to have a very long life cycle and is thereby maintained through different service agreements conducted with the purchase of the product. These service agreements contain support of different kinds including repairs, preventive maintenance, supply of parts, follow ups, documentation and any transports that may seem necessary between Saab and client.

Saab AB is involved with several long-term service agreements with different clients. One of these service agreements covers maintenance, support systems, and reparations for Saab's products has demanded net average lead time of N+12 days between the client and Saab AB's facilities. This is an agreement conducted after the original purchase and the repairs, maintenance and storage assignments moved inside Saab AB is conducted in a separate project for all involved parts from the newly produced products.

The movement is illustrated in Figure 2 where the client sends the unit for maintenance mostly through to Saab Support & Services (S&S) located in Arboga, Sweden, who administers and makes a physical first look at the unit but sometimes directly to Saab's production site in Järfälla. At Saab Järfälla the unit is diagnosed for errors, determined for actions on the sub units, reinstalled and assembled, then rediagnosed to able send back the unit directly to the client or through Saab Support & Services.

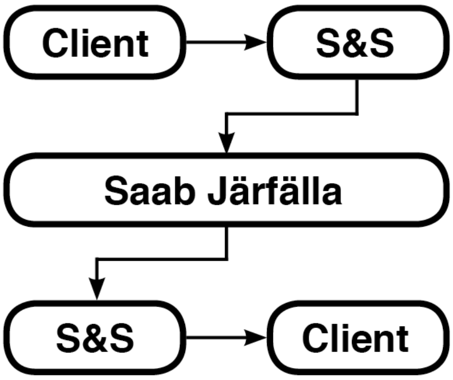

Figure 2: Movement of the Service agreement's after sales services flow through different facilities.

In the current state of the agreement, a disruption clause onto the net average lead time can be chosen to be applied by Saab AB if it follows one of the contractual criteria's. The disruption clause stops the count of the net average lead time in order for Saab AB to get sufficient information or materials. A penalty fee can be taken out by the client depending on how many days the products arrives late during a year.

3 Theoretical framework

This section acts as a theoretical backbone to strengthen and support the conclusions and results conducted through the project. The theoretical framework is built upon an introduction to Industrial Design Engineering to ensure the project's relevance to the university programme, and then proceeds to presents narrower areas relevant to the research questions. The presented areas involve insights into lean production through its organizational strategy for efficient production, high-mix/low-volume production approaches overall and with lean, and the after sales services definitions, similarities and differences.

3.1 Industrial Design Engineering

The theoretical framework of this master thesis lies within the area of Industrial Design Engineering, a broad subject concluded as the interference between Industrial Design and Design Engineering where industrial design runs parallel to design engineering (Dumas, 2000). Industrial Design studies function and form and is the connection between developing products, systems, organizations, processes and/or services with main focus in the subjects' human-machine relations, sustainability, human needs and efficiency. It provides a more aesthetic or style concerning design, to include both the technical and physical parts along with the subjects above (Dumas, 2000). The foundation of this master thesis lies within production development and is a key part in Industrial design engineering.

3.2 Production development

As a branch to the big industrial design tree, production development is the creation of building and improving effective production systems but also to streamline the already existing systems (Bellgran & Säfsten, 2005). Bellgran & Säfsten (2005) describes that in most companies, production development is an object for continuous development in the way of working, in the organization and methods used.

A production system can be described as the transformation from input to output, see Figure 3. This transformation is compared to a black box where everything that is necessary for the transformation is put in and later comes out as a product or component (Wu, 1994).

Figure 3: Black box theory (Wu, 1994).

For this project the focus is to analyze and improving an already existing production system. This lies inside the black box and will be a part of the transformation from input to output. Bellgran & Säfsten (2005) has developed a structured way of working, which Abrahamsson et al. (2016) explain improves the effectiveness and simplifies the work. A structured way of working leads to less time figuring out what to do and in the order to do it. Instead that time can be put on finding the right information, design and evaluate the solutions which later affect the production system (Abrahamsson et al., 2016).

When improving and developing an existing production system, the level of education, experience and knowledge among the people developing the system is an essential ingredient for success (Bellgran & Säfsten, 2005). Having people from all the levels in the hierarchy tree is a great advantage and crucial for making a successful development work. The operators are often production technicians and have a lot of experience of the existing production and the productions technical function (Bellgran & Säfsten, 2005). In the higher level of the hierarchy tree lays the experience in project management, economy as well as the knowledge of the activity development, which also is much needed when developing a production system.

3.3 Lean Production

Lean production, lean manufacturing or just lean is an organizational philosophy originated from the Japanese automotive manufacturer Toyota's production system (TPS) made famous by Womack's book "The machine that changed the World" published in 1990 (Holweg, 2007; Ohno, 1988). The term lean production is most famous for being a concept replacing mass production with a target to eliminate wastes in a production system (Womack, Jones & Roos, 1990).

Lean production stands for a rationalized production system where the focus lies in the capital bound by the products instead of solely on the labor and fixed capital. In combination to achieve a lean production various methods are used such as just-in-time (JIT), standardization, 5S, kanban, quality assurance, continuous improvement, with more (Johansson & Abrahamsson, 2011).

To start implementing lean production, a production strategy can be used and modified after TPS to create the House of Lean of your own company (Figure 4). The House is not constrained to look exactly like in Figure 4 but the features of stability, values, continuous improvements (kaizen),

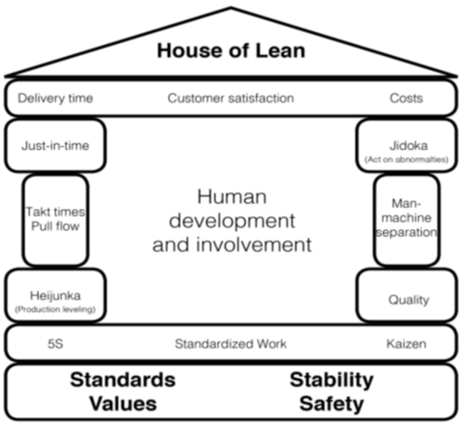

Figure 4: the House of Lean, modified after Kaizen Institute (2017) and Effective Partnerships Inc. (2017).

standardized work and so forth is used as foundation for the whole organization. The left pillar consists of JIT features of the production. The right pillar consists of cooperation between autonomy and intelligent automation, jidoka. Together they hold up the roof to results in lead- and delivery time reduction, cost efficiency and customer satisfaction. (Kaizen Institute, 2017; Effective Partnerships Inc., 2017)

As a growing understanding and experience by both researchers and practitioners of lean evolves, Petersson et al. (2015) explains that it becomes increasingly clear that lean is not an activity or method that can just be implemented then left alone in order to get better. It has rather become an approach or long-term strategy for how the business should be managed. To use lean is instead about working step by step continuously into a vision of a desired state, where value is created and there are no wastes in the system.

3.3.1 Waste elimination

Something that has been adapted from TPS to lean is the philosophy to identify and eliminate waste, or muda. Liker (2004) defines the answer to what customer (both internally and externally) wants from the processes as a value-adding activity and that everything else is waste. Toyota identified seven major types of non-value adding waste in a manufacturing industry which has been updated by eighth waste by Liker (2004). This is more popularly known as the 7+1 wastes which is according to Liker (2004) waste in terms of:

- Overproduction
- Time on hand i.e. waiting
- Transportation or conveyance
- Overprocessing or incorrect processing
- Excess inventory
- Unnecessary movement
- Defects
- Unused employee creativity.

3.3.2 Work In Process, JIT, pull, Kanban and CONWIP

The idea of just-in-time, JIT, builds on the approach of an unwillingness to have more than absolutely necessary material and only provide a certain component in the exact right time and location when it is needed rather than before (Schonberger, 1982). A principle that with different sets of tools and techniques can help generate a production in small quantities with short lead times and large variation to a specific customer demand (Bellgran & Säfsten, 2005). Through JIT, this keeps the work-in-process (WIP) to a minimum, since the material handling is considered in all inventory stages of the production system (Schonberger, 1982).

In a JIT system, the production flow is controlled by the customer order and not by any processes, also known as a make-to-order (MTO) system. A MTO system is a system that pulls products through the production system, meaning that manufacturing orders is only given to the final processing stage of the material flow chain and from there retrieves parts from previous stage, which in turn retrieves parts from further upstream. This causes an effect that only products that are already has a physical demand gets produced. An MTO system handles production of products with a high mix of parts to small quantities. (Bellgran & Säfsten, 2005)

To calculate the WIP-level of the production system Little's law is often used where the planned lead time and rate of throughput for each product (Segerstedt, 2009):

WIP = Throughput rate • lead time

A method inside lean production to manage and to assure the left pillar of the house of lean *(Section 3.3 Lean production)* and JIT production is called kanban. Kanban is Japanese for "card" and the method itself is a simple form as a card for communication directed and located at the point where it is needed. There're different kinds of kanban systems according to Ohno (1988) and Liker (2003) such as Transport kanban that authorize transport to downstream station and Production (in-process) kanban that allows upstreaming station to produce. In TPS kanban is represented by physical card moving through the product cycle triggering the pull flow of JIT manufacturing to better visualize material- and information flow, identify involuntary inventory, stops and "bottlenecks" in the production system (Ohno, 1988; Liker, 2003).

CONstant Work In Process, CONWIP is a theory for having control of WIP in the production. Unlike the Kanban theory where there is a maximum WIP in the inventories, CONWIP have a maximum WIP for the whole line (Segerstedt, 2009). This means that if the line has a maximum of 20 products of WIP the production cannot release a new product before one has left the line. For this theory the production does not have to count products for WIP, if it is possible they can count pallets in the production (Segerstedt, 2009). This will make it easier to have control over the number of WIP in the production.

3.3.3 Resource, flow efficiency and variability

How efficient a production system could be analyzed in two ways, through resource efficiency and/or flow efficiency (Modig & Åhlström, 2013). Modig and Åhlström (2013) describe resource efficiency as a value measurement of each resource, machine or workers effect in prospect to the available work time. Further they describe flow efficiency not as a focus in resources, but in the parts being processed through the production system in relation to throughput rate. The basis for flow efficiency is to increase the throughput rate of products to a maximum, without decreasing or risking quality by reducing the non-value adding time to a minimum (Modig & Åhlström, 2013).

In a more traditional and common production system where resource efficiency usually has the main focus, the lead time is longer and WIP is larger (Modig & Åhlström, 2013). This originates from the need for every resource to constantly remain active at all available time. In a resource efficient system, it is considered better ensure that each resource have a buffer waiting to be used to keep the utilization to 100 % leading to an increase in lead time according to the previously mentioned Little's law.

Modig and Åhlström (2013) presents an efficiency matrix with axis of resource and flow efficiency from low to high in four types of states a production organization could find themselves in, as illustrated in Figure 5.

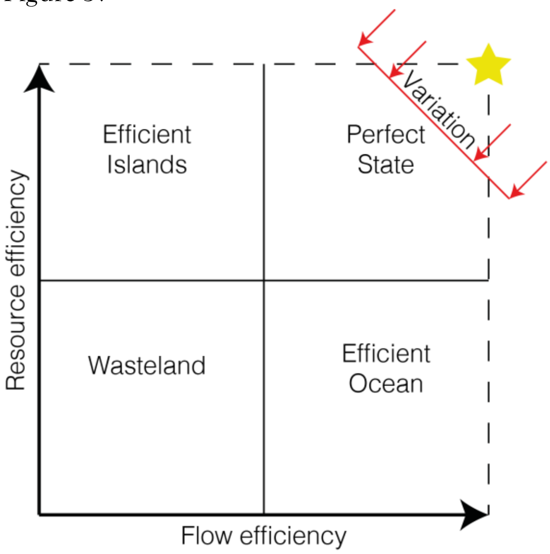

Figure 5: Flow and resource efficiency matrix (Modig & Åhlström, 2013).

The upper left state, called Efficient Islands, is a system where each resource is considered to work independently towards maximizing their utilization. Between these "islands" are buffers, which leads to unnecessary wait time and bound capital. The lower right state, Efficient Ocean, a system which has a main focus on creating value for the customer and the product by maximizing the flow efficiency. By creating an efficient production flow between resources, at the expense of having a lower utilization of resources since they are only used when needed and kept waiting when the demand is lower. The lower left state, Wasteland, is a system with neither good resource efficiency nor good flow efficiency. An undesirable state where resources and customer values are considered wasted. The Perfect State as the name says is a desirable state which all organization strive to achieve. This state is considered by Modig and Åhlström (2013) exceptionally hard to achieve, mainly because from the start it is hard to create a successful combination of resource efficiency and flow efficiency, but also because every production system has variations that limits their ability to reach certain points in the efficiency matrix. The variations of the production system create an efficiency front which limits the operational state an organization can attain, dependent on variations in demand, resources and products (Modig & Åhlström, 2013). Variation has major impact on flow efficiency, this can be explained by Kingman's equation Figure 6 which illustrates the correlation between variation, resource efficiency and lead time, shows as you have more and more resource efficiency while having more variation, the lead time will grow (Kingman, 1966). The more proficient an organization is to develop an organizational strategy to anticipate demand together with ensuring a flexible and reliable supply chain, the less impact the efficiency front will have (Modig & Åhlström, 2013).

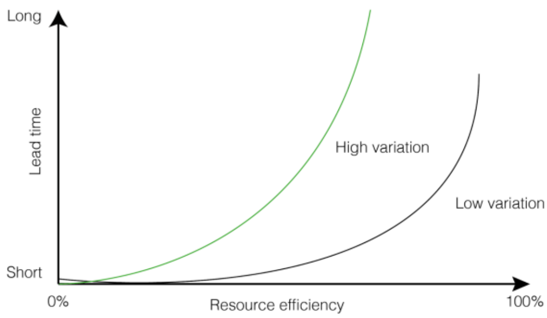

Figure 6: Kingman´s equation (Kingman, 1966).

The efficiency matrix Figure 5 serves as a foundation to create a general understanding of lean on a universal level. The definition of lean needs to be understood as a philosophy and organizational strategy for the way of improving life in a highly abstract level instead of meaning tools or methods to improve or lose waste in specific areas. In the matrix, reaching closer to the "star" of a perfect state is a matter of strategy. Modig and Åhlström (2013) explain a lean organizational strategy should have fundamental main focus on flow efficiency before resource efficiency, never the other way around. When success has been made in flow efficiency through various theories and methods, later it becomes relevant to focus on each resource inside the production flow.

3.4 High-mix/low-volume production

There are several varieties of part classes in manufacturing, the two most extreme are high volume/low variety (HVLV), and high mix/low volume (HMLV) production. Where the former is more commonly exercises classic manufacturing method whilst HMLV manufacturers must continuously adapt to market changes through the constant change of demand. (Pandian, Yang & Liu, 2010)

Jina, Bhattacharya and Walton (1997) suggests that HMLV has typically a characteristic of an annual production volume of less than 20,000 units with mostly bespoke products, whereas an HVLV typically produce more than 100,000 units per year of less complexity and variety.

According to Irani (2011) the fundamental differences between a high mix/low volume and a high volume/low variety organizations are that a HMLV has unlike HVLV:

- A high variation in demand and delivery dates
- Complex material flows due to the large variety of products, also leading to variable setup- and cycle times between different routings
- Complex production control and scheduling
- Limited influence on supplier delivery dates
- Limited ability to train the workforce and focus on continuous improvement

Jina et al. (1997) states that HMLV organizations are also generally experiencing more "turbulence" than mass producers, explained as a volatility and unreliability of inputs to achieve desired outputs in the manufacturing system. The authors have identified four types of causal factors creating more turbulence in HMLV production as:

1. Schedule changes
2. Product mix
3. Changes in product volumes
4. Frequency of design changes of the products

These are considered to have far greater impact on HMLV manufacturing than a company with mass production (Jina et al., 1997). HMLV organizations are considered to be bound to use a make-to-order approach in their production according to Jina et al (1997).

3.4.1 HMLV and lean production

Together with the nowadays lean tools a HMLV production systems could have a hard time accessing the value and applicability of the tools that a normal high volume, low variety manufacturer can (Irani, 2011). Irani (2011) states that some of the lean tools could fit HMLV but some ought to be replaced by more appropriate methods that could handle the complexities in a HMLV production. Outlined in Figure 7 he states the tools as those of which would be essential to any production system and which would be less workable or too complex inside a HMLV production.

Lean tools that work in any production system
5S
Employee involvement
Strategic planning
Visual management
Jidoka
Quality at the source
Standardization

Tools that may not be suitable in most HMLV systems
One-piece flow cells
Product-specific kanbans
FIFO sequencing at work centers
Tak time/level loading (Heijunka)
Value stream mapping
Pacemaker scheduling
Inventory supermarkets
Single function manual machines
Assembly line balancing

Figure 7: Lean tools who may or may not be suitable in HMLV systems (Irani, 2011)

Raghavan, Yoon, & Srihari (2014), Pandian, Yang & Liu (2010) and Wang, Mohamed, Abourizk & Rawa (2009) shows in their results, effects of reduced lead-time, better product and process quality and additional positive effects by implementing certain general lean tools into a production system with HMLV characteristics.

Standards and general strategies mainly used in mass producing companies explains Jina et al. (1997) needs almost in all cases a modification and extensive research for each HMLV manufacturer's to be able to adapt their own values and standards into the production system.

Lane (2007) suggests implementation steps of lean into an HMLV organization by first focus on the quality of the work and products. Once the quality is stable, design a better way for using visual management to align volume with capacity in the production system. Next vital thing to do is to associate a time with each operation to set expectations for production and planning, often used methods are First-In-First-Out (FIFO)-boards or day-by-hour boards. Once these things are done, first then Lane (2007) suggests that you can begin using various lean tools.

3.5 After-sales services

Products have followed the evolution of cultural, sociological and sustainable needs as well as the success of technological prosperity. This pushes the customers to make greater demands on the durability of the product other than the joy of buying and owning, forcing industrial companies to shift their objective from a "only product" manufacturer to a "product and service" provider (Pezzotta, Cavalieri & Gaiardelli, 2008).

According to Lewitt (1983), the initial sale of a product is only the beginning of a seller-buyer relationship where a long lasting contract or relation could enhance profitability, making after-sales services essential for a company's short term and long term success. To be able to provide a flexible, strategic and competitive after-sales service in the manufacturing industry has strong connections to company profitability, customer retention and product development (Saccani, Johansson & Perona, 2007).

Goffin (1999) has summarized the role of after-sales services as a relevant source of revenue, competitive advantage and a lever for profit and customer satisfaction in the manufacturing industry.

Patton and Bleuel (2000) have formed two basic concepts of after-sale services. The first one as a customer buys a product to excel in capability and productivity of their choice, it is the after-sale services purpose to help the customer to maintain and optimize the product performance. The second one is the obligation of the manufacturer to ensure what the product promises in levels of performance and applicability in form of marketing perspective.

Through Bundschuh and Dezvane (2003), the after-sales service market often called the aftermarket has been found to be four or five times larger than the market of new products. And after-sales services and spare parts may generate more than three times the turnover of the original purchase during the product life-cycle (Wise & Baumgartner, 1999).

3.5.1 After-sales service management in the manufacturing industry

Findings by Saccani et al. (2007) shows that the configuration of the aftermarket supply chain has no "best way" but instead has to be based on which approach that the company chooses to adopt. The authors mentions that the approach should be based on multiple factors; on the product in substitutability, complexity and life-cycle; on the company's after-sales strategy in quality, differentiation and/or cost management; and the products distribution supply chain. Considering all the factors together could help make the choice to configure an optimized trade-off between cost and service performance in the after-sales supply chain.

Three major activities are identified to play a crucial role in the manufacturing industry are field technical assistance, spare parts distribution and customer care (Saccani et al., 2007). These are necessary to align with an aim of having a convincing and profound after sales offer (Saccani et al., 2007). Patton and Bleuel (2000) underlines ten techniques that are considered most important for managing service parts in Figure 8.

1. Gain management support
2. Emphasize customer satisfaction
3. Establish goals
4. Use life cycle cost and profit analysis
5. Minimize personnel delays
6. Centralize
7. Concentrate on the critical few
8. Control provision, forecasting, and excess
9. Promote quality
10. Use computers to expand on human capabilities

Figure 8: Ten techniques concerning managing service parts (Patton and Bleuel, 2000).

Decontextualizing these principles by Patton and Bleuel (2000) means that to champion the aftermarket, the organization need to be lifted by supporting management that ensures customers positive response. Measurements by creating challenging, achievable and well written goals for customer response, personnel and organization. Using life-cycle cost and profit analysis to be able to exceed service demands, contracts and customer retention. Be able to minimize transports and plan ahead inside the factory with a good inventory and visual management system. Part stocks needs to be located at the point need, but additional supply should be centralized to rapidly be able to use them in service handling or manufacturing. Using Pareto's 80/20-rule, focus on the critical few meaning to focus the energy on those products. Furthermore, Patton and Bleuel (2000) states to control and promote quality, an after sales strategy for meeting customers' needs through controlling how the company acts with inventory policies. Then use computers and systems to keep track on every number and stock to be ready for every consequence.

3.5.2 After-sales services from a sustainable perspective

Saab who has large focus on product manufacturing, but also on providing services and support to their aftermarket inside their organization. The entire organization, especially the aftermarket, has to keep up with the demand of the increasing market complexity and competitive intensity by continuously improve their service business. Gebauer (2008) means that after-sales service providers has to concentrate on cost leadership and ensure to have a properly functioning product. Cost leadership means making the after sales services standardized and predefined to achieve substantial economic growth and manufacturing efficiency (Gebauer, 2008).

A new high technological products life-cycle should always begin according to Mildenberger and Kare (2000) with a proper concept and design that corresponds with a retirement phase to ensure the social, economical and environmental aspects of today's world. Socially an after sales service provider in high-tech industries needs to focus and ensure customer satisfaction and retention to be able to compete with similar providers (Cohen & Lee, 1990).

An after sales service creates an additional win-win situation for both customers and providers by adding life and value to the product and the relationship (Kumar, Markeset & Kumar, 2004). Negotiating a service agreement considers a relation to the occurrence of planned maintenance, unpredictable failures and warranties to create long lasting bond between the two parties. Kumar et al. (2004) further implies that in a manufacturing company with their own after sales services, service agreements shows specific technical requirements that pushes the company to have a high efficiency and uptime, as well as quality and low cost, in their production system. Making the availability of the production system, through reliability, maintainability and supportability, one of the most crucial insights of a service agreement (Kumar et al., 2004), illustrated in Figure 9. In some cases, concerning high-technology machines and applications, most products have long life-cycle from 25 to 40 years and needs to be treated with an agreement covering the overall aspects of a sustainable future for the company, the customer and the environment (Mildenberger & Kare, 2000; Kumar et al., 2004). The key is to always have value adding for each involved party to safeguard a long-term relationship between the client and service provider.

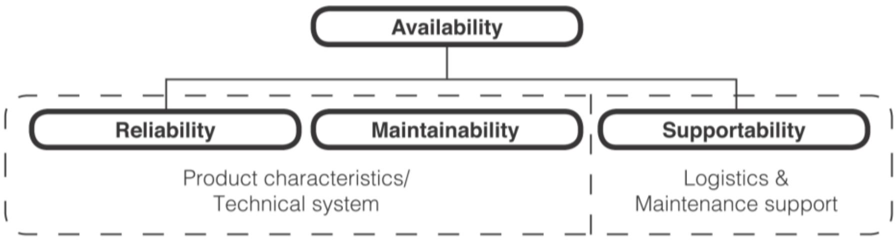

Figure 9: Elements of availability (Kumar et al., 2004).

4 Course of Action

This chapter describes the processes and methodology of this thesis. The eight phases that is described in 4.1 Process is the structure of this chapter. Each phase is first described and later their corresponding methods are explained. First the theory concerning the method and then how and why our work with the method were executed.

4.1 Process

The project is outlined by Plan-Do-Study-Act (PDSA) cycle (Figure 10), a cyclical flow diagram for learning, improvement and quality assurance of the project. This is an iterative process that includes the four stages of the title. The foundation of the cycle is the planning stage that answers the questions of *which? what? who? where?* and compares the possible outcomes to achieve the goal of the project. The do stage concentrates on to carry out the plan from previous stage by either testing, collecting data or start analyzing the data. The study stage focuses on the collected data and results, how the results correspond to the projections of the project and to summarize the information obtained. The act stage is about using a decision or prediction to either act by implementing the new change, abandon it or possibly run through the cycle again through different conditions. As an iterative process when the cycle is complete, the process starts over on the planning stage. (Deming, 1993)

This project will mostly fall under the planning and do stage since the project will make an extensive mapping of situation at Saab. The stages it selves will be followed by the phases in project spiral (Ranhagen, 1995) to conclude a study for Saab if they want to act on the result.

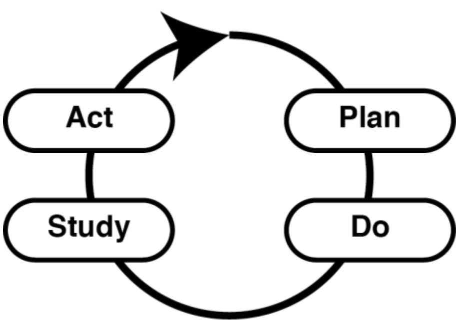

Figure 10: PDSA-cycle modified after Deming (1993).

The project spiral and circle will be part of the iterative work during the project as guideline for success. Ranhagen's (1995) circle consists of eight steps divided into three laps resembling a spiral. The general model includes the following eight steps:

1. Plan for changes
2. Diagnose the current state and future state
3. Formulate goals and specifications
4. Search for alternatives
5. Summarizing, evaluate and choose concept
6. Develop and finalize chosen concept
7. Carry out stepwise
8. Follow up and evaluate effects learnt

These eight steps will set up the order for this chapter and the guide for the methodology used in this thesis. Illustrated in Figure 11 are the phases used specific for this thesis project. The thesis project as

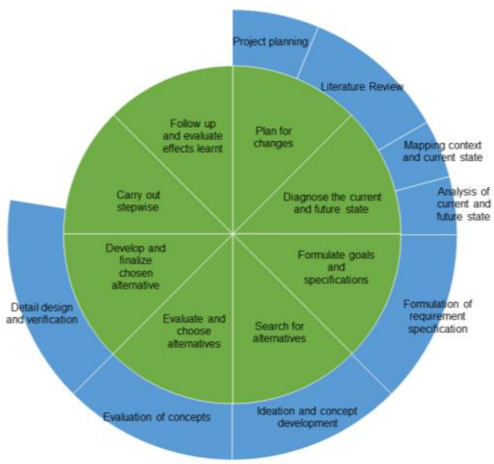

Figure 11: The project circle (Ranhagen, 1995) outlined with the involved parts used in this project.

shown in the project circle and previously mentioned falls mostly under the diagnosing and analyzing stage to be able to create an extensive diagnosis of the current situation. With a goal to be able to come up with improvements. Meaning that the stages 7 and 8 inside the project circle will be mentioned by suggestions how these solutions and improvements may be implemented.

4.2 Plan for changes

This phase holds all the information about how the project's own planning was conducted and based on.

4.2.1 Project planning

This project has taken place from January 16th to the beginning of September. During the first period of time, between January through March, both of the group members started early by studying 50 % on the thesis project to make up for the industrial vacation that shutdown the production for four weeks in the month of July.

The project was divided into different phases. The first phases contained more of a theoretical and contextual approach to the project, to include a focus area of the project concerning goals, scope, planned approaches and resource planning. This resulted in a project plan with an overview of every phase and resource overlooked by both the university and the company to ensure the quality and content of a master thesis.

To ensure time- and resources would be met and visualized, a Gantt chart was created. The Gantt chart together with goals and time limitations of each phase acted as a guideline for the progression of this project. A summarized version of the resource plan, Gantt chart and goals of each phase is shown in Appendix 1. Being two persons in the thesis project, coordination through the project was essential for each person to have all information available. Documents for weekly and monthly goals were established every Monday. This included what we need to do to hold up to the deadlines that were coming up. Later to make it easier for us to go back and check for what has been done, we created a work log that was updated daily and summarized weekly every Friday.

4.2.2 Literature review

The literature review acted as theoretical basis to ensure the project has reliable background for each conducted outcome. The literature review sought to answer the previously written main- and sub-research questions inside different areas. These research questions are illustrated in Figure 12 and will together with the project's results and theoretical frameworks help answer the questions through the project.

The literature was found for the most part using search engines accessed through the LTU's network and library. The searches

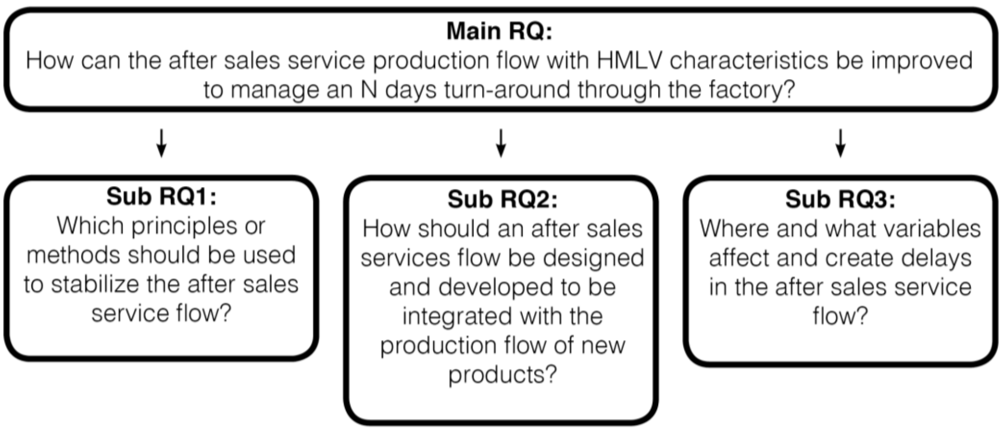

Figure 12: Research questions sought to answer through the thesis project.

were made for the most part through the search engines *Scopus* and *Web of Science*, but also through *Primo* and *Google Scholar*. Phrases used in the search involved but was not limited to; after sales service, aftermarket, high mix low volume production, lean production, material handling, optimization, material flow, production development, production planning and control, and national defense equipment. Articles and books were chosen mainly through relevance of their titles and abstracts, through used citations in previously executed master theses with similar topics in regards to the research questions. The books were gathered with help from library staff and supervisor at LTU or from former attended courses during the university programme Industrial Design Engineering.

4.3 Diagnose the current state and future state

This phase holds all the collected data and information about the current and future state in the after sales service production at Saab Järfälla. The objective of the phase was to acquire a foundation on which the after sales services at Saab stands on through various data collections and mapping of the relevant products causing problems in the productions to get results which can help reach a more desirable state.

4.3.1 Data collection

In order to gain experience how the after sales production flow operates, continuous observations, interviews and data collections were conducted. The data collection continued throughout the project by following product's way through the production system by documenting operator's pace, lead-time, involved operators, operations, locations in the factory and material handling.

Interviews

Interviews according to Osvalder, Rose and Karlsson (2011) is a way of obtaining quick and personal intel of workers' opinions, relevant knowledge, experiences and understanding of processes and underlying work culture.

Multiple interviews were conducted throughout the project process. At first, open structured (Osvalder et al., 2011) interviews were made with planners, material handlers, managers and other personnel involved in the project, to gain an idea of what problems Saab are having and vague individual opinions of the workers' situation. As the project proceeded, the interviews grew to be more semi-structured to get more detailed information about the specific processes and difficulties (Osvalder et al., 2011).

Around fifteen semi-structured interviews were conducted face to face and open-structured daily meetings with the workers and production control of the aftermarket. Regular email contact with relevant personnel was used throughout the project as complements to face-to-face interviews and to get fast, short and specific answers.

Observations and data collection

Observation is a method that enables the performer to gather and process information of users and systems in objective way without disturbing the current process (Osvalder, Rose & Karlsson, 2011). Osvalder et al. (2011) mentions that observations could be performed one of two ways through either direct or indirect encounters in the field or in a constructed fictional environment. Where direct observation requires the observer to be present in the system and indirect observation is conducted through recordings discreetly placed inside the system to see how users act when they don't know they are being watched. An observation could also be unsystematic or systematic, where the former means that every fund of interest is documented and the latter is made after a specific schedule where the observer knows which events or actions that provides relevant data (Osvalder et al., 2011).

All observations in this project were direct as one or both project members were present during each observation. In order to gain experience and quickly get into how the current state is at Saab, the earlier observations were guided by persons and groups directly involved in the projects, both with people involved in our project, surrounding projects and the ongoing change in the production flow for new products. Further documentation has been made through reading earlier conducted projects, different manuals, operator's work instructions and plant designs. Our observations and interviews have been documented through mostly notes. No sound recordings and footage have been performed since some of the information is a matter of national defense.

Systematic observation

To get real- and new lead times and value added times for the operations we chose to follow five products through the production line. This also helped to get a better understanding of the production and exactly where the products were taken and put. Every day during the daily meeting the products were checked with the operators. Documentations where the products were and what have been done since yesterday was done. This information together with the lead-time were documented and made it possible to map all steps in the production line.

These products have been followed thoroughly through the production system where information and lead time from every operation and station have been collected along the way. We have not only followed the physical product but also the information that concerns the product. This has helped us with mapping the current state.

Historic data collection

In order to receive a greater data collection, historic data of already finished and shipped repaired products has been analyzed. The historic data was acquired through the different projects SPM, sub-project managers, taken out of Saabs information channels. The five products from the systematic collection have set the standard for which type of products that fits in the historic data collection. The products from the past that has the same type of errors that the product from the systematic observation has been used in the historic data collection. Their lead time was compared to each other and told us if the way to document the lead-time were correct or not.

In order to gather the value added time from the products from the systematic observation and the historic data collection, calculations was made as followed:

$$\text{Value added time} = \frac{\sum \text{Time reported work on products}}{\sum \text{Time reported weeks in the production system } x \text{ } 40}$$

To get a mean value for each type of product in the historical data collection further calculation were performed:

$$\text{Mean value added time} = \frac{\sum \text{Value added time}}{\text{Total number of products}}$$

These values could then be summarized and compared in a table in current state.

4.3.2 Value Stream Mapping

To find out how an organization can improve their flow efficiency, the method Value Stream Mapping or VSM is a good support in the working process. The VSM method is used primarily as an eye-opener to not only see improvement in single processes but also to see improvements in the whole system. The main focus in VSM is to improve the value flow system in the whole production system not just improvements in a single process. A VSM follows the product through the production system, from the supplier to the customer in form of a visual representation of the value flow, illustrated through Figure 13. (Petersson et al., 2015)

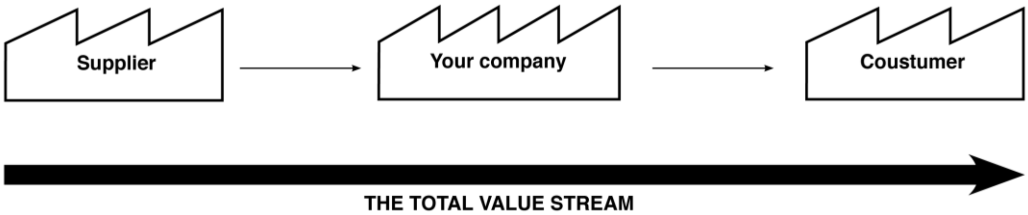

Figure 13: Illustration over "The total value stream" (Rother & Shook, 2002)

A VSM is a mapping over the value stream in the factory with the paper-and-pencil method that will help you to see the whole production system through its value stream. The value stream of both material- and information flow, is made backwards from the customer to the supplier and illustrated with representative figures and signs. (Rother & Shook, 2002)

Before it is possible to start illustrating or even start using the VSM method, it must be clear which products that the VSM will include. Normally in a company not just one product is made, either they are producing many different products or the product has different models. Therefore, before starting using VSM you need to divide the products into different product families. It is important while dividing the products that the families are made from which processes they going through while following the flow through the factory, not because that they look similar (Rother & Shook, 2002). When illustrating and working with the VSM method, it is important to follow the steps that are illustrated in Figure 14. In this thesis project, one selected agreements and involved products, is the product family analyzed using the VSM method.

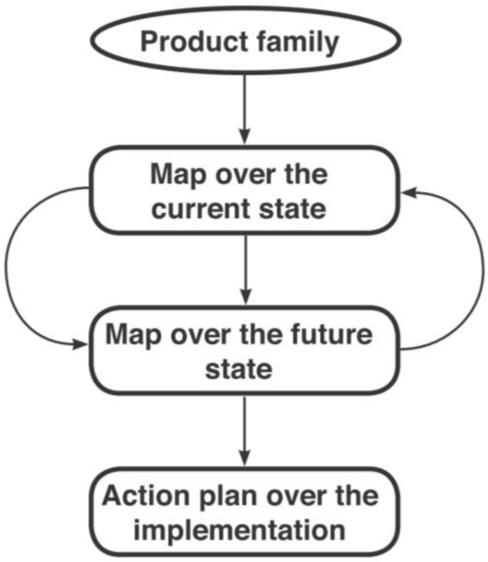

Figure 14: The steps of illustrating a value stream (Rother & Shook, 2002)

The first step of mapping the current state starts with sketching the different processes and how the chosen product family flows from door to door against the stream in the factory (Rother & Shook, 2002). When mapping the current state, it is time to "walk the flow" system again backwards, both in the information flow and in the process flow to collect significant data for each part of the process (Petersson et al., 2015).

To further find a suitable future state, the principles of lean will help to make the necessary changes in the value stream. Lean specifies the way of thinking when finding the solutions that will drive wastes in the system and improve the results. To make these easier, rules has been made so the risk of missing parts in the factory will reduce. In Figure 15 a guide to find the wastes is shown and by following this from left to right, the critical questioning of the value stream is done. (Petersson et al., 2015)

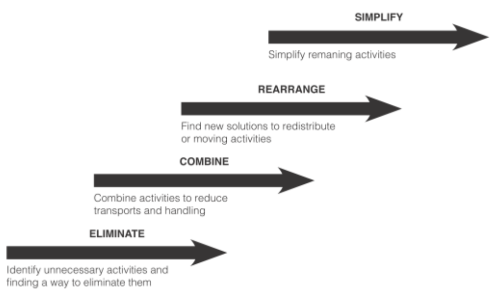

Figure 15: ECRS - Improvement rules (Petersson et al., 2015)

Further work includes an action plan where it is important to decompose the improvement activities into manageable work tasks to ensure the best result. Every improvement block should have a responsible person who will drives the work to the put up goals and when the activity should be finished. (Petersson et al., 2015)

VSM Saab Järfälla

The VSM map were made for one type of product that have been followed in the data collection phase, because the easiness of having a physical product to follow. At first a VSM map over both the processes flow and information flow were sketch by the "walk the flow" system. To get all the needed data for the products, searches and calculation from the historical data were made. Data of consisting lead time and value of each process and information was collected from the physical observations but also from the company's time reporting database, Agresso, and their own created information channel called Springbok. These values together with an altogether process map are used to identify the current factors creating issues and problems in today's aftermarket production. Methods previously discussed from lean are used to find suitable future state for the production, which will be presented in the recommendation chapter.

4.3.3 Ishikawa diagram

The Ishikawa diagram, often called fishbone or the cause-effect-diagram is a graphical analyzing tool to simplify and define root, sub-problems and issues to a certain area. The problems and issues are found using approaches in pre-set or self-selected categories by mounting effects and causes onto the problems to form a sort of mapping that looks like a fishbone. (Osvalder et. al, 2011)

To better understand the factors that causes delays in the entire aftermarket service flow, a diagram was considered using self-selected categories; in the production, in the organization and the subcontractors. The causes mapped further into a root causes or effects for the productions delivery delays based on interviews, observations and general conversations with operators and managers illustrated in Figure 16.

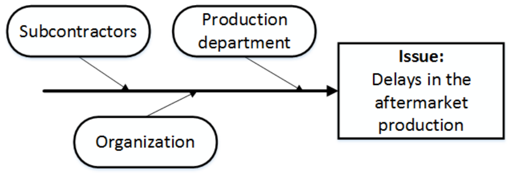

Figure 16: Ishikawa diagram applied to the thesis project.

4.4 Formulate goals and specifications

During this step in the project circle, the wanted goals were specified in a requirement specification. The goals were formulated and based from the previous phases and later used as a foundation for finding alternate solutions.

4.4.1 Requirements specification

This section uses the information gathered in the analysis of the current and the vision for a future state by looking forward onto what is expected for upcoming solutions in a requirement specification. According to Bellgran and Säfsten (2005) the requirement specification should reflect the future production systems desirable features though lists of wishful demands and goals. The specification has two important functions; to give directions for generating solutions and help with normative information in the evaluation of future solutions (Roozenburg & Eekles, 1995).

To this thesis project the requirement specification acted as both a decision maker and solution generator in working towards a final developed concept that solves the problems brought up by the analysis. The requirement specification was conducted using all the collected information during the process of the project in order to break a common ground with the involved personnel and that the thesis project goes in the right direction.

Figure 17: Benchmarking wheel (Andersen & Pettersen, 1997)

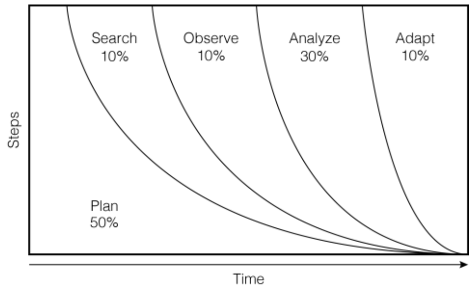

Figure 18: Benchmarking steps, how they overlap and the average time distribution (Andersen & Pettersen, 1997).

4.5 Search for alternatives

The phase of searching for alternate solutions to the current state was an overlaying stage that followed throughout the project through spending time with workers, managers and experiencing the situation in a daily interaction. But to get a more concentrated view of the problematic situations and how they may be solved, a couple methods such as benchmarking of a similar production, specified workshops and brainstorming were used.

4.5.1 Benchmarking

Benchmarking is a tool for finding improvements where the company compare themselves against other companies who is best in a specific area. Andersen & Pettersen (1997) defines benchmarking as the process of continuously describe and compare, from a business to business standpoint, one process from another in leading organizations that can help one's own business to find and implement improvements or solutions in a specific area.

To make it easier to understand which activities and steps that needs to be done to complete a benchmarking, a model for the steps has been made as shown in Figure 17. This model shows in which sequence that the steps needs to be done in. As a complement to Figure 17, Figure 18 shows how much time in average that each step takes and how they overlap each other.

In the project, benchmarking had the purpose of actively see how another similar production site working with aftermarket products and to collect information how the process differs from Saab Järfälla site. The visit was conducted at Saabs production site in Kallebäck at April 20, 2017 which is a part of the same business area, Surveillance, but focusing mainly on land based, air based and naval radars and lasers for national defense. The visit served as a complement to a later explained workshop handled by other fellow thesis workers at the Kallebäck site.

The benchmarking visit was performed using semi-structured observations and interviews during a walk-through, workshop and their explained process flow of material and information handling. A full explanation of the findings, discussions and differences of the benchmarking visit are attached in Appendix 2.

4.5.2 Workshop

A workshop is a creative meeting where workers, experts or unrelated persons get together and discuss a problem in a creative way (Wikberg Nilsson, Ericson & Törlind, 2015). The goal with this method is to use the creativeness in the group to attack a given problem and/or explore future or potential solutions. Before having the workshop, it is important to formulate the purpose of the workshop. The purpose helps form the workshop, by deciding what kind of people you want to invite and what results you want to have (Wikberg Nilsson et al., 2015).

When starting the workshop, you should start by dividing the participants into groups of 3-4 persons and inform what this workshop is for and what the results will be used for. The first step is to problematize the current state, when the groups are finished they will present the results to the other groups. Next step is to let the group find creative solutions to the current state, and as in the first step later present the results. (Wikberg Nilsson et al., 2015).

Two workshops were done to this thesis, one at Saab Kallebäck in Gothenburg and one at Saab Järfälla in Stockholm. The full disposition of the two workshops is documented and can be found in Appendix 3.

Workshop in Gothenburg

A participation in a workshop was done to get more overview Saabs aftermarket. The invite was sent from two students from Chalmers University of Technology who were doing their master thesis at Saab Kallebäck. They were also writing about the aftermarket production and wanted a workshop with all the people at all Saabs production sites who concerned the aftermarket production. The main focuses in the workshop were goals and measurements to evaluate the aftermarket department as a whole at Saab and to create a future strategy.

Workshop at Saab Järfälla

During the process of mapping the current state of the aftermarket production, it was noted that most problems lies between the operations, the operations themselves works smooth and seemingly flawless. To get a better understanding of these problems and the bigger picture of the aftermarket production, a workshop at Saab Järfälla were conducted. The goal with the workshop was to understand the underlying problems between the operations and what solutions the personnel together can come up with. One person involved in each part of the full process was participating in the workshop. In this way the knowledge was greater and the all processes could easier be discussed. This later helped us during the ideation and concept development part of the thesis.

4.5.3 Brainstorming

The brainstorming method is normally used when a great amount of ideas is wanted. There are many different versions and ways to do a brainstorming session, but there are some ground rules that used to be followed. (Wikberg Nilsson et al., 2015)

- It is important not to criticize any ideas and skip thinking what is possible or not, all ideas are good.
- Search for combination possibilities, often ideas can grow and be better if they can be combined with other ideas.
- Quantity before quality, try to get as many ideas as possible.

When starting a brainstorming session, you should inform the participants the rules, describe the resource question and hand out post-its to write on. The session starts by introducing a leading question. When the ideas start to subside it is time to stop the session by telling the participants to put up their ideas on a whiteboard or wall. As a finishing phase you should all discuss and explain the ideas. (Wikberg Nilsson et al., 2015)

Brainstorming sessions always started with booking a meeting room with a whiteboard and inviting specific attendees. Discussions were first held to find and formulate problems and areas that required attention. The brainstorming sessions then started by using post-its to write done all ideas that came up on that area to later put them on the whiteboard. The ideas were then presented and discussed in a group session. When the discussions were finished the next problem was presented and a new brainstorming session was started.

The point with the brainstorming sessions were to first discuss how the work with the aftermarket is going (the focus of this thesis), and how the work that the key initiative of production effectiveness is going. The wanted outcome is to step by step find a way that the aftermarket production and new production can collaborate and work as a function.

Alongside these sessions, a continuous process of new ideas and elaborations from observations and daily meetings with people in the organization that came as a brainstorming on daily situations were put up on a post-it on the study wall to remember the ideas.

4.6 Summarizing, evaluate and choose concept

To formulate the suggestions for improvements into concepts, summarizing and grouping methods can be used. Later the concepts need to be evaluated and choosing one concept to continue to work with. In this section this step has been done as the fifth step of the project circle, where the summarizing part is divided from the evaluation and concept choosing part.

4.6.1 Summarizing

Before an evaluation of the suggestions for improvement, a structuring and summarizing of the suggestions needed to be done. Wikberg Nilsson, Ericson and Törlind (2013) describe that the point is to summarize and group similar suggestions together and then give the group a suitable name.

The improvement suggestions from benchmarking, workshop and brainstorming were listed together with the challenges and benefits of each suggestion. Because of the large amount of suggestions most of them were grouped together. Different colors, depending on if they were similar and/or based on same problems. The summarized suggestions formed six concepts that were more well formulated and with a wider perspective. These six concepts at last were given names that had to do with the type of solution that the summarized suggestion presented.

4.6.2 Evaluation and choose concept

0To find out and choose which concept to develop further, a concept selection matrix (Table 1) can be used using specified criteria's (Wikberg Nilsson et al., 2013). The concepts should then be valued on the base of each criteria, and the total points the concepts get is later compared to the rest of the concepts. Wikberg Nilsson et al. (2013) describes finally that it is important to consider if the concept that got the most points actually is the most suitable concept for the problem and situation.

Table 1: Example of a concept selection matrix (Wikberg Nilsson et al., 2013)

Criteria	Concept 1	Concept 2	Concept 3	Concept 4
Experience	1	2	0	2
Ergonomics	1	1	1	2
Aesthetics	0	1	1	1
Technology	0	2	1	1
Quality	1	1	1	0
Total	3	7	4	6

To find out which concept to continue to work with in this project, the six concepts were compared to the requirement specification. A concept selection table where the six concepts was given points depending on how well the suggestion suited each requirement, from one to five where one was considered a low score and five was high. All requirements were first given a score, also from one to five on how important the requirement is. The concept with the highest score believed to be the one to continue to work with. To check if the winning concept was relevant, the score from the two highest ranked requirements were compared to the scores from the other concept, seeing if the score on the winning concept got the highest. In this way it was clear that the winning concept not only got the highest score but was relevant to requirement specification.

4.7 Develop and finalize chosen concept(s)

The final phase of the thesis acted as a detail and development phase of the final solution concepts. The phase involved collecting the gathered solutions and join them together to form a final solution that could be carried out to the case company.

The chosen concept acted out from as the winner from the requirement specification was formed through the analysis, observations and theory to be adjusted to the current state of the production. The theoretical framework acted as a base and the analysis as a help to detail the solution and to make the production fully integrated with each process.

Discussions and interviews with operators, planners and managers about each part of the process was always an act to make sure everything was thoroughly tested before being included in the solution to verify a positive effect in the production that could be compared as steps in the iterative PDSA cycle.

How each operation is performed physically is not changed due to the fact that production works but each part in between and the production flow is considered. The thesis project has focused to visualize the whole production flow by detailing the physical flow into a virtual one. The virtual solution proposal was combined with earlier ideas and theories to describe the guidelines for the concept. The guidelines explained how the solution is supposed to be used in practice, possible routings and simplifications to make it user friendly and semi-autonomous. A final draft for the virtual solution is presented as a guideline booklet in Swedish for Saab AB in Appendix 4.

4.8 Reliability and validity

Throughout this thesis it has been important to combine our own thoughts with given data and information from workers and other personnel. Doing an extensive mapping, a lot of own thoughts and ideas have come up and the knowledge of the whole production have been formed. Combining this with all given and collected data and interviews with different personnel have completed the understanding of the production, stations and operations. To use an already known methods have been a rule of thumb throughout the whole thesis. A second rule of thumb has been to always confirm with the personnel that the work made is in line with what have been previously discussed. This has been done during daily contact and has led to great relations between us and the personnel at Saab.

The biggest challenge with mapping the current state has been to handle all the given and collected data. The collected data have come from many different persons, projects and files, which have led to problems finding the right data and get it structured. Knowing from the beginning that the historical data was unorganized would have helped us knowing how much time to spend on the data collection phase. To have added a method on structuring all the data would have been a great benefit when analyzing the current state.

We have strived to follow the theoretical underlying base of the methods themselves that have been used in the thesis. This worked out great with all methods except with the VSM-method. To create a VSM over the current state and in the end create a new VSM over the future state is the objective of the method. For this thesis the VSM-method have been used only in the process of mapping the current state. Because of the unstructured given data, it has not been possible to sort out the specific process times of each process. Only the process time of the whole system could be sorted and the value added time for the system was calculated. The result that we have presented has not changed the process steps of the production but the visual control management of the whole system. This makes it not possible to create a VSM map over the future state yet.

From the beginning the thesis scope was delimited to the aftermarket products. The final concept that has been developed is not only concerning these products but for all the products manufactured at Saab Järfälla, due to wanted outcome of an integration of the two parts. Some of the results concerning the newly manufactured products have come from the key initiative group of production effectiveness. They have done tests and studies on these products which have not been controlled by us but have been combined when forming the final concept.

5 Current state

To be able to analyze the aftermarket situation at Saab Järfälla, it has been important to actively observe, interview and collect data to be able to create a broad foundation of the current states strengths and weaknesses in the products, agreements, communications and processes. This chapter aims to explain the current state of the aftermarket through the acquired results of mapping the material and information flow inside the Järfälla production site.

The mapping will further become a baseline for an analysis where problems can be brought to the surface and later solved so the whole aftermarket can have a better performance and stability, more detailed in the upcoming chapters. This chapter is outlined by a general description of the products and service agreement at hand followed by the communications management and how the processes at Saab Järfälla works first with aftermarket products then with newly manufactured products.

5.1 Products inside aftermarket Järfälla

This section briefly describes the products involved in the aftermarket process flow for a service agreement produced, maintained and repaired at Saab Järfälla production site. Inside Saab Järfälla's production site, products are manufactured and repaired in the same production flow with some differences. Generally, the test and assembly sequences in the production line are overlapped with both the manufacturing of new products and reparation of previously sold products.

The products manufactured and repaired inside Saab Järfälla are used for national defense and other military applications., Larger components and parts is called LRUs (Line Replaceable Units) are used in sequence to each other for electronic warfare and countermeasure applications for national military defense. The LRUs are built up by integrating different SRUs, shop replaceable units, into the main component. Some of these SRUs are made from scratch but some are ordered through subcontractors from all over the world. Each LRU contains from 2 to 14 different SRUs with their separate spare units (SU) and parts, making the total part number of each LRU between a few hundred to almost a thousand.

All these products need to be able to perform in these extreme environments and needs to be handled with special care. Meaning in each production step, careful material handling through special packing, wrappings, cleanliness and use of special dresscodes in the production areas with ESD-markings to not cause any disruptions with any electrical components.

5.2 Service agreement

The service agreement concerns components between Saab and the client involved in military applications. Maintenance and support are handled foremost by Saab Support & Services (S&S) in Arboga, Sweden, who distributes the parts into specific areas at various production and contractor sites for services.

For Saab Järfälla, this agreement concerns components in the aircraft's electronic warfare (EW)- and countermeasure systems sent directly from the client or through Saab SS. The PBL agreement covers all maintenance of components (LRU/SRU/SU/Spare parts), support systems and type-specific ground support systems against an average delivery precision consisting of a net average lead time (ALT) of N+12 days for services between the client and Saab facilities. This is calculated through by using the net ALT for all incoming products during the year before to decide if Saab should pay a penalty fee if the product has not been delivered in the right time to the client.

Saab is accountable for purchasing, storing, documentation, transports and supply sufficient spare part quantities to be able perform repairs, follow ups and preventive maintenance in accordance to the decided maximum average lead time (Max ALT). The net ALT refers the time between arrivals at Saab Support & Services or Saab Järfälla and delivery back to the client's facility but excludes the time for approved interruptions in accordance to the disruption clause and with regards the 50 % reduced work load during the holiday season (w.27-30).

Approved interruptions in the disruption clause concerns having to stop a product in the production process due to contractual criteria's such as lack of material, information, intelligence or other arrangement.

5.3 Communications inside after sales production

Inside the after sales services at Saab Järfälla, communication interfaces between the different work units of the production and project is used to help spread information to the main responsible unit. Each unit has their own responsibilities where the communication is controlled from an in-between position of project management called a subproject manager, illustrated in Figure 19.

The subproject manager handles the communication and information from the project manager, who in turn handles the external information from the client and supporting organization Saab SS, Arboga and in some part notifies the strategic purchasing unit, to internal communication between the subproject manager and planners of the internal logistics unit. The subproject manager's responsibilities lie in preparations of incoming maintenance and repair objects in scheduling, time delimitations, preliminary test diagnosis and documentations. The planner of the internal logistics unit in turn is responsible for getting the repair unit through the processes inside the production units, analyzing the production flow and material handling with operational purchasing of new and in stock components. The test and assembly functions reports progress, troubles and material requirements to the planner in internal logistics.

5.3.1 Databases and information channels

Two different kinds of databases are used for tracking and administration of progress, called Industrial and Finance System (IFS) and Springbok (SB). Generally everything is logged in IFS from arrival to delivery but small parts are kept outside in SB and

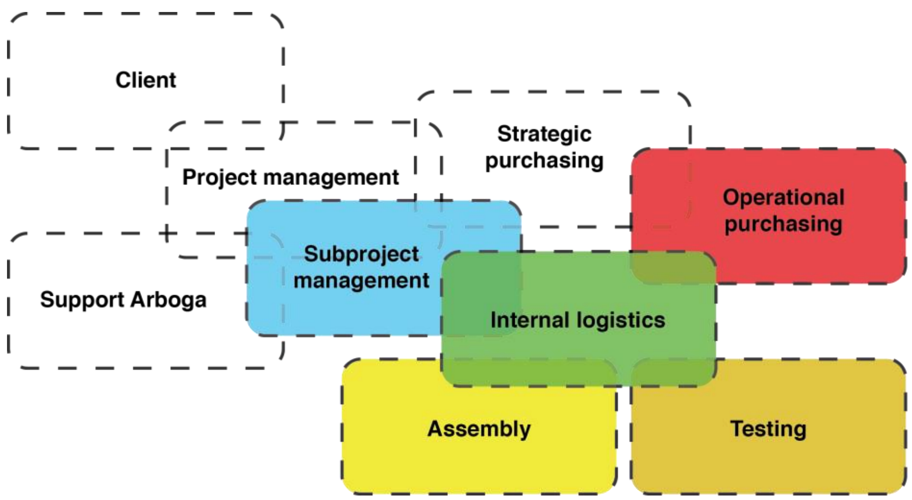

Figure 19: Communication interfaces inside the after sales services, colored parts illustrate functions inside Saab Järfälla.

physical form like lead time counts, test records and communication between operators in assembly and testing. But some parts of the administration between personnel inside the production and planners are kept via email and excel sheets making it harder keep track on what is really happening when it is not logged inside a database.

Other systems for information and unit tracking are physical production control boards, shelves and excel files concerning several key elements in previous maintenances made, lead times, test data and so on. Each person in aftermarket process flow has to be acquainted with several different databases and equipment to be able use the information flow to go smoothly through all the processes.

In total there are approximately 12 different types of database/document/physical information channels that holds all the needed information for the operators, planners etc. In many cases same information is documented in different channels because of that different person looks in different places for the same information. This makes unit tracking, information searching and documentation a time consuming part because all of different database and information channels. A summarized stakeholder analysis of the databases and information channels used at Saab Järfälla in the aftermarket process flow can be overlooked in Appendix 5.

5.4 Processes inside Järfälla production site

The aftermarket process flow in the service agreement has an inflow that fluctuates from 20 to around 80 LRUs per year into the Järfälla production site. One might ask whether this production system could count as an HMLV production system since the LRUs are quite few. But mainly the system and each LRU has parts in their SRU as well, parts that makes total number of parts to more than a few hundred. In turn, each of the SRUs needs different sorts of tests, and depending of the outcome of the test, requests of new or modified parts can differ a lot. The variability and different needs of parts and modification can be commonly referred to some of the complexities and characteristics in an HMLV system. Even the different demands of testing when a fault is found to the determination of action from a specialist, a technical design authority (TDA), creates different value adding processes through the production system.

The production at Järfälla has been very resource heavy through the years, trying to make the most each resource capacity and push through products with various priorities without knowing what to set as priority between other products. Operators, managers and planners had troubles in the past and still have troubles controlling what to prioritize since every product has different needs after the first fault diagnosis. Especially this service agreement, which has a demanded net average lead time of N+12 days (N days inside Järfälla), creates a complexity in planning with products that cannot be interrupted versus previous products that has been on approved interruptions. By making approved interruptions through the disruption clause in the agreement, Saab has not suffered from any penalty fees as of late since the net average lead time, net ALT, is stopped from counting.

At the production department, the production control is visualized by different physical boards that are planned out from available resources pushed into an interval of 3 weeks sorted by days. The testing and assembly personnel are divided into separate boards shifting tiles from when they are moved to a resource. This sort of visual production control causes lot of movement of tiles through the week, creating extra work for the responsible planning resource. Each LRU has their own specific TDA, and each SRU inside the LRU has their own TDA which more often than not, is not the person responsible for the LRU. This causes a lot

Table 2: Net Average lead time versus Gross Average Lead time inside the Järfälla production site. *Only counts the first months of 2017

Incoming year to Järfälla	2012	2013	2014	2015	2016	2017*
Net average lead time (days)	N+11,4 (±146,2)	N+3,1 (±20,7)	N+17,5 (±80,3)	N-4,4 (±38,0)	N+6,1 (±35,1)	N+0,5 (±13,4)
Gross average lead time (days)	N+587,6 (±291,4)	N+398,2 (±253,4)	N+241,3 (±226,7)	N+198,3 (±184,0)	N+41,4 (±58,1)	N+1,4 (±14,6)
Av. Interruption time (days)	575,3	395,1	223,8	202,7	35,3	1,9

of different resources to be active and have their say on each incoming product to be able to move to downstream in the process, also affecting visual basis of the production control board.

Illustrated in the graph of inflow versus outflow of service agreement's articles between 2010 and 2017 through the Järfälla production site in Figure 20 one can see how the production of the aftermarket has improved during the year and how many ongoing repairs are in the system.

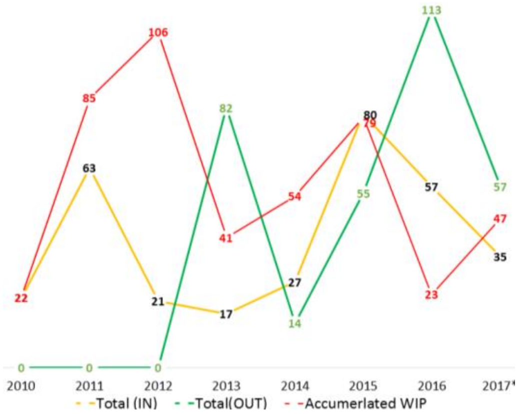

Figure 20: Inflow versus outflow of the products inside the service agreement. *Data from 2017 has only been counted until May 23rd 2017.

By looking at the production of these products, the LRUs distributed through the Järfälla production site and their respective lead times (Table 2). The lead time through the years 2012 to today has a varied net average lead time between N-1 days and N+17 days, with a wide spread of standard variation. But has a gross average lead time that has gone down from over 500 interruption days to under 2 days. These times are measured by the products incoming between 2012 and 2017. By looking at these times inside the Järfälla facility, it is clear that interruptions have been made on most the products to keep the net ALT to a minimum. But the turn-around time are not held to N days every year as requested through the facility, excluding the 5-12 days it can take for handling the goods through Saab S&S and distribution channels.

5.4.1 Aftermarket processes

In this section, the processes involved] in the aftermarket production flow is explained to provide an overview of the objective of this study. To get a better understanding over the aftermarket production, an overall VSM was made (Figure 21).

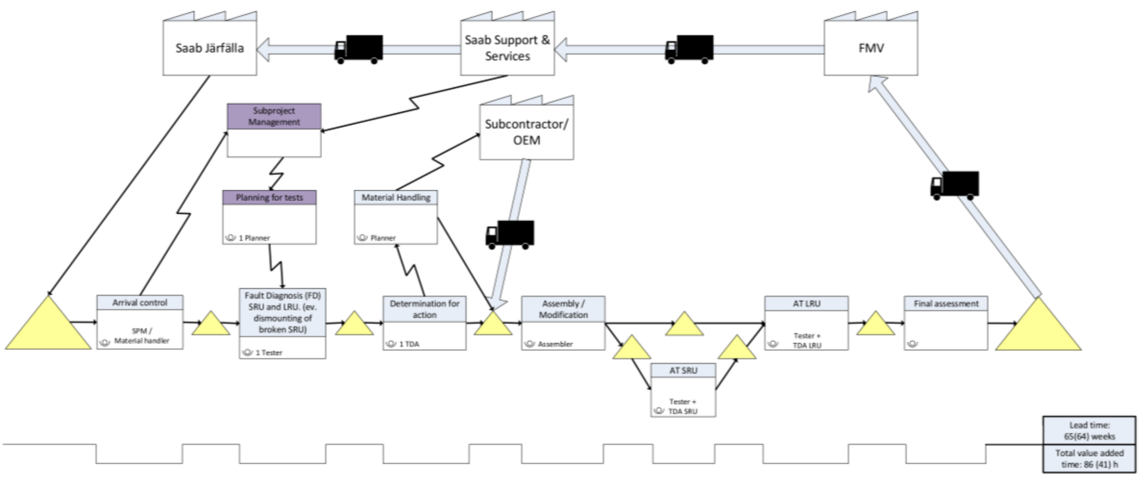

Figure 21: VSM-map over an aftermarket product, with same kind of error

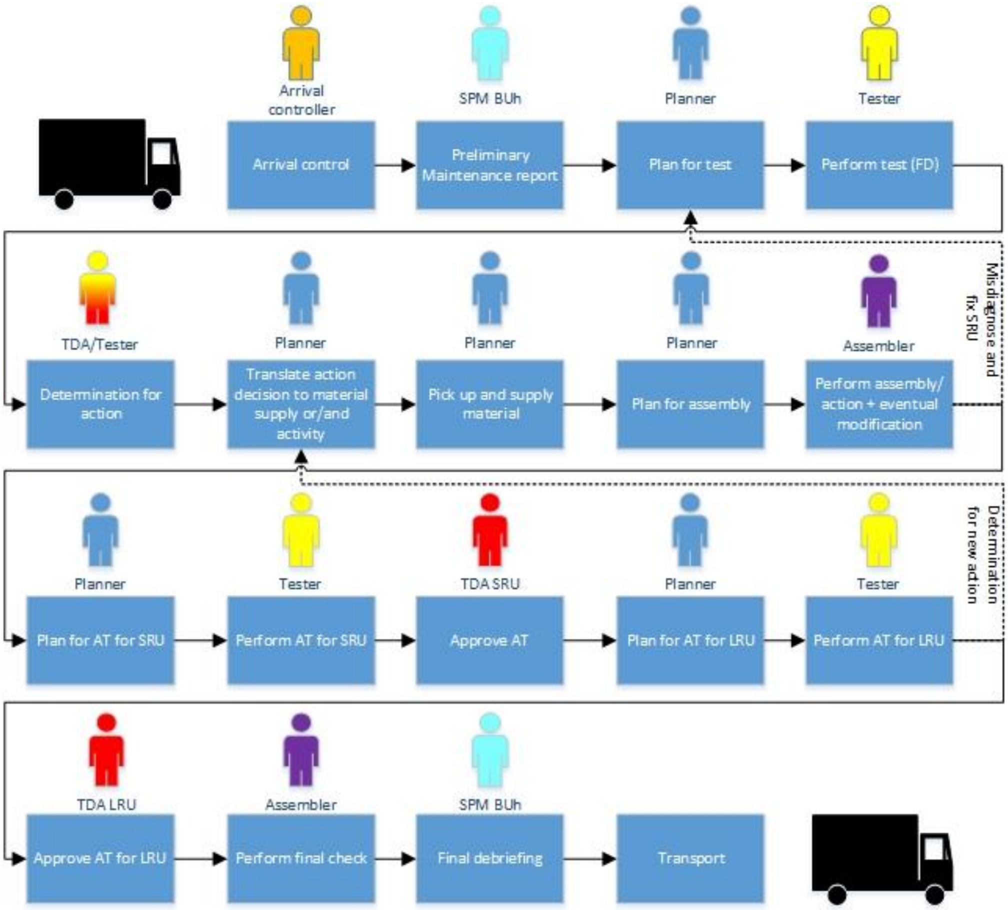

Figure 22: Aftermarket processes in the current state

The current state of the aftermarket processes illustrated in Figure 22, is divided into several steps inside the Järfälla production site has been the object of the study. See full process map in Appendix 6. The movement through the system is illustrated in nine steps (Figure 23). As previously mentioned, Saab has N+12 days in net average lead time to complete maintenance, repairs and support for each incoming product but the days starts counting from the first connection to any Saab facility. Meaning that 5-10 days will disappear for first overview, dismounting of LRUs and transport from and to the Saab S&S in Arboga, leaving Saab Järfälla with N+2 days to complete the repair process. The steps are presented as following:

1. Arrival
2. Arrival control
3. Test 1 (FD)
4. TDA control (FD)
5. Material finding
6. Assembly
7. Test 2 (AT)
8. TDA control (AT)
9. Final assessment
    a. Debriefing (Mondays)
    b. Transport admin (Tuesdays)
    c. Control board meeting (CBM) (Thursdays)
    d. Transport (Fridays)

Arrival

When the product arrives to the production site, the arrival personnel tells Saabs arrival controller and material handler that "confidential" goods have arrived. These kinds of goods cannot stay in the arrival center for more than 24 hours because of certain regulations that concern confidential goods.

Arrival control

The material handler later makes an arrival control where the person checks the goods for preliminary damages and condition from the delivery and make sure all the papers are there. This documented on a

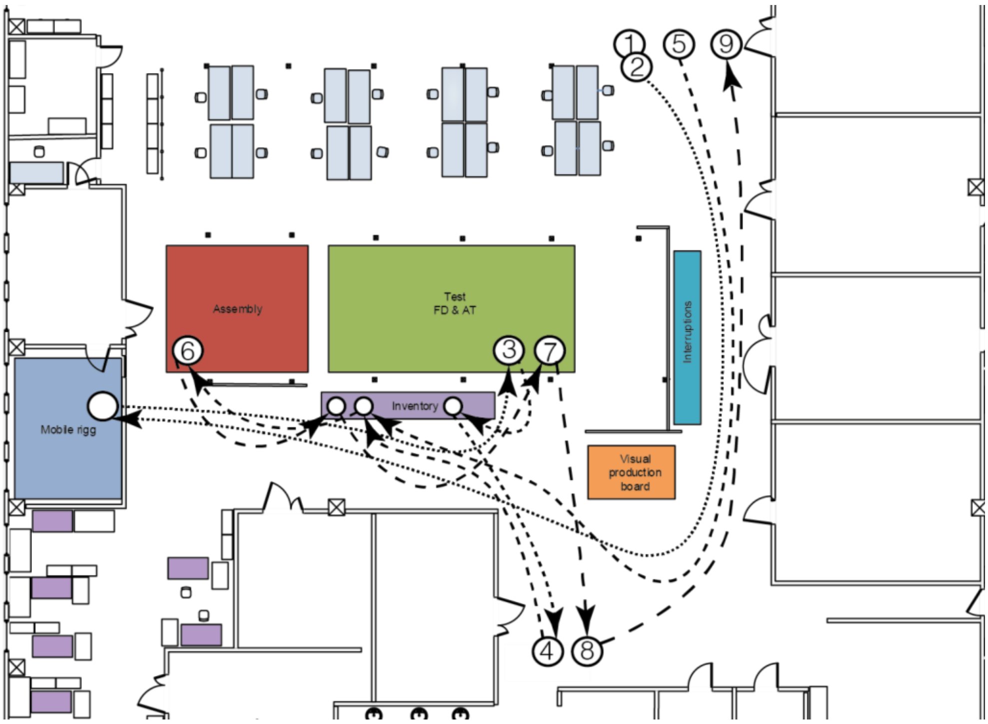

Figure 23: Movement shown in the separate stages inside the production of aftermarket products.

specific paper for arrived goods with a description of a summary of the arrived product(s) and the paper that followed. The goods are then moved to an inventory (the mobile rig) and the papers go to the sub-project manager, SPM, who makes a preliminary maintenance preparation/diagnosis and a preliminary production plan of the product. The papers then put together where the product is in the mobile rig and waits for the first test.

Test 1 (FD, Fault diagnosis)

In the first tests, the Fault Diagnosis (FD), test person confirms or not what SPM thought the misdiagnosis was. The test person runs all tests for the specific product and checks if there are more components that is defect. Additionally, sub-level components are dismounted and tested if needed to be diagnosed for errors. The whole test is then documented in every step and will later follow the product to the later processes.

TDA control (Determination for action)

When all tests are done and the misdiagnosis is confirmed, a TDA person, technical design authority, that knows the LRU product inside and out must make the final determination for action what to do next with the product. If a part needs to be exchanged, repaired or further tested on a sub-level part or that no fault has been found on the LRU for example.

Material finding

When the determination for action is set. The action is written down as change orders to specific cases and then has to be translated by a planner for what new materials or components needs to be picked up from the inventory and also what activity needs to be fixed. The planner of the project will get a list with the materials and/or components that must be picked up. This person will later place the pieces with the product back into the mobile rig for further assembling. During this process, the planner will set up a time for assembly depending on what action needs to be taken.

Assembling/Eventual modification

The assembling personnel take the product, the new pieces and the change order. Switches the defective components with the new and/or eventually perform a modification on the part depending on what the change order describes. This process is like in Test 1 (FD) thoroughly documented with time spent on the assembly. The updated is then moved to the mobile rig with all the belonging papers.

Test 2 (AT, Acceptance test)
When the new pieces are mounted inside the product the same test as in Test 1 (FD) are conducted. First an acceptance test, AT, on the sub-level components that is sent to an appropriate TDA specialized on those (or that) SRU(s) for approval. When this is done, an AT for the main components has to be approved by an appropriate TDA. This confirms that the old pieces where defected and the product now is fixed. This process is documented in the same way as in Test 1 (FD).

TDA control (Approval of AT LRU)
An experienced TDA person then needs to give approval of the actions and tests made on the LRU. The TDA person will control and check all the documentation and papers so the customers will get all the information that is needed.

Final assessment (Debriefing, Transport, Delivery)
Debriefing needs to be done by Mondays the same week the goods need to be transported. This gives the transport unit 2 days to finish the administration work. On Thursday that same week the Control Board Meeting, CBM, is held where all the papers and the product are checked one last time to ensure that the customer gets everything that is promised. This meeting is between three persons, the sub-project manager, a project quality manager and configuration manager. On Friday the same week the transportation is done and the repaired gods is transported directly to the customer or to Saab S&S in Arboga, Sweden.

5.4.2 Production of new products
The production of new products inside Saab Järfälla has a similar look as the aftermarket processes. The differences lie in the processes before the tests and modifications in assembly. Here the SRUs and SUs are ordered in from the start in exact amounts in accordance to demand. Processed in their respective process unit for each new SRU to be inspected and acceptance tested (AT). In difference for the aftermarket processes who continue with assembling to an LRU and AT, the SRU are made to storage for up to 1 month. Then later assembled to an LRU for an additional AT for the whole unit. The resources for testing, assembly and approval by a TDA are here shared between the production of new products and the aftermarket.

This also affects the test and assembly equipment, causing standby-times between some of the test rigs since each new test requires a new calibration if it is not used by the same product over and over.

An effect of what the production of new units creates is a problem controlling the number of WIP (Work-In-Process) products. Each project working towards manufacturing their own products inside the Järfälla production site. The shared resources between new products and aftermarket create today numerous conflicts on what to prioritize in the system.

5.5 Systematic observation and data collection
From the chosen products that have been followed through the aftermarket production flow, there were three products that could be used when comparing against the historical data. A1, B1 and C1, where the two other products were put on approved interruption due to lack of SRUs. As seen in Table 3 there are big differences between the systematic observation and data collection. This because of that no interruptions have been made on two of the followed products, A1 and B1. This means that the data that is shown is the possible throughput time, if there are spare SRUs and spare units in the inventory. The product C1 which has a lead time that is twice as long as the two other products were set on approved interruption for five weeks. The products that are taken from

the historical data are products A, B and C with the same types of errors as the A1, B1 and C1. Data was taken from 2012 to today and there were thirteen A, fourteen B and eleven C in the study.

Table 3: Analyzing data between systematic observation and data collection

Product	Average lead time (weeks)	St. dev lead time (weeks)	Average process-ing time (h)	St. dev process time (h)	Average value-added time %	St dev value-added time %
A	65,1	63,9	85,4	41,2	7,8	9,8
A1	4		29,2		18,2	
B	40	24,6	51,7	33,1	4,5	3,9
B1	5		40,5		20,2	
C	68,7	27,8	77,9	50,5	2,8	2,1
C1	11		45,37		10,3	

Flow efficiency, which is explained as the parts being processed through the production system in relation to throughput rate (Modig & Åhlström, 2013) is in Table 3 the total value added time including both value enable and value added process time. The goal is to go from a resource efficient to a flow efficient production at Saab, which can be seen in Table 3 that they have become better at. Since the value added time for the following products have a higher percent than the mean value.

5.6 Additional observations over the production and organization

The production environment has a functional structured layout, where each product is moved to the desired position through the facility causing a lot of transport and information handling. Each part of the process has a lot of handoffs, meaning leaving a product on a shelf and the next person is responsible for the next part of the process.

All the stationed personnel are extremely knowledgeable and resourceful in their own specific station of the production. Each of these test, assembling or TDA personnel though are specialized in their respective field with no additional resource if they are absent from work. Sub-project managers and planners need to beware at all times to plan for each worker's respective vacations and absence.

All personnel at Saab whether they are planners, assemblers or managers are planned for total efficient time of 80% of their total available time i.e. 40 hours a week. Each personnel who shares their time between operating with newly manufactured products and aftermarket repairs, are planned to spend about 75 % of their efficient time in the newly produces production flow and about 25 % on the after sales service flow.

The working environment has a very meeting based culture, meaning that each little (or big) thing is scheduled for discussions causing each personnel to be on meetings more than their actual work, this concerns especially planners and managers. With only the upper management using activity based workspace and other white-collar workers using offices creates a little gap between them. This seems to affect workers' capability to transfer their own suggestions for improvements.

Saab Kallebäck

After the conducted benchmarking visit on April 20, 2017 at Saab Kallebäck which is also included in the Surveillance business area with wider focus on radar and laser applications. The production at Kallebäck was controlled by daily meetings by managers who knew all the ongoing orders in production/aftermarket, the material and product flaws, and who should be responsible for each problem. Each day has different subjects focusing on improvements, reports and future planning.

Unlike Saab Järfälla, Kallebäck has their own head manager of the aftermarket department instead of being controlled by projects, their managers and planners. The initiative and status of the aftermarket is at Kallebäck somewhat higher because of this management principle and the visualization of the amount of repairs, disruptions and ongoing products.

One thing that differs from the Järfälla site is the surrounding environment. In 2015, Saab Kallebäck started implementing ABW (Activity Based Workspace), a modern open environment without personalized spaces everywhere but the specific production processes. This has freed up spaces and created a more user-friendly environment for the ongoing meeting based culture at Saab, making it easier for interaction with their surrounding peers. ABW has also created a lower noise level and better lighting for the workers.

5.6.1 Ongoing changes/initiatives at Saab Järfälla

A transformation of the current layout and production flow is ongoing at Järfälla through not only this thesis project but a key initiative formed by planners and production managers of both the production of new products and the aftermarket production. The current process is about changing the awareness of each shop orders process through the production system. Mainly the key initiatives focus is on the effectiveness and layout of the manufacturing processes concerning new products.

The restructuring of the production work environment is also based on the same foundation as the thesis project, using theory of converting the resource efficient workplace to become a more flow focused organization. Their work is focused on three parts to keep moving to a perfect state:

1. Reducing variation
2. Reducing WIP
3. Increase flexibility and capacity

These pillars involve using lean principles and techniques in standardization, visualization and work centers to improve the flow efficiency. In order to reduce variation in the workplace, workstations, processes and disruptions in proposed to be standardized in their instructions, locations and complexity. Meaning that the workstations are not specialized for the purpose of one individual but to the purpose of the application and product flow.

The number of total WIP products has been hard to visualize since the number of ongoing orders and product in the system have not been held transparent or even been counted on. The key initiatives focus to reduce WIP has together with the thesis project come to methods trying using a number of wagons to enclose the production system and create a control over the number of WIP. This will also visualize in the system where the lack of resources lies which has been hard to comprehend. In order to improve flexibility and capacity, these standardizations and wagons opens the opportunity for a more flexible and transparent workplace and creates a further implication on possibility that the workers should be able to perform the things needed for every product produced.

Generally, Saab Järfälla is focused to become a better workplace and the rising demand of their products causing a lot of ongoing change initiatives in order to be a viable competitor both in development and delivering. Thereby a lot new workers have come into the organization over the past few months and more are employed every week to keep up with the new challenges.

5.7 Summarizing the current state

Summarized from mapping of the aftermarket current state are the causes that create troubles inside the Järfälla site in three different areas; in the organization, in the production department and with the subcontractors. The organizational issues coming from traditional approaches, maximizing utility and an uninterest of changes. In the production issues lies in visual management, information, responsibility and flexibility whereas the subcontractors do not provide enough material or information about their lead time that creates problems for the production.

6 Analysis of Current State

There are a lot of factors that creates a complexity and increase in throughput rate and lead time in the current after sales service production flow at Saab Järfälla. In this chapter the analysis of the current state aim is to facilitate the causes of the identified problems, how these affect the rest of the organization and further help together with the thesis objectives and theoretical framework form a requirements specification in the ideation and concept development.

In order to make this chapter understandable, the outlines follow the previous chapter with identified problems and affected variables in the products, the service agreement, material and information flow, and the communication inside the aftermarket.

6.1 Main issues in the current state

Analyzing the process- and information flow of the aftermarket in the service agreement project is tricky. Especially since the flows involves a lot of handoffs, paperwork and communicating peers through various information channels. It is a complex production system that has the ability for improvements all over the organization. Summarized in Figure 25 and fully listed in Appendix 7 is a list of the conducted Ishikawa diagram, mapping the factors causing delays (or affects production time) in the service agreement production flow. These are further analyzed in their respective category in the upcoming sections.

6.1.1 In the organization

The organizational structure and culture of Saab causing problems in the production through a resistance, poorly conducted subcontractor's agreements and information channels. These factors are a result of previously made "improvements" that has not been fully thought out to their application and need further and constant development for being applicable to their situation. As mentioned in the previous chapter, most the information today is being double-logged in separate systems with some involved personnel using 2-6 different systems through a product repair process. One of these, the IFS system, has the possibility if constructed right to remove (or help) the demand for each planner, manager and operator to use a large number of different systems.

The cultural resistance lies in a mistrust towards lean production since it's said to

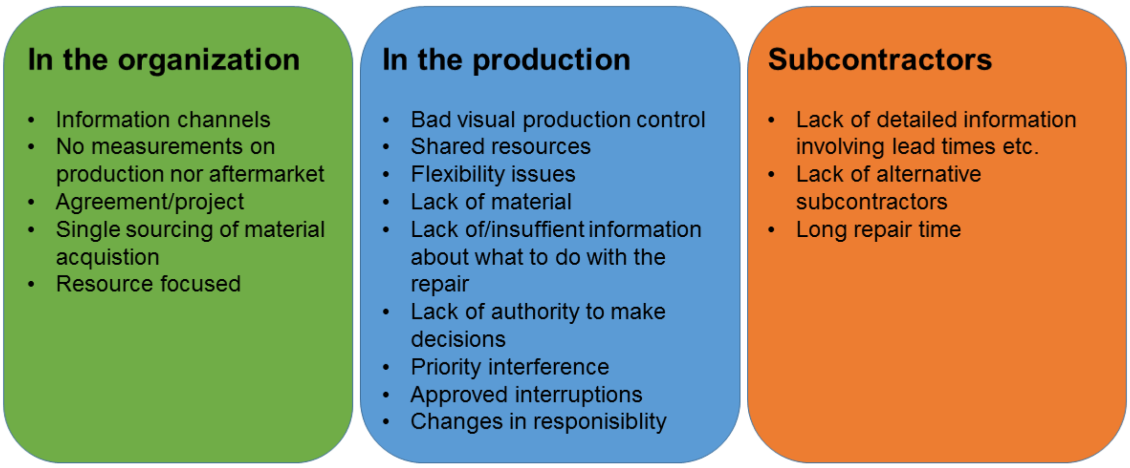

Figure 24: Summarized factors causing delays in the current aftermarket production

by upper management, not to be applicable in the Saab organization and production. It is clear through various interviews and observations that it is not fully understood what lean production means. Trying to use the fully evolved lean tools as used in a high volume, low variety (HVLV) production without modification at Saab as Irani (2011) states is very hard. A production like Saab's have a harder time to access the value of the tools in a flexible and complex production and thereby needs more work in order to get the same results as a HVLV production company.

Furthermore, in the production and in the organization as, also previously mentioned, lies a big resource focus, trying use every available time of a resource to maximize utility. But using every resource to their maximum capability creates an unevenness between the functions and sub-optimal islands inside each function can cause as Modig and Åhlström (2013) states unnecessary wait time and bound capital. In the Saab Järfälla case creating massive work-in-process (WIP) levels throughout the whole production since pushing in orders into the production system without constraints or real information what to prioritize from the start between the different projects. Caused by a project controlled management, each project manager wants their products finished on time without consideration on the other ongoing project's products.

What to account for in this service agreement is the time between Saab's different facilities, since the counting of days starts when the units arrives to one of them. The uncertainty of number of days spent on another site doesn't shine through and can differ between 2-5 days on the arrival point and another 2-5 days for final assessment at Saab S&S plus another day or two for transport distribution. This causes the maximum number of days being able to use lies between less than N days up to N+8 days inside the Järfälla site. As Saab will still be able in some cases apply the "approved interruption" clause, it must lie in the client's best interest to support Saab with all available intelligence from the start of the submission. In example, to able to find and determine the cause of an intermittent fault, the data applied in flight/use needs to be sent for each serviced unit.

Problematics caused by the information channels also lies as foundation for uncertainty of using metrics inside the production and organization. As the information channels are not fully applicable but works, all the pieces seem not really though out for their current situation.

6.1.2 In the production

Throughout the process of mapping the current state it has been clear that the problems in the production that leads to delays in the aftermarket lays between the operations, most of the time. This may be due to many factors, but often it depends on the lack of or insufficient communication. The operators that work at Saab are very good at their jobs and most of them have long experience both of the products and the operations which clarifies that the operations are working very well. But surrounding factors makes it hard to create a production flow to a desired perfect state.

The visual control of the production is sometimes hard to understand and follow, which leads to a constant demand of having close checkups of the products in the productions. Despite that, some products are lost in the production. A problem to create a fully working control board is because that the operators that work in the aftermarket also works with the new production, the same problem exists with the machines. Each project is working towards manufacturing their own products inside the Järfälla production site with viable demands. This makes today's visual control board very complex to follow and is at the moment split up in several physical production control boards. Shared operators and machines also leads to problems when priorities in their separate projects. Not only for the planners but also for the operators not knowing what to prioritize and when. The problems because of sharing operators and machines are especially big for the aftermarket, due to the distribution of workload between the aftermarket and new production.

During the process of repairing a product, there are lots of information and papers that physically flows with the product. These are sometimes hard to understand due the information is sometimes poor and/or insufficient. The underlying problem is that the sent information and/or papers is not customized for the receiver but for the sender, causing translation delays for the receiver who has to spend extra time on something that could easily be avoided. More problems with the information is that it does not always get to the right person, which causes lost products and unnecessary storage time between the operations. For example, the product can be waiting for materials or waiting for a TDA to control the product but the information has not reached the concerned person. This also leads to not knowing under whose responsibility the product is in the respective part of the process. The person who sends the information thinks they have sent the product and information further in the flow, but the receiver does not receive a notification that they have got it.

Much of this confusions and project controlling has led to that the production have more ongoing units than they are able to produce at the site causing delays in production planning, information and product flow. This concerns the previously mentioned workstations being suited the individual instead of the application it is used for. But also releasing more orders into the production system without recognition between the workload of the different projects and stations that shares resources. Problems lies in the previously unknown total amount of open orders inside the system and it somehow needs to managed to decrease the number of WIP and increase the flow capacity inside the entire system.

There are some more factors that cause delays in the aftermarket production. The possibility for an approved interruption causes delays, because of the way the agreement is formulated. This does not directly cause delays to the client but it leads to differences between the gross- and net average lead time. The fact that the operators are very good at their station and specialized at some operations can sometimes be a problem if a person is sick or are away on a business trip, causing that no other operator can take his or her place which can cause delays when the product just lies. Causes the production system to decrease their flexibility and has to wait until that person is back from absence or has start educating a new person that can take over.

6.1.3 Subcontractors

The long lead time for the subcontractors leads to long gross lead time for Saab. Because of the service agreement, Saab can use the "approved interruption" clause when a SRU for example is sent to a subcontractor for reparation, in this way the net lead time will not be affected. Even so there are some more problems that cause unnecessary long gross lead time. Today Saab does not have any or very little demands on the subcontractors, how long the lead time can be for example. This may depend on the lack of alternative subcontractors which mean that the current subcontractors have a sort of monopoly on the repaired parts. But in the end it should not mean that Saab cannot put up viable demands.

6.2 Requirement specification for future solutions

The requirements for solving these analyzed issues is presented as an overall guideline on what the solutions should involve acted on the results from analysis and previously mentioned issues in the current state. The suggested solutions should, showed in the form of; description (weight):

1. Help stabilize the turnaround time of aftermarket products through the Järfälla facility to N days (5)
2. Make the production more flow efficient (3)
3. Help aid the sharing of resources inside the production (1)
4. Create a better visual control (4)
5. Create better standard for the information flow between and inside the projects (3)
6. Be understandable for everyone involved in the organization (2)

The specifications are weighed in from 1-5 where the highest number represents the most relevant factor for the thesis project to later correspond with the concepts trial to fulfill the requirement.

7 Ideation, evaluation and development of concepts

During phase 4: searching for alternatives, workshops, a benchmarking and brainstorming sessions were executed. In this chapter suggestions for improvements from underlying problems is presented and later summarized. The summarized improvements are then in phase 5: evaluate and choose alternative, compared to the formulated requirement specification.

7.1 Outcome of the workshop at Järfälla

Because of that most problems lie between the operations, the workshop was performed to understand the underlying problems between the operations and what solutions the personnel together can come up with. During the workshop a lot of improvement suggestions were put up on the table for discussion. All participants had an assignment before the workshop to formulate a problem that affected their own operation/workstation because of others work. The improvement suggestions for all the listed problems have been summarized in Table 4 with their respective underlying reason is formulated from the workshop, which are as important as the improvement suggestions.

7.2 Outcome from benchmarking and workshop, Saab Kallebäck

On the benchmarking visit to Saab Kallebäck, the whole Sourcing & Production division for the aftermarket, Järfälla, Jönköping and Kallebäck sought out to find answer how aftermarket comes into play when it comes to handling of materials, information and the responsible's view and opinions of Saabs present aftermarket situation.

Table 4: Suggestions from the workshop at Saab Järfälla

Who	Problem	Reason/Underlying problem	Solutions/Needs
Tester	***Long turn around time for external supplier***	• Service agreements • No follow up against supplier • No follow up of actions between Saab and supplier • Wrong contact surfaces • No meditating of priorities • Quantity of SRUs sent for repair versus received	• Better agreements by negotiation and demands • Create a contact web • Same priority as at Saab for supplier • Have spare SRUs
Tester	***Low TDA-capacity in the aftermarket***	• Not enough information from client or Saab SS • Missing information of statistical data and reference system • Hard to see the need for the TDA (finish dates, workload)	• Create a need for TDA • Educate testers to do some of the TDAs work • Priorities on workload between aftermarket and new production • More general statistics of previous units • Reference systems inside the facility • One TDA per LRU and their respective SRUs
Assembler	***Wait time on material to start working***	• Need for a planner/material handler to receive material • Wait time for planner to get material from inventory personnel • Mistakes in picking material or missing items	• A product cannot released in production until all of the materials is retrieved • CONWIP-wagons
Planner	***Unknown location of the products in the production system***	• The path between the operation is not clear • Hard to locate in the information channels	• Use just one information channel for preparation, planning and routing • If a LRU/SRU is taken from the shelf, a note needs be there telling where the product is • Better visual control
Arrival/Final assessment /Transport	***Lack of responsibility at arrival and delivery points. Saab does some of COORs work***	• Not decided • Based on routine and it is fading	• Create a responsibility web • Create preconditions/routine for the delivery process • Standardization of the document process
TDA	***The TDAs action does not always translates from TDA to test/assembler***	• The interface is unclear who will take over • No obvious receiver	• Increase competence of involved persons • The result of material picking action needs to connected back to the TDA for completion of action • Standardize the communication to test/assembler from the TDA

These are the main suggestions for improvements of the benchmarking visit of the aftermarket production at Saab Kallebäck:

- Have less TDA controlled production, instead use the reliability of the test personnel on a more basic level.
- Create goals in the aftermarket production that can be measured
- Form a vision for the aftermarket that anchors the aftermarkets importance by upper management and that encourages sharing of knowledge and information throughout the organization.
- Mutual understanding how the different sites works with aftermarket
- Employ a head manager of aftermarket
- Creation of a prototype system in tracking all ongoing repair orders that tracks location, operation, times, need dates and priorities. This is supposed to help production planners and other personnel be able to see the operation schedule and location.
- Working in a standardized way for all sites of the organization with databases and systems.
- Creating a mutual communication platform for the aftermarket departments.

7.3 Outcome of the brainstorming

There has been a number of brainstorming sessions together with the key initiative of production effectiveness with discussions surrounding how an integration of the aftermarket flow with the new production flow could be accomplished. Different methods have been discussed how this integration could be made possible a production system with HMLV characteristics. Kanban and CONWIP are two methods that have been discussed. Table 5 lists the needs in a HMLV production, which demands all needs have and if the method satisfy the need (Livingstone, 2016).

The table shows that CONWIP is the best method for a HMLV type of production. Because of the high variation of incoming products at Saab it is important that the chosen method can manage the variation of the product mix. CONWIP can manage a high variation in demand, product mix and execution as shown in the table, which makes it well suited for Saab Järfälla's production. In order to sustain a CONWIP production and reduce WIP, signals for integration must be implemented and a system to keep the WIP to a decided amount. One way to do this has come up to discussion together with the key initiative as using a specific number of wagons with room for one shop order that can only be used around the production. This limits the number of released WIP

Table 5: Table of needs in a HMLV-production (Livingstone, 2016)

HMLV-characteristic	Demand	CONWIP	Kanban
Variable product mix	Can manage high variation	✓	✗
Variable execution times	Can manage variability	✓	✗
Complex material flow network	Not required to handle complex networks, only general flow shop	✓	✗
Variable demand	Can level variable demand	✓	✓
Frequent change in product design	Not relevant	-	-
Planning complexity	Simple to understand and to execute	✓	✓

products and gives a better overview of what Saab is able to produce. But this might also be fixed virtually in their databases if the not releasing products into production if there are more than specific amount.

During the brainstorming sessions and through the analysis of the current state at Saab Järfälla, a new version of a visual production control board that can provide an overlook over the whole production has come up as a suggestion for improvement. Looking back at the current boards which more or less creates confusions and neglects information about the rest of the production parts. Concluded in both the Ishikawa diagram (Appendix 7) and the requirement specification (*Section 6.2*), the need is great for a new visual control board.

7.4 Summarizing and evaluation

To get a better overview of all the suggestions for improvements that have come up in the earlier in the chapter, a summary has been made in Table 6. A short explanation what the suggestions is, what challenges is has and what benefits it gives has been written with all suggestions.

Suggestions for improvements	Challenges	Benefits
Better service agreements to suppliers with greater demands	Challenge to get to an agreement that both part will accept. Evaluate terms that will benefit both parties and how they should be upholded	Will result in easier knowing the delivery times and create more decisive planning for products
Create a contact web between suppliers and Saab	How the communication should be and who should be responsible inside Saab for external communications	Easier connections between the suppliers and Saab resulting in better relations and more reliable supplements
Have spare SRUs in inventory at Saab. (Safety stock)	Decide who will pay for the spare parts and evaluate how many big the safety stocks should be (ongoing internal project).	Faster lead time and less "approved interruptions"
Suppliers are supposed to have the same priority on SRUs as Saab	Get the suppliers to understand that Saabs SRUs are the most important. How the information about priorities should reach the supplier.	Will result in easier knowing the delivery times and less WIP
Create a need for TDA	Visualization and get the communication that it is needed. Workload balance	Better information flow
Educate testers to do some of the TDAs work	Requires lot of time and might stop production if the testers is getting educated. (Short term)	Greater production flow and better variations for the workers
Priorities on workload between aftermarket and new production	Decide whos project is the most important. Challenge to visualize when the products could enter and exit the production system	Easier to plan the production and see which products are able to leave the system and when
More general statistics of previous units	To get all operators to start documenting in an more exact way what they did, problems, and cycle times.	Faster lead time. Able to create more specific VSMs for each product or process
Reference systems inside the facility for the TDA	Get the organization to understand if it is worth it.	More reliable tests and measurements
Have one TDA per LRU and their respective SRUs	Create an understanding how this might work and the benefits. Balancing workload between different TDA or set more TDAs to a specific LRU.	Greater production flow
A product cannot be released in production until all of the materials is retrieved	Knowing when all of the material is retrieved.	Greater production flow
Use a number of wagons in the production (CONWIP)	Knowing/Calculate how many wagons that is the right amount.	Faster lead time, a controlled number of WIP and easier overview of the production
If a LRU/SRU is taken from the shelf, a note needs be there telling where the product is	To get all operators to start document positions in the current information channel.	Greater information flow
Use just one information channel for prepartion, planning and routing	Make it usable for all parts in the organization and make "HOW TO" manuals.	Better information flow
Create a better visual control over the production	The production is very complex and account for all parts.	Better information flow
Create a responsibility web	Getting in contact with the right persons who can make this happend.	Easier to gain knowledge what to do
Create preconditions/routine for the delivery process	Getting in contact with the right persons who can make this happend.	Better production flow
Standardization of the document process	The documentation process today is very complex and needs a lot work to be standardize sets of operations, routings and material handling.	Better information flow
Increase competence of involved persons	Create time for educations, seminars and conferences.	Better understanding and strive to move forward. (Continuous improvements)
The result of material picking action needs to connected back to the TDA for completion of action	Create notifications statuses that the TDA recieves when a material picking action is made.	Better information flow
Standardize the communication to test/assembler from the TDA	Making sure it is done right and in the same way.	Better information flow
Have less TDA controlled production, instead use the reliability of the test personnel on a more basic level.	Decide where the basic level stops and when the TDA needs to be informed	Faster lead time
Create goals in the aftermarket production that can be measured	Choosing goals and metrics that is essential for the aftermarket production	Creating standards, increase morals and/or objectives
Form a vision for the aftermarket that anchors the aftermarkets importance by upper management and that encourages sharing of knowledge and information throughout the organization.	Mutual understanding of the key principles why the workload differs between the projects.	Better information flow
Mutual understanding how the different sites works with aftermarket	Getting in contact with the right persons who can mediate the right information.	Greater knowledge exchanges
Employ a head manager of aftermarket	Convince the upper management of the need	Better overview of the after market
Creation of a prototype system in tracking all ongoing repair orders that tracks location, operation, times, need dates and priorities. This is suppose to help production planners and other personnel be able to see the operation schedule and location.	The production- and information flow is very complex	Better information- and production flow
Working in a standardized way for all sites of the organization with databases and systems.	Needs to have resources and projects moving towards a common goal of standardization	Better information flow
Creating a mutual communication platform.	Getting in contact with the right persons who can mediate the right information.	Better connections between the sitez

Table 6: Summarizing of all suggestions

Table 7: Combination of concepts

Color	Summarizing	Name
	Create better relation between Saab and the suppliers	Saab relation between suppliers
	Review the TDAs work and surroundings	Saab relation between suppliers
	Communicate the importance of the aftermarket to the upper management	Communication upper management
	Create a better overall documentation	Documentation standard
	Create better visual control over the production	Visual control board
	Create better relation between all sites at Saab	Saab relation between sites

As seen in the table most of the suggestions have been paired up in different colors, which have formed six concepts. These concepts were given names (Table 7) and then compared to the requirement specifications shown in Table 8.

Table 8: Comparison of the concepts against the requirement specifications

Concepts		Saab relation between suppliers	TDA work	Communication upper management	Documentation standard	Visual control board	Saab relation between sites
Requirement specifications	**Weight**	Create better relation between Saab and the suppliers	Review the TDAs work and surroundings	Communicate the importance of the aftermarket to the upper management	Create a better overall documentation	Create better visual control over the production	Create better relation between all sites at Saab
Help stabilize the turn around time of aftermarket products through the Järfälla facility to N days	5	2	2	2	3	3	1
Make the production more flow efficient	3	1	3	2	3	4	1
Help aid the sharing of resources inside the production	1	1	3	3	3	3	2
Create a better visual control	4	1	1	1	1	5	2
Create better standard for the information flow between and inside the projects	3	2	3	3	5	3	2
Be understandable for everyone involved in the organization	2	2	2	3	4	4	3
Total Points	90	28	39	38	54	67	30

Score 1-5
1= Does not fulfill demand
5= Fulfills demand

The concept that got most points was the "Visual control board" concept. The concept got 67 of maximum 90 point almost 75%. The visual control board also got the highest score on the two requirements that were given the highest rank, which proves that the concept is the most suitable for this case. Receiving the highest score from the selection matrix proves that the winning concept not only is the most suitable but gives the most positive effect in relevance to the different concepts to start with.

Important to notice is that developing and implementing the visual control board, does not mean that the other concepts cannot be implemented later. The concept selection matrix can be seen as a prioritization list, which concept to start developing and in which order. The different concepts do not collide with each other, making it possible to use the other concept in a later stage.

8 Developing and finalizing the final concept

This chapter describes how the final concept, visual control boards, was created in order to improve the production at Saab, what changes needs to be made from the current state and way of working. The concept is described through the principles used together with a proposed solution and the positive effects of the physical final concept.

8.1 Changing the way of working

The main reason for this visual production control board is to make the whole production work as one unit and to get a better overview in the production. Ideas for how these new visual control boards should work have been spun together with managers, operators and the key initiative. Using flow efficiency theories and workshop experiences to eventually reach the desired perfect state as a less complex system. Using production queues with FIFO (First-In-First-Out) together with daily meetings with operators and planners will set the base of the production board. During these daily meetings, it is decided which products are going into the production system, what products should be prioritized and what delivery deadlines are coming up. This helps both planners and operators manage their work.

The new visual control boards are supposed to create a current image over the production, which will benefit both operators and planners. As mentioned earlier the operators shares time while working both the aftermarket- and new production, which has been a problem based on a lot causes earlier explained in the analysis. The visual control board should help the operator to see all the products and every prioritization that is put up from the different projects. Later during the daily meeting there will opportunities to ask questions or discuss problems if there are some things that are unclear. One observation also seen was the lack of knowledge between the operations, causing problems both in the communication and knowing what is going on around you.

In the visual control board it is easy to see what all operators are working on and where in the production. It also makes it easier knowing where all products are and where to find them, which will make the work much easier and faster.

Talking to planners and project leaders it has been noted that it is hard to make the production work together with different projects. Much because of the knowledge in others project but also due to the lack of communication. With the visual control board it will be possible to see an overview over all ongoing projects, which phase they are in and what products and resources is being used. This should help the planners understand the current situation in the production and what the different prioritizations are. Prioritizations which also has been a problem in the production both for planners and operators. Different projects have different prioritizations and knowing which one to follow for the operators have been a problem. The different prioritizations cause problems for the planners and project leaders as well. All projects cannot have prioritizations on their products at the same time causing conflicts and situations when deciding which project prioritize in front of each other. A visual production control board should help the planners and project leaders to understand how the projects are going and hopefully see which project to prioritize first. This will later help the operators when the same information comes from all parts of the organization.

8.2 Planning, control and flow principles

As already been showed in the analysis of the current state, the main problems lie in not seeing the production as a whole and what lies in between the stations, how long they are there and when the products will be in order to be worked on. In order to take control over the production and seeing all the angles, a visualization of the production in sequences is needed. In a production system with HMLV characteristics, using queues adaptations for each specific process to develop an overlook for easier planning and production control.

The proposed and worked in solution from the ideation and theoretical phase is to start using lean production from the start by starting visualizing the production flow as a whole using a FIFO queue system to help the priority levels of the different projects at Saab. The goal here is to establish a sense where the demand is highest of stations and localize which stations are having troubles getting products through their part of the production flow. A modification and addition of the FIFO-queues is making it more transparent by using the current magnetically bricks on the physical boards but having work-in-process spaces and what available resource (person) currently working on that job and where. Making it easier to locate and easier to discuss needs and finish dates with managers and planners. Similarities as seen in research by Horbal, Kagan and Koch (2008) by using the FIFO-queues station- or areawise to try and implement a pull system through thorough integration of the planners, managers and operators in daily interactions. The FIFO-queues are shown to visualize the needs of the current products in the system and priorities could be made using daily meetings for the involved operators, managers and planners to arrange one product that has a higher priority in front of others in line by open communication and specified physical locations.

In order to make the flow through the visual control boards work, as mentioned earlier each part using the board must have a standardized set of rules and regulations how each brick/work order should move. Each bricks placed on the visual control should represents its physical location in the production layout and each mover of the bricks should know where to move the psychical product and the brick. By ideation and cooperation of managers, planners and operators the emphasis of the boards must first be established then teached out to the rest of the workers to make them move the bricks in general set of movement rules.

The movement of each brick on and between the visual control boards should almost be operator controlled by the exception of moving new work orders in and out the system than today's very vague planner control of each separate project and three-week planning. The daily control meetings by the boards should in this case work as help for the operator to communicate for assistance and create an atmosphere for openness.

By creating this overlook over the whole production system, a person can easily see how many orders are in process. Using wagons as proposed by the key initiative, and one wagon per work order together with physical visual control boards, a control over the WIP-levels could easily be established through a CONWIP-policy. Starting a CONWIP control should be done by setting an initial WIP-level to the whole system through a general mean value then creating iterations by following and evaluating the products lead time through the system to later reduce the WIP-level until the level of maximized utilization is found (Hopp & Roof, 1998; Hopp & Spearman, 1996).

In the visualization of the whole production and setting the initial WIP-level for the whole system, using Little's law could have very little effect but it can help the decision for what number to reduce to by calculating average throughput rate and planned lead time to find an appropriate WIP-level (Lödding, 2013).

8.3 Developing the physical visual control boards

In order to make the visual control boards, a couple delimitations were put on mind. The physical sizes of the boards had to be considered, sizes and color coding of the magnetic bricks and how many stations, areas and resources are used on the applicable production floor.

A simplification of the possible physical routings of the production is illustrated in Figure 25. The illustrations involve necessary parts for the creation of the visual production control boards. By setting parts or work order on the deviation shelf should visualize that action to fix the problem is required as fast as possible and should be prioritized when the part is able to be worked on.

A proposed solution how this could be done is visualized in the two slightly similar ways, by assembly areas, Figure 26 and by test stations, Figure 27. The slight differences depend on the test stations being very many and can only test specific products and the assembly areas can assemble a lot of similar products. The

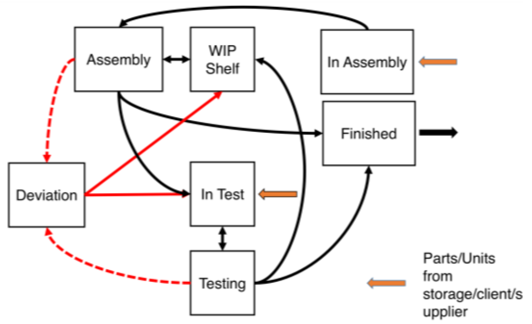

Figure 25: Simplification of the possible physical routings each product from all products can go through in the new production system.

figures only represent an example of the build of the visual production control boards, a full scale view of the final result is presented in a guideline booklet in Appendix 4.

Aftermarket and new products uses slightly similar routes with the differences being the startup place. New products take material from storage or suppliers and start with assembling smaller parts (SRU and SU) then goes to further assembling of larger LRUs or testing of the part to make it flow through the system. Aftermarket product starts with a fault diagnosis and further onto determinations for action since each part often is different. Decided between the thesis group, the key initiative and managers, a product that has entered the system and work has been done to it

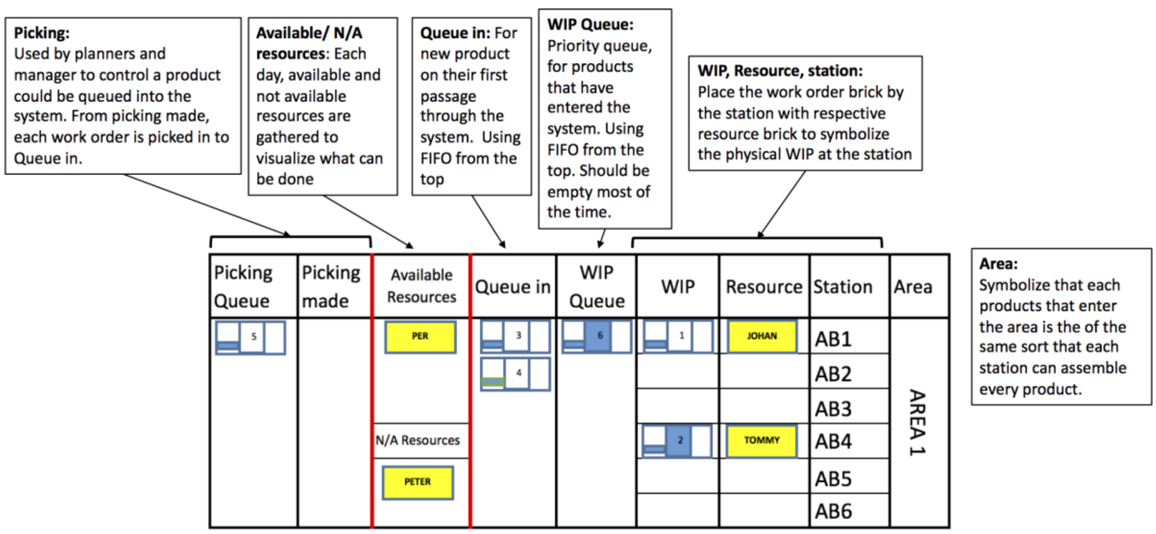

Figure 26: An example of an assembly area on the production visual control board

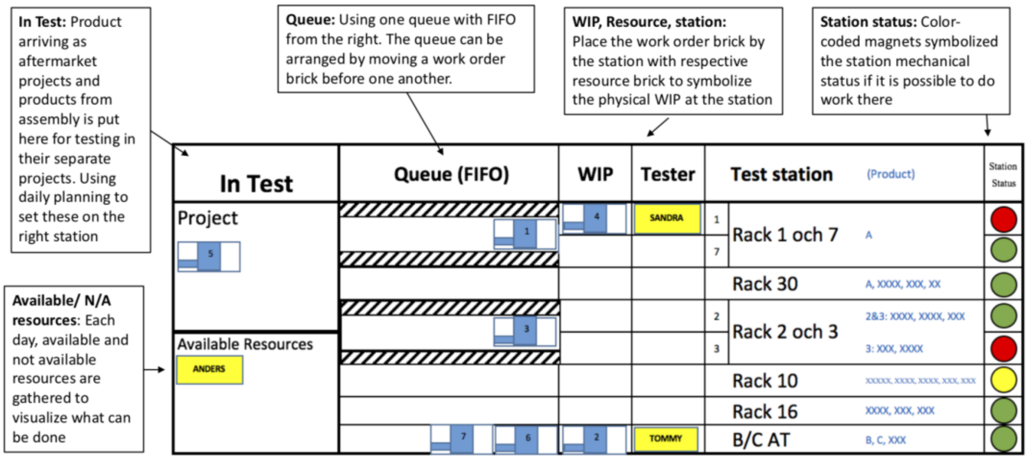

Figure 27: An example of visual production control board of testing

will always have a priority next to a product that waiting in line to be started its first process. What also need to be kept in mind is that once a product has been started working on, the priority is to finish the product first and not allowing more products inside the system than it can handle to be more flow efficient. It is easy to find the amount of workload and capacity for the system when each station or area forms queues that have to get through the system.

The deviations inside the system should be moved to another board where a responsible person to solve the issue should be specified with stop date, location, possible cause and a feasible restart date. When the deviations are ready for work again, the work order should be placed in the WIP queue (assembly) or front of the line for a station (test) to be able to leave the system as fast as possible.

Using TDAs for some parts in the process, a tester or assembly is sometimes required to get help from a TDA. To visualize the demand for a TDA and material acquisition, a determination for action and material request part is put up next to the test stations with the same principles using FIFO priorities to ensure parts are moving.

A CONWIP signal should be determined by amount of wagons already in the system, an amount that needs to be decided by trial-and-error. The wagons should be stations by the right workplace when being worked upon, and placed on a marked spot by the in- and out station when be ready for another work order.

9 Discussion

This chapter critically reflects, reviews and discusses the execution of the project as well as the results and insights of the master thesis in accordance to the stated aims and objectives. Further development, additional thoughts and the solutions it selves is reflected by their validity and relevance to the case company's future and finishing off with conclusions with answers to the research questions.

9.1 Project execution

Writing a master thesis together have been as fun as it has been challenging. Always having someone to discuss with is the biggest benefit comparing to writing alone. But it also makes it much more important to always have a close communication. Writing the last 25% of the thesis from two different places complicated some of the communication that was not a problem earlier. Though one of our greatest advantage working together is that we in the thesis group had worked together before in other successful projects and know how each other operates in order make use of our strengths and weaknesses to achieve the best result possible. This makes it easy to find new ways to make the communication work between us. Making sure to plan each phase, writing session and talking over the phone, created an atmosphere as the one where we were working at the same location.

This thesis has worked out smooth with only few problems along the way. From the beginning when the project plan and timeline were conducted, the work has run as planned in the expected time-frame. When structuring the thesis, we decided to stay in Luleå the first 25% of the time, writing the first four chapters. This because of that we thought it was important to have the library and our supervisor from LTU close to us, when focusing on the theoretical parts of the thesis. Further we planned to stay the next 50% of the time on location at Saab, during the mapping- and analyzing the current state phases. It was necessary to have a close relation to all the personnel and to have the proximity to the production, in order to create the correct image of the production and the current situation. The last 25% of the thesis was written from two places outside the case company, this because of that the time was under the vacation period and different plans separated the project group.

To be located in Luleå during the theoretical part of the thesis and to be at Saab under the mapping- and analyzing part, we believe was a smart move. This gave us the best chance to use our supervisors in the best way and taking the opportunity of being close to both campus and Saab in the right time frame of the thesis. The communication to our supervisor at LTU has worked out perfectly, with questions and thoughts that have come up during the thesis has been answered which is all we can ask for. During the first 25% of the thesis it was possible to book meetings where we could discuss upcoming problems face to face because of that we were located in Luleå. Later when staying at Saab and during the semester all contact have been through mail, which have worked as well.

The biggest challenge was to find out that our supervisor at Saab was getting a new position not in the same building in the middle of thesis project, making it much harder communicating. But when starting to get to know "the key initiatives" Peter, Alexander and Niklas who worked with the production planning, this led to a close connection to the production and operators, as well as great support in the mapping- and analyzing part of the thesis.

Having the key initiatives almost as our new supervisors have been a great benefit for the result and the thesis. It has led to a wider knowledge of the production, not only over the aftermarket production but making it possible to create the visual control board for the whole production. Since all of the key initiatives are MSc engineers with almost the same background, dialogs surrounding the thesis and how to execute it in the best way have been a great benefit for us.

9.2 Results

To ensure that results of the project are valid and reliable, each result have been presented for company stakeholders and involved users, to shine light on direct and indirect issues in daily situation. This was met with questions and reassurance that the project's result was reliable and easily understood. Each result or solutions are also reviewed from theoretical basis to form argumentation for the presented work. It should be mentioned though that the result of this thesis project is simply the result from using these specific methods to this specific context and could maybe with another approach led to a different result if other methods or another context were involved.

The main idea from the start of the project was only to present an analysis of the current state and some proposed suggestions to change the production. But the thesis project expanded even further to come up with a concrete improvement solution that was instantly implemented during the course of the project additionally to analysis.

9.2.1 Aftermarket

Watching the results from the systematic observation and data collection there are big differences between both the lead time and the average processing time. This shows that there is a great potential in the production if there is a safety stock for each part in the inventory. The results also show that the mean value from the historical data cannot be entirely trusted. The standard deviation for both the lead time and the average processing time is too high and cannot create representative image over the products full lead time. Having standards and statistics that is representative is important when working with improvements. There has to be historical data and reliable metrics that can be compared with to know if the results found is trustworthy. Starting by making a new VSM over the aftermarket when the visual control boards have a standardized roll in the production, it will be possible to see if the visual control boards is making the lead time shorter. Doing a VSM over the aftermarket in a locked proposedly quarterly time frame, new historical data can be collected and compared in the future. By doing this work with more products and stations more and more historical data is going to be collected which will be a great advantage for Saab.

From the current state it became clear that many of the operators only could manage one or a few products/stations. To have an effective and flexible production it is important that as many operators as possible can manage as many products/stations as possible. We could see during the time spending at Saab that when an operator called in sick, problems occurred to find a person who overtake the work made by that operator in order to make the product flow through the system. Since each operator is specialized on just one or two products/stations this creates stops and interruptions in the products flow. In statistical terms this affects standard deviation on the products lead time which was the main problem in production discovered by observations and data collection.

Creating a more flexible production where operators can manage many production/stations and variety in their work will hopefully make the aftermarket production a more attractive place to work in. In the current state we explained that working with new products was a much more attractive option for the operators, creating prioritizations problems for the aftermarket products. Still having prioritizations between the productions from the operators is close to the opposite of having a flexible production and will be a bigger problem by the time if nothing is done to counteract it. By changing and neutralizing prioritizing through being able to do what is needed instead of just working with one or two products will create a more flexible and attractive production for both ends.

9.2.2 Visual control boards

The visual production control boards have been presented in a guideline booklet containing use recommendations, instructions, explanations and suggestions for further development on that specific area of the production. To ensure each involved persons understanding of the purpose and objectives of the solution, it has been explained in face to face conversion during daily meetings and if questions are raised, you should be urged to check the guideline booklet located next to the boards. The guideline booklet might not be read explicitly but we are confident that the booklet will help be helpful to answer most of the questions raised.

Due to the customization to the applicable floor and to current state of Saab Järfälla's production, the creation of the visual control boards may need to be modified to fit other sites' situation but the fundamental usage of them might be possible to use around the entire organization. The development of the boards during the course of the thesis came to resemble the PDSA-cycle due a plan was established for each small suggestion, then testing and implementation, onwards to a study how well it worked and lastly an act to control for optimal outcome (Deming, 1993).

In the current state, an operator only has knowledge of a specific station or product process, this is going to show quickly on the visual control boards if the queues starting to grow when a specific operator is unavailable. By trying to become a workplace that want to be more versatile, education and skill matrices is essential for further development in the next stage.

As Saab's entire production is trying to be more flow efficient and the quality of the work is stable, Lane (2007) suggested to use visual management and FIFO-boards to later starting to use more and more lean tools. Because of these visual control boards, we are sure that Saab could use more of a lean approach towards their production and be more explicit specialized using tools as value stream mapping, CONWIP and employee involvement.

For aftermarket and new products to be integrated in the same production flow, creates opportunities to use techniques and theories from other after sales services, HMLV production systems and lean production. Through using CONWIP to later measure and focus on availability and capacity, this could lead increase in better overall production in both the aftermarket department and every other production project.

The purpose of these visual control boards is creating an overview of the entire production flow and to create a way to be able to quickly act and adapt on deviations to have continuous flow in the production without interruptions. Further and continuous development will be essential to ensure the success of the company and the visual control boards. When the physical boards' purposes are achieved, a standardization is already in the make into a program that could be further used in a digital form with monitors instead of a physical board.

9.3 Relevance

This project is mostly relevant for Saab Järfälla's production site where the current state has been analyzed but the result and the solutions could possibly benefit a larger part of the organizations other part. The result from the thesis visualizes previously unexplored or non-transparent statistical areas to a broader audience and could potentially be easier dealt with to make the whole production better. The thesis project had been highly relevant to current situation with the production going under a remodeling phase at Järfälla together with the key initiatives during the course of thesis. This has made the solutions being able to be tested and/or implemented while the thesis was conducted. Becoming a more transparent, reducing lead time and stabilize production company lies in line with the decided goals for the thesis and for Saab, making the result and further development very relevant.

Some parts of this thesis may also be relevant for others analyzing, improving and changing their production system with or without aftermarket production. Especially if their situation is in need of change in the planning, control and management of the production, the exploited literature, solutions and discussions could be of use in order to help decide whether the way is applicable for their production or not. Even though most of this thesis focuses on the aftermarket production, it been highly regarded that the thesis has put great weight in combining the aftermarket products with the new.

In an even broader view, the thesis shows how a development process can be conducted providing help for new projects with using project planning and processes to reach a certain result. The used literature and methods have been modified in a way to create solutions suiting the thesis situation and will have to be considered and modified to their own situation if other practitioners are to produce a similar result.

9.4 Conclusions

To summarize this project, the research questions that were formulated at the start of the thesis project will be answered. A discussion around the answers whether the objectives and aims of the thesis is fulfilled is shortly followed.

Main RQ1. How can the after sales service production flow with HMLV characteristics be improved to manage a N days turn-around through the factory?

As shown in the Kingsman equation *(Section 3.3.3)*, that the higher the variation inside the production system, the lower possibilities of having a high resource efficient production (Kingsman, 1966). Therefore, the need of a more flow effective production is a fact to achieve the perfect state (Modig and Åhlström, 2013). Using visual control boards to have a better control over the production and all products in it, will make the production more efficient and stable. The need of clearer responsibilities and standardized handoffs will make the downtimes shorter, more constant and predicted, which will also create a more stable production.

Further and continuously developing, standardizing and creating better transparency is key in all aspect of the HMLV production system together with user involvement. In mapping the current state at Saab Järfälla, a conclusion that a similar production needs clear objectives in responsibilities and handoffs to change from a resource efficient to a flow efficient organization.

Sub RQ1. Which principles or methods should be used to stabilize the after sales service flow?

Using control means and standardized working between the operations will create a more stable service flow. Patton and Bleuel (2000) describes that to champion the aftermarket having a visual management system is essential. The use of the visual control board will thereby stabilize the aftermarket.

Sub RQ2. How should an after sales services flow be designed and developed to be integrated with the production flow of new products?

Through the visual control board the after sales service flow have been integrated with the production flow of new products. Even if there are two different productions there are now connected which they were not before. Identifying what variables that the different productions shares, how they can collaborate and how the products flows in the both productions have been the key when developing the connection. Making both productions as flexible as possible, starting with not having person based workstations have been successful under the development.

Sub RQ3. Where and what variables affect and create delays in the after sales service flow?

Through the extensive mapping in the thesis, a conclusion is that variables that cause delays come from three different categories; in the production, in the organization and the subcontractors. The main variable that causes delays lies between the stations, not in the operations themselves. Not having structured ways of handling both information and products and not taking the responsibility that needs to be taken causes delays that can easily be avoided. A full Ishikawa diagram over the variables that causes delays in the after sales service flow can be found in Appendix 7.

10 Recommendations

In this chapter the final recommendations discovered through the thesis project's results and discussions at Saab Järfälla outlined. The recommendations summarize the findings throughout the project, and gives suggestions on what Saab Järfälla may need to adjust, implement or further research upon before they reach their potential in an optimal way.

10.1 Recommendation to Saab

Saab AB Surveillance Järfälla is recommended to implement or adjust to the following solutions at their production site;

- Keep more statistics and decide metrics around the aftermarket and entire production to later be able to develop value stream maps over separate projects
- Continuously keep standardizing as much as possible through iterative studies and create guidelines for each production process
- Open up communication inside the company to continuously get and handle development suggestions from the daily operators
- Negotiate better agreements and means of communications with subcontractors
- Implement skill matrices for all workers in order to broaden the competencies, handle variation and becoming more flexible in the production
- Continuously develop and evaluate the implemented visual production control boards by using the guideline booklet in Appendix 4
- Control and adjust the amount of product by wagons inside production flow through trial-and-error and statistics, previously mentioned in section 8.2 about CONWIP

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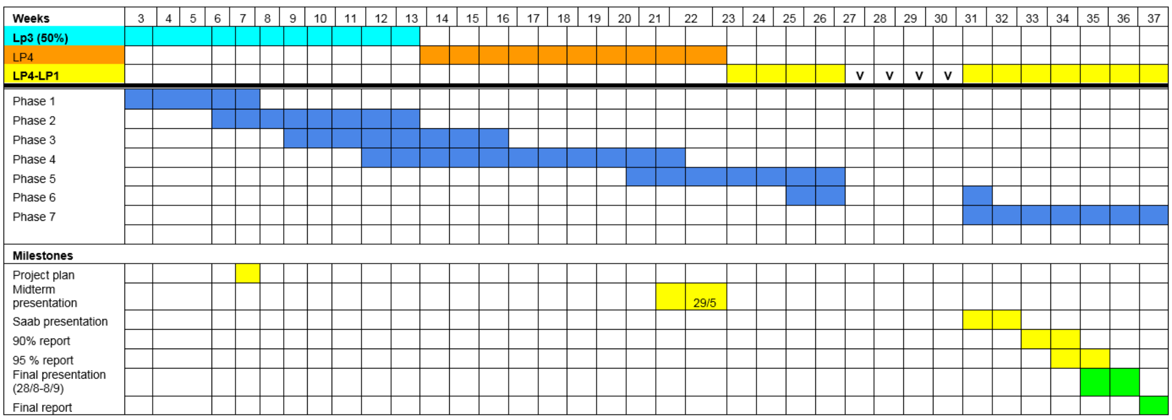
Appendix 1 – Project plan summary (1 page)

Plan for thesis project process and deliverables

Project Phase	Goal of the phase	Deliverable	Time*
1. Project planning	Define the project what the goal should be, how it should be reached and what needs to involved	Project plan	40 h
2. Literature review	Find and summarize theories and research that is relevant to the research questions and the success of the project	Theoretical framework	160 h
3. Default mapping of context and current state	Mapping the current situation at the company	Contextual framework Current state (Future state)	120 h
4. Analysis of current state and possible future state.	Extensive analysis of the current state	Requirement specification	200 h
5. Ideation and concept development	Search and combine possible solutions for improvement	Concept suggestions	120 h
6. Evaluate and choose concept	Evaluate the alternatives, choose a final concept to develop and finalize further	Final concept Plan for implementation	80 h
7. Finalization	Completion of the project last part and	Final report	80 h

*counted on one person's time in the project

TIME PLAN



PROJECT TEAM

Thesis students
Gustaf Jörnelius
Viktor Toftberger

Supervisors
Magnus Stenberg, Luleå University of Technology
Sven Pettersson, Saab AB Surveillance (Project employer)
Peter Flodin, Saab AB Surveillance

Appendix 2 – Benchmarking Saab Kallebäck (1 page)

Saab Kallebäck, Gothenburg, is part of the business area Surveillance and is now partnering up with Järfälla in the Sourcing & Production division to become a more efficient unit in all sides of the Surveillance production. Not unlike Järfälla, the Kallebäck production consists of a number of products with really high or medium customization in selection of parts. At Kallebäck the main focus is production of land based, air based and naval radars, lasers for national defence.

As part of an initiative for the whole Sourcing & Production division, Järfälla, Jönköping and Kallebäck work together implementing new ways to improve efficiency, stability and work environment. On this benchmarking visit, the group sought out to find answer how aftermarket comes into play when it comes to handling of materials, information and the responsible's view and opinions of Saabs present aftermarket situation.

Entering Kallebäck, we found out that a similar approach on the aftermarket as our thesis was ongoing at the Kallebäck aftermarket department. Unlike Järfälla, Kallebäck has a head manager of just the aftermarket department which is at Järfälla handled by several managers and planners.

Implementing ABW, Activity based workspace at Kallebäck has freed up space and created a more open environment where workers set their own set for working neat and more independently. Observations of this culture and restructuring brings a more meeting based organization and ability for the worker to interact easier with their surrounding peers.

At Kallebäck production, the supervisors and managers have daily morning meeting at “Guldgruvan/Dagbrottet” where they discuss how well the production are going, how many orders are in production, material and product flaws and responsibilities. Each day of the week have different subjects focusing on improvements, reports and future planning. At these meetings, they are presented with ongoing productions and repairs on an open visual board available for anyone which makes it easier for everyone to see where the problems lie and what to focus on next. This is something that has been used at Järfälla but not currently working since the large number of shop orders that exist and is handled.

The production at Kallebäck are generally using functionally structured layout, where the products are flowing for each unit to the next creating a lot of transport and information handling during the way. Especially since Kallebäck are using transport between floors, causing it somewhat harder to track where specific parts are located in an already high-mix part facilities.

Main findings of the benchmarking visit of the aftermarket production at Saab Kallebäck:

- Very similar in the process schedule but less TDA controlled. Instead using the reliability of the test personnel on a more basic level.
- The aftermarket production doesn’t have a goal(s) that can be measured since no focus has been on what measurements needs to be retrieved.
- A general feeling of less focus on the aftermarket by upper management. Might be a good idea to form a vision for the aftermarket.
- IT-systems are used very differently. Less focus at Kallebäck on CRO (Customer Repair Order) writings in IFS, using NCR instead. And in Jönköping more focus on CRO.
- Meeting for understanding creates an overview for everyone.
- Visual boards are all different everywhere. Creates a little bit of confusion. A need for digital visual boards was established.
- A head manager of aftermarket.
- Want to create similarities between Järfälla, Jönköping and Kallebäck.
- Creation of a prototype system in tracking all ongoing repair orders. Works for Kallebäck that tracks location, operation, times, need dates and priorities. In the future this is supposed to help production planners and other personnel be able to see the operation schedule and location.

Appendix 3 – Workshops (3 pages)

In this project two workshops were made. One at an offsite and one on the case company but in at Saab AB within the aftermarket of both sites.

Workshop in Gothenburg, Saab Kallebäck (2017-04-20)

Six persons from Saab Järfälla were invited to a workshop in Saab Kallebäck 2017-04-20 including us. The invite was sent from two students from Chalmers who were doing their master thesis at Saab Kallebäck. They were also writing about the aftermarket production and wanted a workshop with all the people at all Saabs production sites who concerned the aftermarket production. 15 persons from Saab Järfälla, Jönköping and Kallebäck were participating in the workshop. The main focus in the workshop where goals and measurements to evaluate the aftermarket department as a whole at Saab and to create a future strategy.

The student then present why it is important to measure and how to set up smart and relevant goals. They showed the SMART theory for putting up goals and explained the different steps. The participants were then divided into four groups before the exercises started. (SMART stands for S=Specific, M=Measurable, A=Applicable, R=Relevant, T=Time based)

EXERCISE 1

In the first exercise the groups were supposed to write down all the goals that existed today in the aftermarket production in all production sites. The questions were:

- Which goals/measurements exist **today** in the aftermarket production?
  - Goals/measurements for **you**?
  - Goals/measurements for the **customer**?
  - Goals/measurements for **Saab**?

All goals were written down on post it notes and later presented to the other groups.

EXERCISE 2

The second exercise started with that all the participants were supposed to write down all the measurements that they wanted to have in the future. This were in the next step presented to the other group members, discussed and then categorized together with the rest of the suggested measurements from the group members. As a finishing step in the exercise the group members was told to score the suggested measurements and then present the results to the other groups. The group members were given three points each for scoring individually the suggested measurements.

EXERCISE 3

The finishing exercise started with new groups were made and the task was to write on post it notes how the three aftermarket productions can collaborate more in the future and suggestions for how this can look in the future.

Workshop at Saab Järfälla (2017-05-11)

BACKGROUND

Under the process of mapping the current state of the aftermarket production we have seen that the problem lies between the operations, the operations themselves works smooth and flawless. The administrative steps in the aftermarket are also a critical part where the improvement potential is great.

To get at a better understanding of these problems and to get a better understanding of the bigger picture of the aftermarket production, this workshop is conducted. The goal with the workshop is to understand the underlying problems between the operations and what solutions the personnel can come up with. This will then help us during the ideation and concept development part of the thesis.

OBJECTIVE

The objective of this workshop is to produce a large amount of diverging ideas on how the aftermarket production flow can be improved and the lead time can be decreased.

TEAM

Manager Planning; Sven Pettersson
Arrival Controller; Rosemarie Bergström
Sub-project Manager; Niklas Båvenstrand
Planner; Peter Flodin
TDA; Sophie Griph
Assembler; Arne Sandin
Test personnel; Sören Andersson

AGENDA

Introduction 09.00 - 09.10
Introduction of the thesis and the workshop. The agenda and the goals with the workshop will also be presented.

VSM walk-through 09.15-10.00
A walk-through of the production flow in the aftermarket production. All operations and processes are presented by a responsible member and explained to the group.

Brainstorming/Workshop 10.10 - 11.30
The group is divided into two groups.

The operations are presented one at the time were the specific problem with the operation is explained. The groups will then discuss the problem, try to find solutions and present them under 10 minutes for each operation.

Concluding part 11.30 - 11.45
Concluding discussion of the workshop and question time.

EXECUTION

In this section the execution of the workshop is explained. A longer explanation of what did happened under the different steps and what the participants did do.

Introduction 09.00 - 09.10

The workshop started with a short agenda presentation of the workshop, showing the steps and how much time we were supposed to spend in each step. A summary of the thesis was also shown. The goals with the thesis, what we have done to this day and why we wanted to have the workshop were presented. Why we wanted to have the workshop were strengthened with a graph over the input- and output frequency of the LRUs. The graph showed that the amount of outputted products has doubled from 2015-2016 but that they need to continue the improvement because that the net average lead time still is over N days.

VSM walk-through 09.15 - 10.10

The walk-through started at the arrival point. The people involved in the step described how the work goes on and answered the questions that came up.

This was done at all the steps in Figure 28. Because of the 10-minute overtime the last step “finish/transport” were presented back in the conference room.

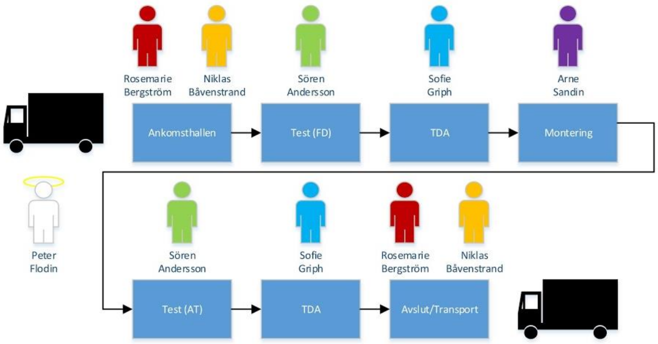


Figure 28: How the VSM was conducted through Saab Järfälla.

Brainstorming/Workshop 10.10 - 11.30

Part of the homework was to gather a problem that affects them because of other units. The problem from the different units is shown in the Figure 29. Every problem was then discussed under 10 minutes. 4 minutes discussing how the problem is occurred, 4 minutes discussing how the problem can be solved and 2 minutes presenting the results.

Concluding part 11.30 - 11.35

The participants were thankful for partaking in the workshop. No further questions were asked.

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Appendix 4 (19 pages)

Lathund för styrningstavlorna för B2 produktion

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Appendix I: Flödesschema för brickornas rörelse genom systemet (1 sida)
Appendix II: Styrtavla I: Monteringstavla, preliminär utformning (1 sida)
Appendix III: Styrtavla II: Test- och åtgärdstavla, preliminär utformning (1 sida)

1 Syfte

De nya produktionsstyrningstavlorna har som syfte att göra helheten av flödet mer överskådligt och skapa ett sätt för kunna agera snabbt för att ha ett kontinuerligt flöde i produktionen. Dessa tavlor skapa en bättre interaktion mellan nyproduktion och eftermarknadsproduktion för att lättare se hur resurserna kan delas upp mellan olika projekt på bästa sätt.

Vilket på sikt ska leda till en bättre flödeseffektivitet, resurseffektivitet och större leveranssäkerhet.

1.1 Definitioner

FIFO	*First-In-First-Out. Kösystem där den äldsta produkten som tagits in i systemet ska också vara den som kommer ut först ur systemet*
IFS	*Databassystemet som används för hela organisationen*
PIA	*Produkter i arbete. Produkter som har kommit in systemet och/eller arbetas på*
Resurs	*Refereras till i denna lathund till en mänsklig resurs som kan utföra ett arbete och tillför något i organisationen*
SO	*Shop Order. En tillverkningsorder som fått ett nummer enligt IFS*
Systemet	*I denna lathund kommer systemet refereras till att vara produktionen, produktionssystemet eller i arbete. T.ex. En Shop Order som har kommit in i systemet, har arbete påbörjats på*
TDA	*Technical Design Authority. Ansvarar för konstruktionen av produkten och gör åtgärdsbestämningar efter tester i vissa projekt*

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2 Förändringar som används för produktionsstyrningstavlorna

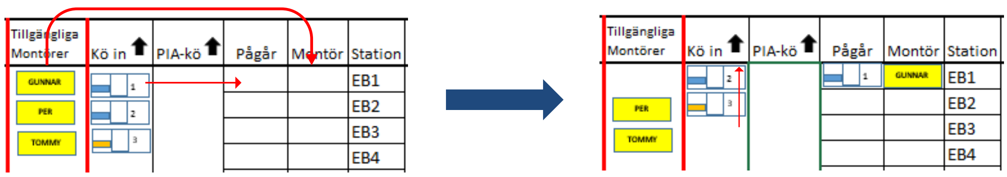
Istället för dagens produktionsstyrning som har baserats på att personalen har personliga bänkar, ska istället styrningen vara baserade på stationer inom de områden som finns kan arbeta på. En station definieras som en fysisk bänk eller uppmärkt plats som en operatör kan arbeta vid.

De nya styrtavlorna är utformade för att montören/testaren själv ska kunna sköta sitt arbete direkt utifrån tavlorna.

2.1 Kösystem, FIFO

De nya tavlorna kommer använda ett *FIFO* (First-In-First-Out) kösystem med vissa undantag. Med *FIFO* menas att den SO som har kommit in först i systemet och legat längst, ska tas först när det är dennes tur. I tavlorna kommer detta visa vilken SO som ska plockas genom att vara längst upp (eller längst fram) till det område (montering) eller den teststationen (test), likt *Figur 1*, brickorna under den flyttade brickan flyttas uppåt och signalerar att det är den SO:n som är näst på tur.

Undantagen görs vid daglig styrningsmöten med direktiv av **ansvarig planerare, delprojektledare** eller **behörig chef** som flyttar brickan längre fram i kön för att



1. 2.

Figur 1: FIFO-styrning av brickorna på tavlorna. Montör/Testare flyttar sin resursbricka och det arbetet (SO) från kön till den station de kommer arbeta på (1.). De kvarvarande brickorna i kön flyttar längre upp för att tas näst på tur (2.).

bli näst på tur att plockas av test- eller monteringspersonal.

2.2 PIA-kö

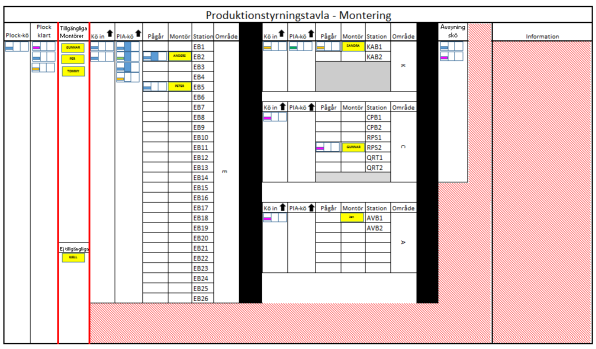
På *Styrtavla I: Monteringstavlan* har varje område en PIA-kö. PIA står för Produkter I Arbete och menas att de arbetats med eller har en gång påbörjats arbete på. Dessa produkter som har påbörjats arbete på är tänkta att man vill ha ut ur systemet så fort som möjligt. Produkter/Shop Orders som hamnar i denna kö **(PIA-kö)** ska därför prioriteras framför nya produkter som i **Kö in**. PIA-kön ska alltid siktas på att tömmas för att kunna släppa in nya produkter in systemet.

Fysiskt kommer denna PIA-kö ha en egen hylla som är uppmärkt **PIA-hylla.**

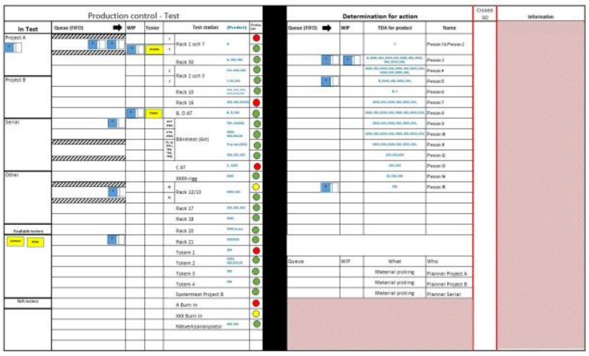
3 Tavlornas ingående komponenter och funktion

De nya tavlorna är uppdelade i två stycken tavlor, en för montering och en för test och åtgärdsbestämning. Dessa två samverkar genom att gå från vänster till höger med en påbörjad Shop Order (SO) i plock kön till avslutad Shop Order. Styrtavlorna visar hur långt varje order har kommit i produktionsflödet, vilka resurser som finns att tillgå för de olika stationerna, hur stora köer som finns för varje station. Dessa tavlor ska representera de SO:n som är släppta till systemet och placeringen på tavlan ska stämma överens med den fysiska placeringen i produktionsflödet.

De två styrningstavlorna som samverkar, (I) Monteringstavla och (II) Test- och åtgärdstavla, visas nedan. (Notera att de röda områdena finns plats för valfri information)



I.



II.

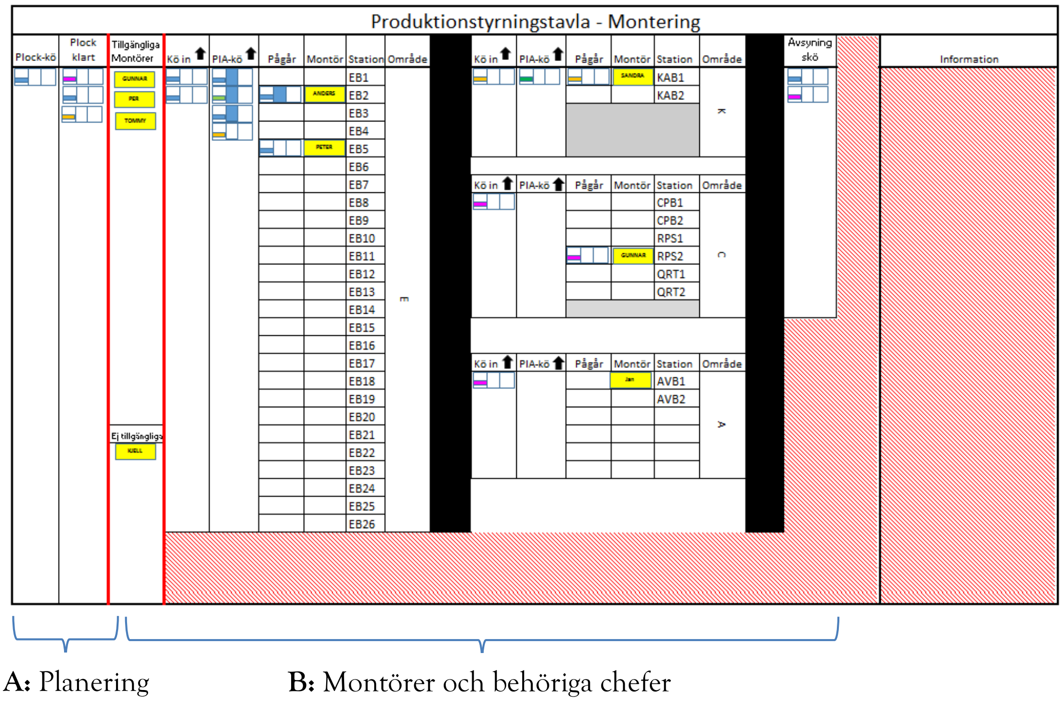
Båda tavlorna har samma sorts funktioner:

- Stationsbaserat, på område och station (montering), teststation (Test) eller kunskapsbaserat (TDA)
- En eller två köer, varav om två menas att de är redan inne i systemet och ska prioriteras
- Pågående arbete
- Arbetande resurs per pågående arbete
- Tillgängliga/Ej tillgängliga resurser
- In kö
- Avslutade SO

För att se hela flödet för SO-brickorna i ett flödesschema se *Appendix I*. I kommande avsnitt kommer tavlan förklaras i detalj.

3.1 Styrtavla I: Montering

Monteringstavlan är indelade i sektioner, A och B. A är en sektion som sköts av planering och behöriga chefer medan B ska anses vara montörsstyrt och ska endast vid behov skötas av behöriga chefer.



Första delen **(A)** som innehåller **Plock kö** och **Plock klart** ska användas av planörer och eventuellt behöriga chefer. **Plock kö** signalerar för planerare att de behöver plocka nytt material för en NY order sedan när materialet är plockat lägger de dessa på **Plock klart**. Dessa SO som ligger i Plock klart, ska på ett dagligt styrningsmöte placeras ut till det tillhörande områdets **Kö in** längst ned i kön (om inget annat nämns).

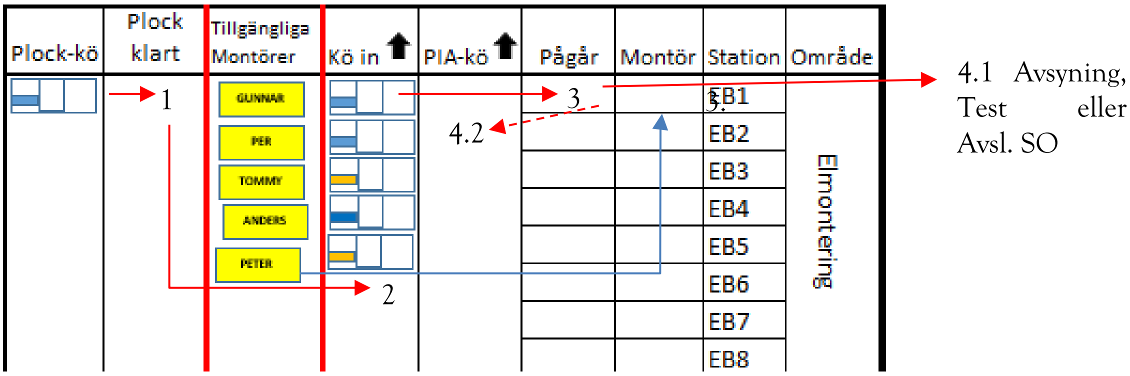
Andra delen (**B**) är uppdelade i områden. Varje område innehåller:

- Kö in
- PIA-kö
- Pågående SO, Montörsplats för en utmärkt station

Tillsammans delar varje område på de **Tillgängliga resurser** som finns inom monteringen. Om en arbetare är sjuk, på semester eller dylikt placeras resursbrickan på **Ej tillgängliga** delen av tavlan. **Avsyning** ligger som en egen del på grund av den endast kräver en **Kö** och flyttas direkt vidare när denna är klar.

3.1.1 Flödet igenom monteringstavlan

I detta stycke förklaras förflyttningen av SO-bricka mellan olika delar av monteringstavlan på ett av områdena.



1. SO-brickan flyttas av planerare till **Plock klart** när material är inhämtat och är redo för att på dagligt styrningsmöte placeras in i rätt område. (Fysisk placing: In hylla Elmontering)

2. SO-brickan flyttas till önskat område **Kö in** kolumn vid dagligt styrningsmöte. Signalerar till Montör att ett jobb är redo.

3. SO-brickan längst UPP i kön tas av Montör och flyttas till ledig station som också tar med sin egna montörsbricka och sätter bredvid. (Fysisk placering: På stationerad bänk)

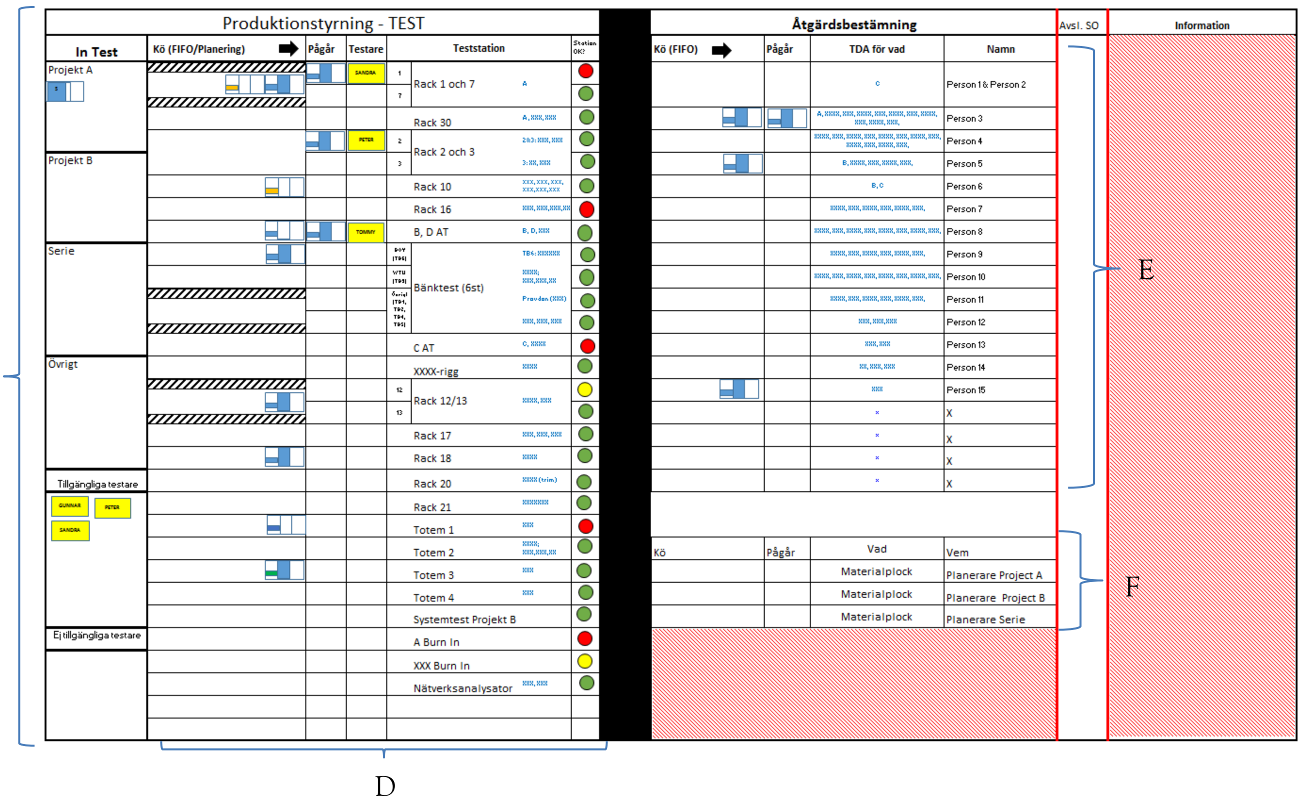
   OBS: Från Kö-in får man endast ta från om PIA-kö är tom eller ansvarig chef har sagt annat

4. Se nedan för olika alternativ (4.1 och 4.2)

Jobbet anses färdigt på den stationen den arbetats på. Se Shop Orderns beskrivning för nästkommande operation och placera antingen enligt följande:

a. **Vidare på test** – SO-brickan läggs till Test-tavlans **In test-**sektion för de projekt de tillhör (4.1). (Fysisk placering: In hylla test)
b. **Avsyning** – SO-brickan flyttas till **Avsyning**s kö (4.1) (Fysisk placering: Avsyningshylla)
c. **Vidare montering** – SO-brickan placeras in sist i **PIA-kön** och ska prioriteras framöver (4.2) (Fysisk placering: PIA-kön)
d. **Färdig produkt** – SO-brickan flyttas till Styrtavla II och hamnar i **Avsl. SO** kolumnen. (4.1) (Fysisk placering: Ligger på hylla för att åka mot förråd/leverans)

3.2 Styrtavla II: Test- och åtgärdstavlan



Test- och åtgärdstavlan är uppdelade i 4 sektioner, C, D, E och F.

Sektion C innehåller **In test,** detta menas att de ska planeras ut på de olika stationerna inom sektion D. Härifrån kan de ha kommit in från montering, kund eller förråd. Planerare eller behörig chef flyttar SO-brickor härifrån.

Sektion D innehåller ett system för att visa hur stor beläggning det är på de olika teststationerna. Varje station har:

- En kö med FIFO system
- Pågående SO, Testpersonalplats för utmärkt station
- Status symbol benämnd **”Station OK?”**, visar om stationen fungerar. *(Detta berättas mer vad de färgerna innebär i avsnitt 4.3)*

Sektion E innehåller ett system för att visa beläggningen för åtgärdsbestämning hos TDA:er. Detta är kunskapsbaserat efter produkt som montörer eller testare kan få hjälp av TDA:er för att bestämma åtgärd på produkt.

Sektion F innehåller delar för att plocka nytt material som saknas eller behövs efter åtgärdsbestämning. Detta är sektion förenklar för planeraren, då nytt material behövs plockas för att arbetet ska kunna fortgå.

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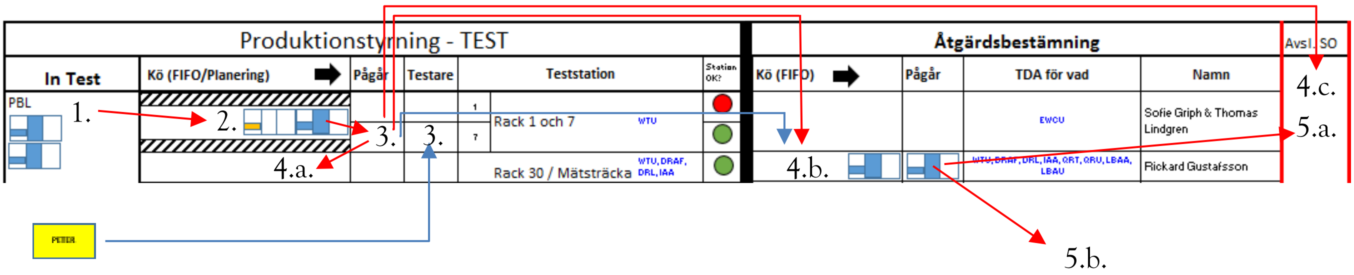
3.2.1 Flödet igenom test- och åtgärdstavlan

I detta stycke förklaras förflyttningen av SO-bricka mellan sektion D och E av test- och åtgärdsbestämningstavlan för en exempel produkt.



I detta exempel visar en produkts flöde in till test och vidare i processen:

1. SO-brickan (produkten) hamnar i **In test** för sitt respektive projekt. (Fysisk placering: In hylla test)

2. Vid dagligt styrningsmöte planeras varje SO-bricka ut till rätt **Teststation** och läggs längst bak i **Kö** (i detta fall till vänster). (Fysisk placering: Kö-hylla till specifik station)

3. När testpersonal är tillgänglig tar denne SO-brickan till den station de arbetar vid och sätter sin egen testare-bricka bredvid. (Fysisk placering: På teststation)

4. Efter testet är gjort finns ett antal alternativ som SO-brickan kan röra sig. Dessa är:

   a. **Ytterligare test behövs** – Flyttar SO-brickan längst bak till den stationen som produkten ska testas i ytterligare och upprepa steg 3. (Fysisk placering: Kö-hylla till specifik station)

   b. **Åtgärdsbestämning krävs** – Flytta SO-brickan till den TDAs Kö som har kunskap om produkten. (Fysisk placering: Väntar åtgärd-hylla, kommunikation mellan testare och TDA)

   c. **Färdig för leverans** – Produkten är färdig testad och har en Godkänd AT. SO-brickan flyttas till **Avsl. SO**. (Fysisk placering: Ligger på hylla för att åka mot förråd/leverans)

5. Om SO-brickan och produkten lagts för åtgärdsbestämning kan den röra sig enligt följande:

    a. **Färdigt för leverans** – TDA har avsynat och gjort en AT och godkänt denne via kommunikation med testare. SO-brickan kan flyttas till **Avsl. SO** (Fysisk placering: Ligger på hylla för att åka mot förråd/leverans)

    b. **Åtgärd bestämd** – En TDA har förmedlat en åtgärd till testaren. Testaren flyttar SO-brickan till den bestämda åtgärdsplatsen, antingen **monteringstavlans PIA-kö** eller för **vidare test** eller **materialplock**. (Fysisk placering: Beror på åtgärd)

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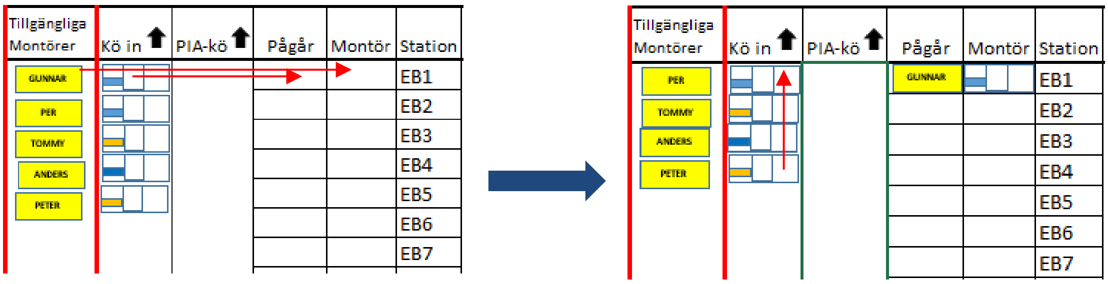
4 Förtydligande detaljanvändning av tavlan

4.1 Användande av resursbricka och pågående arbete

Med resursbricka menas den bricka som det står montörens eller testarens namn på.



Denna ska användas för att visa var man arbetar för tillfället.

Exempel: Som bilderna visar ovan, har montören Anders tagit SO-brickan #2 och arbetar med denna vid station EB1. Detta är en representation av att produkten ska finnas vid denna station. När Anders tog #2 flyttade han även upp resterande SO-brickor längre upp.

4.1.1 Ej avslutat arbete innan dagsslut

Ibland tar montering eller test längre tid än till slutet av arbetsdagen. För att arbetet ska fortsätta i konstant takt:

- Vid dagsslut, låt stå båda brickor om montören/testaren ska fortsätta arbeta med denna nästkommande vardag.
- Om montör/testare ska på semester, ska du som montör/testare:
  - Flytta resursbricka till **Ej tillgänglig**
  - Låt SO-bricka stå kvar på stationsplats. Skriv kommentar i **Montör/Test**-fältet vad som ska göras vidare med produkten.

  Denna SO-bricka kommer fångas upp på dagligt styrningsmöte och kunna fortsätta genom systemet.
- Om montör/testare är sjuk, tas detta upp på dagligt styrningsmöte vad som ska göras.

4.2 Specialfall

I flödet för båda tavlornas och de fysiska produkternas flöden sker vissa specialfall, detta avsnitt förklarar vad som händer fysiskt samt på/mellan tavlorna.

4.2.1 Avbrott

När en produkt sätts på avbrott flyttas den fysiskt till en Avbrotts-hylla och är därmed inte längre inne i systemet. SO-brickan som finns på någon av tavlorna flyttas till en **Avbrotts-tavla,** en separat tavla som ska finnas i närheten av de andra tavlorna.

4.2.2 Prioritetsändringar

Om en produkt eller Shop Order ska prioriteras över någon annan produkt som redan finns i en kö, flyttas brickan vid ett dagligt styrningsmöte framför de andra produkterna så att den finns näst på tur. Detta **måste** ske i kontakt med ansvariga planerare eller berörda chefer till produkter som finns på tur.

4.3 Stationens status – ”Station OK?”

I Styrtavla II: Test- och åtgärdstavla finns en funktion ska signalera en teststations status. Stationens status har på tavlan tre olika nivåer:

Grön visar att teststation fungerar och redo att arbeta med

Röd visar att teststationen är ur funktion och ingen åtgärdsplan finns ännu. Detta menas att testaren bör försöka kontakta en ansvarig chef för att se om detta går att lösa så fort som möjligt

Gul visar på att teststationen är ur funktion men en åtgärdsplan finns.

Dessa placeras som magneter bredvid teststationen och flyttas på ett dagligt styrningsmöte i kommunikation med chefer och testare.

4.4 SO-brickornas utformning

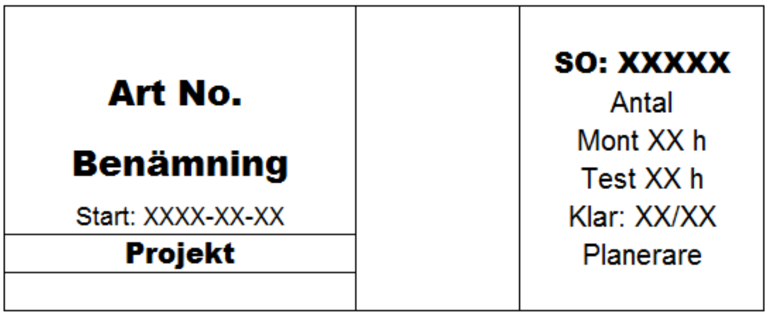
Brickorna även kallade SO-brickorna symboliserar produktens eller Shop Orderns fysiska plats på tavlan och rör sig genom systemet genom att en mänsklig resurs flyttar dem till rätt plats.

Det finns två olika sorters SO-brickor, en för nyproduktion och en för eftermarknadsproduktion.

Alla brickor har dimensionen 27 mm i höjd och 80 mm i längd. Dessa är gjorda i en Excel-fil vid namn *Mall för skylt till tavlorna produktion B2*.

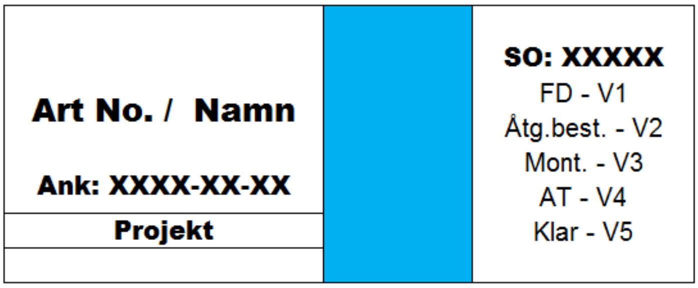
4.4.1 Nyproduktionsbricka

Nyproduktion eller serieproduktions bricka är utformad med helt vit bakgrund och endast färgskiftning på själva Projekt-fälten (*För färgkodning se avsnitt 4.4.3*). Ett exempel på den generella utformningen av brickan ses nedan samt ett exempel.



4.4.2 Eftermarknadsbricka

Eftermarknaden innehåller andra steg än nyproduktion och har därav inga specificerade timmar för montering eller test utan istället en generell beskrivning vilka veckor de olika stegen kan tänkas att göras. En eftermarknadsbricka skiljer sig åt med sitt *”Light Blue”*-fält i mitten av brickan. Denna färgskiftning gör det lättare att se hur många eftermarknadsprodukter som är ute i produktion. En generell utformning samt ett exempel visas nedan. Projekt-fältet följer projektfärger angivelserna i *avsnitt 4.4.3.*



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4.4.3 Projektfärger

I brickan finns ett Projekt fält för båda olika brickorna. Detta ska med olika färgskalor med text visa vilket projekt brickan tillhör. Texten skrivs i typsnittet Arial Black. Vissa färgskalor återkommer för eftermarknad och nyproduktion men har olika mittendel.

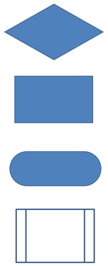
Projekt-fält	Mittendel	Färg(projekt), Excel
AA	Eftermarknad	Light blue
BB		Green
Övrigt		White

CC	Nyproduktion	Light blue
DD		Green
EE		Gold, Accent 4
FF		Lavender
GG		Orange, Accent 2
HH		Green, Accent 6, Lighter 60%
II		Yellow
JJ		Blue, Accent 5
Övrigt		White

5 Implementering och vidare utveckling

1. Färdigställ tavlorna efter behov med hjälp av
   - 2 st Tavlor, 1150 x 2500 mm
   - Laminerade namnlappar för brickor
   - Magnetiska brickor med plats för papperslappar (~100 st)
   - Tejp, svart och röd
   - Magneter för stations status (Röd, Grön, Gul)
2. Tejpa upp enligt *Appendix II och III*
3. Fysisk flytt av alla bänkar enligt plan
4. Utbilda alla berörda montörer/testare hur de ska flytta brickorna på styrtavlan
5. Följa upp med ett möte med alla berörda efter första veckan och red ut oklarheter
6. Utvärdera efter 1-3 månader hur väl styrtavlans funktion fungerar och vad som kan göras för att utveckla tavlan.
   - Tavlans mål är att skapa en mall för att senare kunna bli helt digitalt. Utvärdera om detta går att göra redan efter detta eller vad för förändringar som behöver göras.
   - Bestämma antalet Shop Orders som får vara i systemet samtidigt för att uppnå bästa kapacitet och minska ledtid
   - Bestäm vad man vill göra med de tomma fälten på tavlorna (röda)
7. När den är väl inkörd, försök göra fler tester hur väl ledtiden och leveranssäkerheten har påverkats och om syftet med de nya tavlorna har uppnåtts.

Appendix I: Flödesschema för brickornas rörelse genom systemet

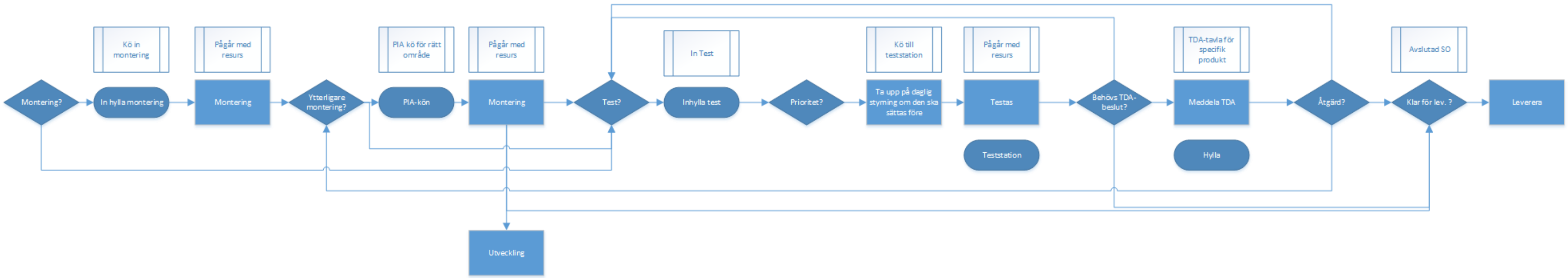


Beslut

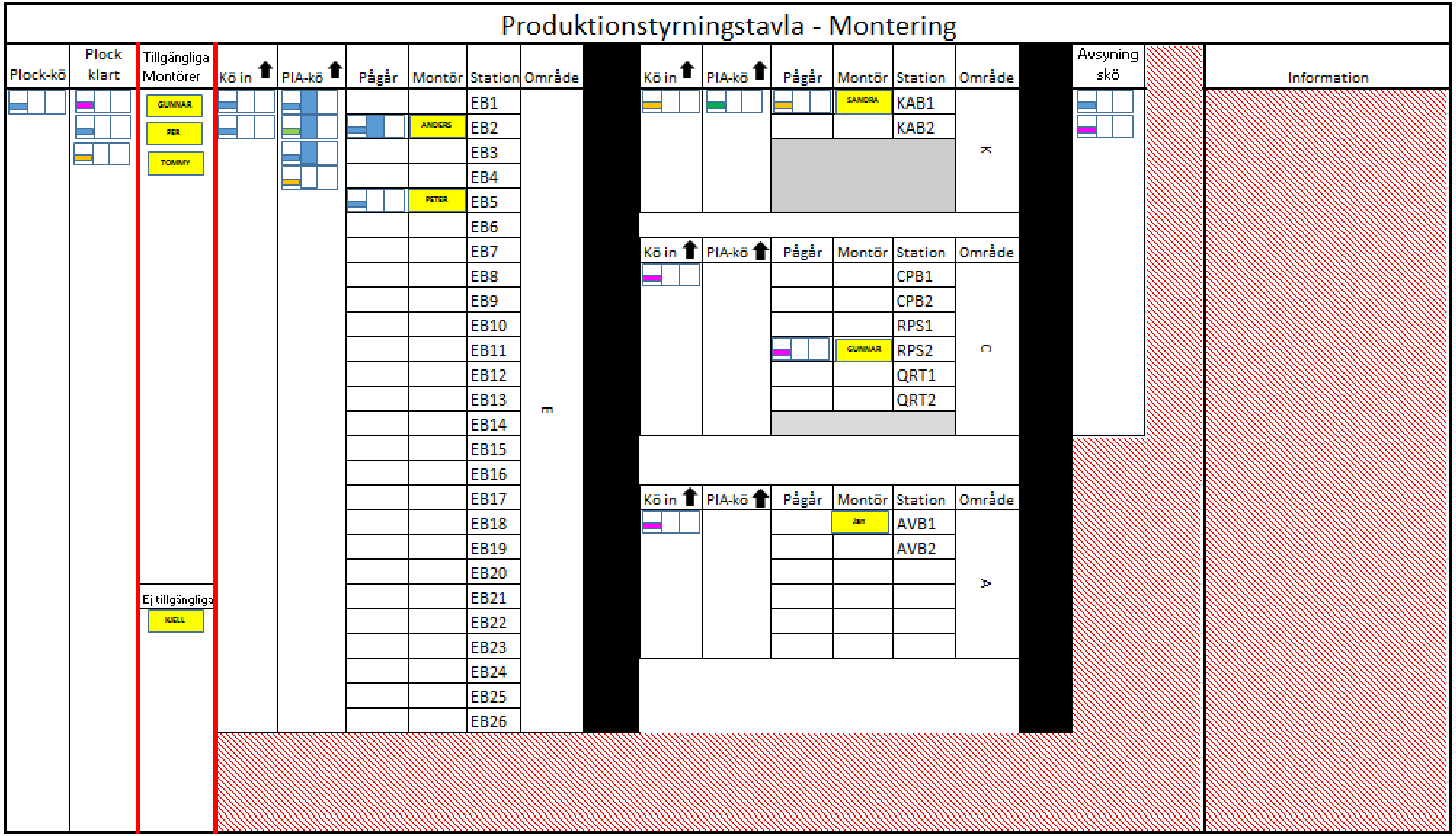
Händelse/Operation

Produktens plats

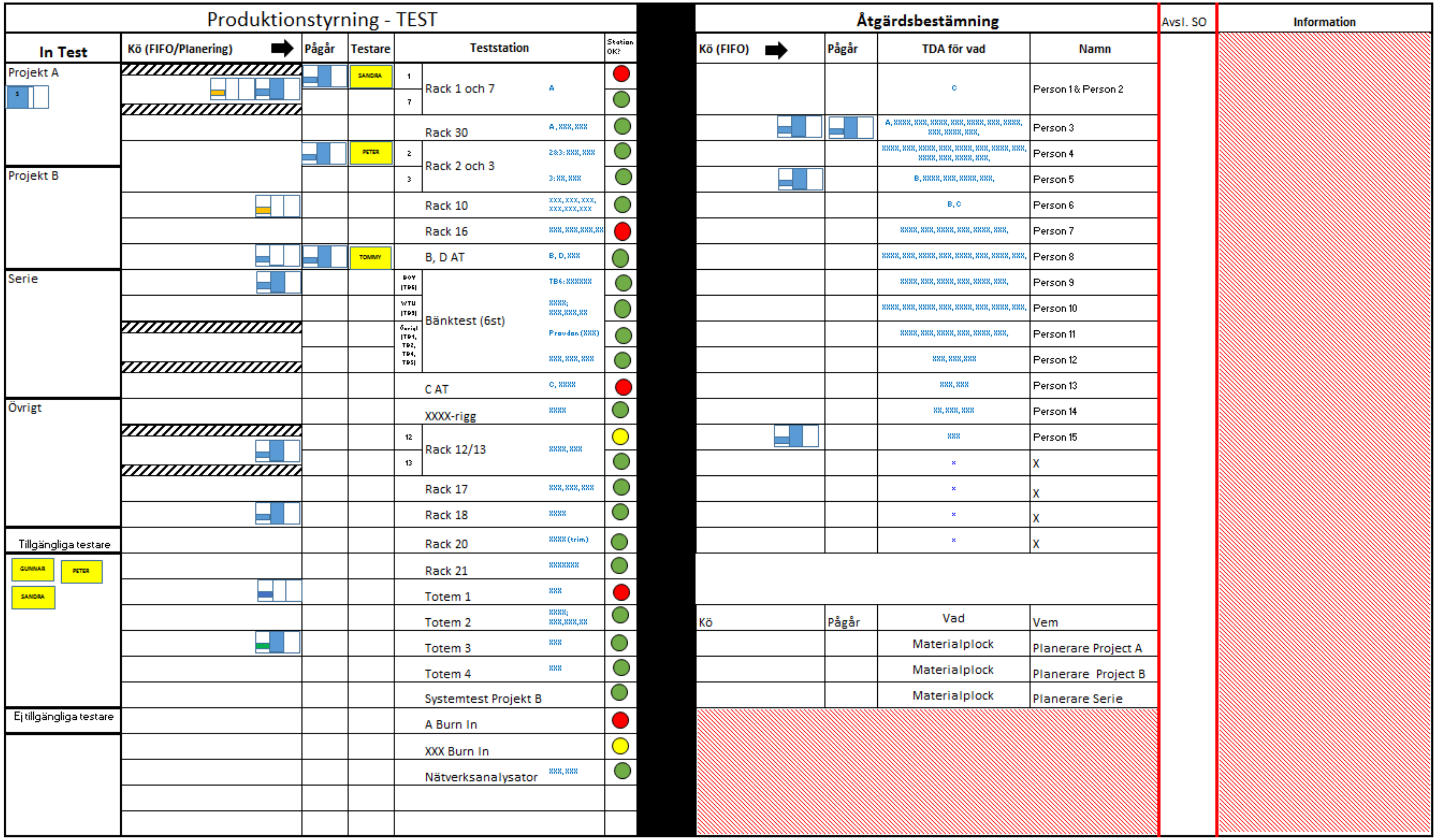
Brickan placering på tavlan



Appendix II: Styrtavla I: Monteringstavla, preliminär utformning



Appendix III: Styrtavla II: Test- och åtgärdstavla, preliminär utformning



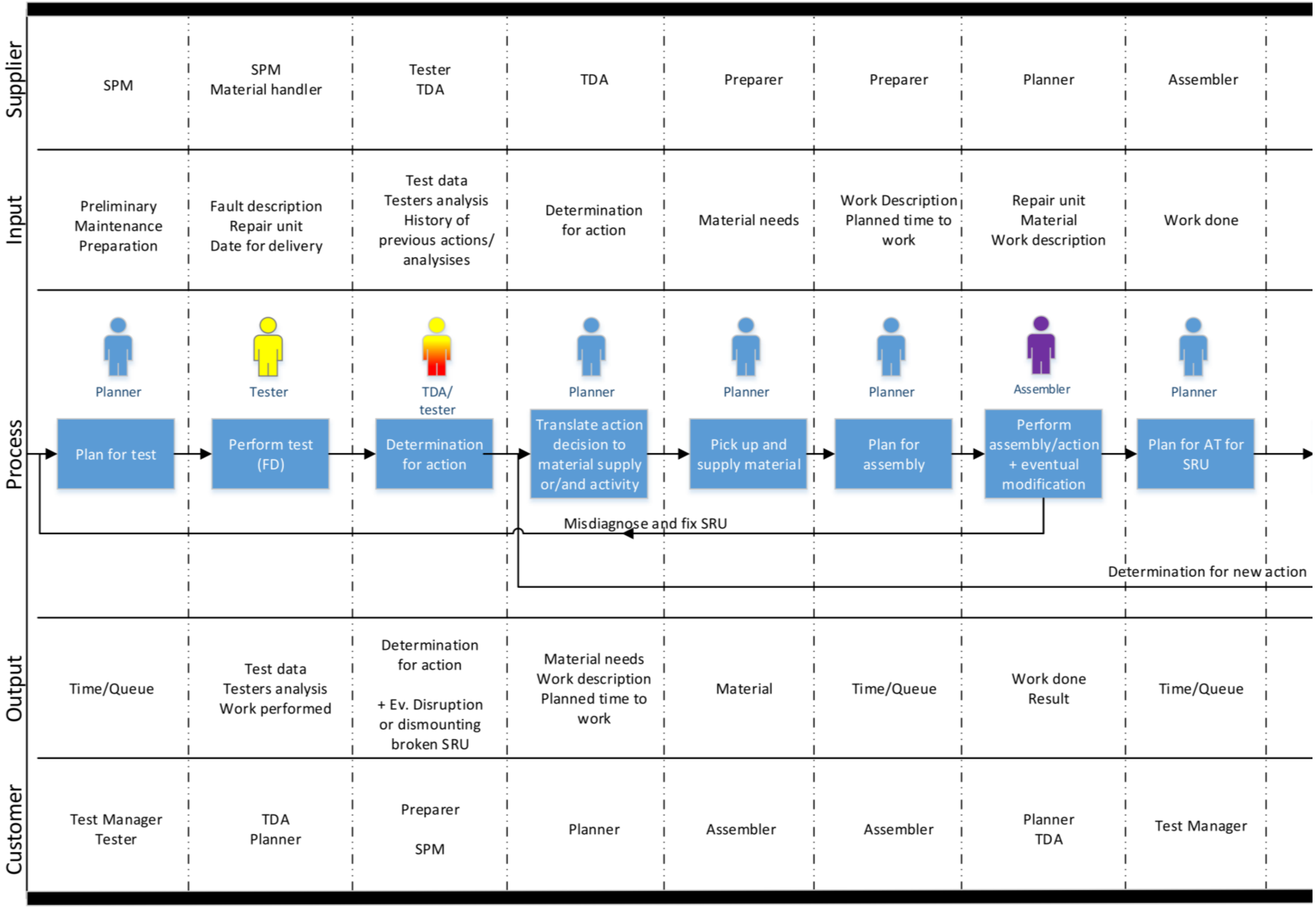
Appendix 5 – Stakeholder analysis of information channels (1 page)

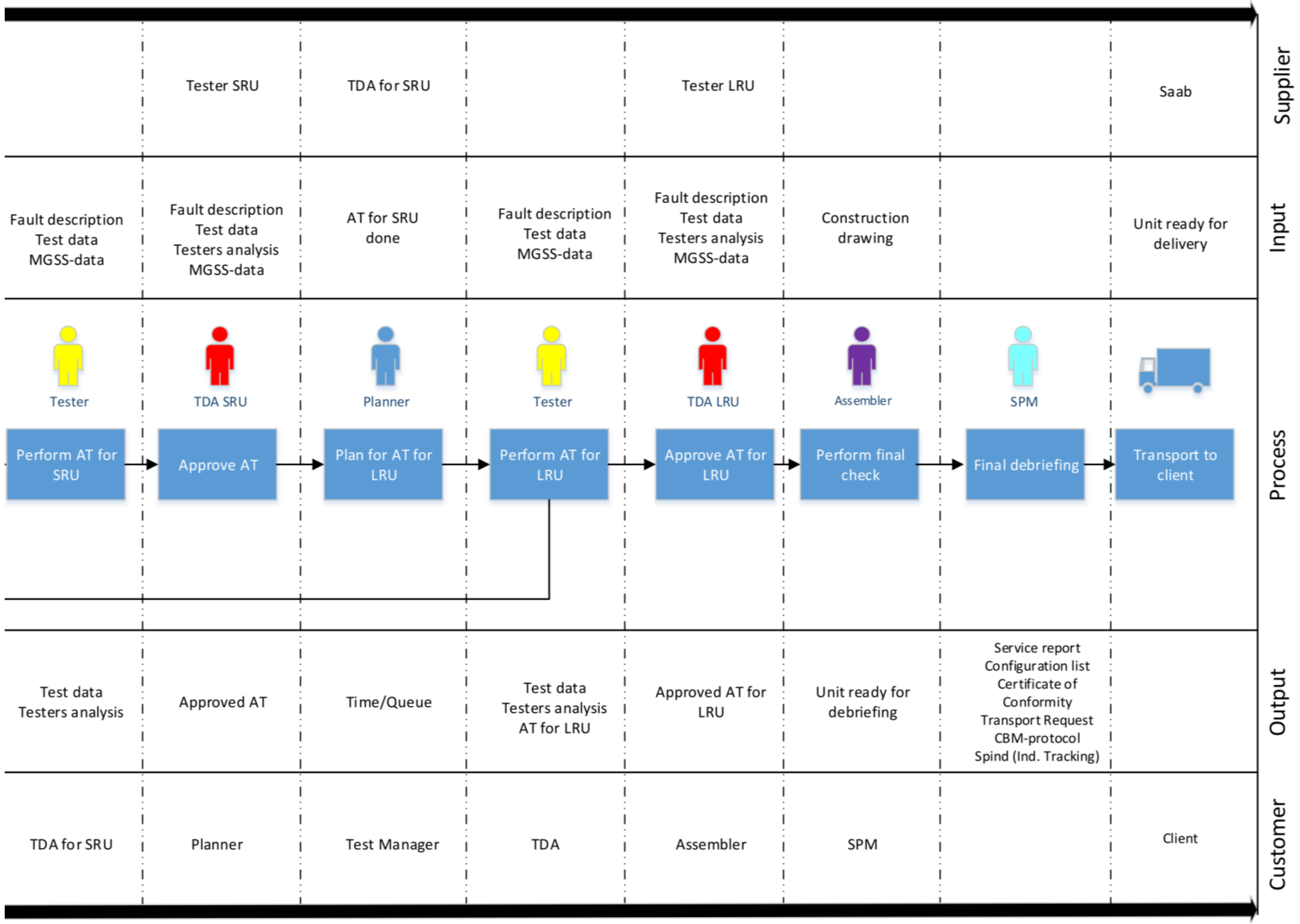
This information is in Swedish based on research with concerned stakeholders inside the aftermarket production system, with focus on the aftermarket's information channels.

Var														Nr	Vad	Intressent								
Fullständig information	IFS	Springbok (individ)	WTUATE	One Note	Aardvark (artikel)	Kameelperd (uh-objekt)	Styrningstavlor produktion	Hyllor produktion	Mapp /Prel. UH-beredning	Hyllor låst område	Excel-ark (Janne)	Excel-ark (TDA EWCU)	Mail			Materialhantering	Delprojektledare BUh	Planerare	Testare - Apparat	TDA - Apparat	Montör	Testare - Underenhet	TDA - Underenhet	ILS
	X	X												1	Apparat in för reparation	X		X						
	X	X							X				X	2	Rapporterat fel (+teknikerns felanmärkning, säkra info från alla aktuella TR)		X		X	X		X	X	X
							(X)	(X)		(X)				3	Köer till planering av DS			X						
		(X)			X						X			4	Historik - Testarens analys				X	X		X		
				(X)			X		X					5	Vilken apparat ska jag jobba med? (Klardatum, Prio/Kö)			X	X	X	X	X		
		(X)			X						X	X		6	Historik - Apparat/Underenhet (åtgärd)				X	X			X	
	X	X		X?					X					7	Projektaktivitetsnummer - Apparat		X	X	X	X		X		
													X	8	MGSS-data - felkoder nyinkommen apparat					X		X		
													X	9	MGSS-data - historik					X		X		
		X	X	X							X			10	Testdata och testarens analys					X				
		X										X		11	Historik - TDA Åtgärdsbeslut/Analys					X				
		(X)		(X)								(X)	(X)	12	Åtgärdsbeslut					X				
	X	X												13	Shop order (SO)						X			
	(X)							(X)	X				(X)	14	Arbetsbeskrivning						X			
	X								X					15	Tid för utförande			X		X			X	
				(X)				(X)	(X)				(X)	16	Materialbehov			X			X			
	X								X					17	Ritning						X			
									(X)					18	Resultat av åtgärd från montering/test					X			X	X
							(X)	(X)					(X)	19	Var befinner sig reparenten i reparationsflödet? (fysiskt, ifh TaT)			X		X				
		X		(X)			(X)							20	Apparater på avbrott (start, stopp, upphov)		X	X		(X)				
							(X)	(X)					(X)	21	När har vi en underenhet tillgänglig? (produktion)			X		(X)				
	(X)												(X)	22	När har vi en underenhet tillgänglig? (underleverantör)			X		(X)				
				X										23	I vilken apparat ska underenheten monteras?		X	X	X	(X)				
	X	X		X?					X					24	Projektaktivitetsnummer - Underenhet			X			X	X	X	
	(X)			(X)			(X)		X	X				25	Apparat klar	X	X	X		(X)				
	X	X												26	Uttaget material (totalen)		X							
	X													27	Uppdaterad konfigurationslista		X	X	X	X				
					X									28	Data FUh (åtgärd, drifttid, flygplan)									X
		X												29	Data BUh (åtgärd, byte av reservdelar)									X
					X									30	Funktionell felyttring (typ: störa, degradera)									X
						X								31	Felkoder									
														32	Antalet apparater som finns inne			X		X				

(X) means that it is partly seen used in the current process.
X? means that is unclear if the information channel is used in the current process

Appendix 6 – Aftermarket process map inside Saab Järfälla (2 pages)




Supplier
Tester SRU
TDA for SRU
Tester LRU
Saab
Input
Fault description
Test data
MGSS-data
Fault description
Test data
Testers analysis
MGSS-data
AT for SRU
done
Fault description
Test data
MGSS-data
Fault description
Test data
Testers analysis
MGSS-data
Construction
drawing
Unit ready for
delivery
Process
Tester
TDA SRU
Planner
Tester
TDA LRU
Assembler
SPM
Perform AT for
SRU
Approve AT
Plan for AT for
LRU
Perform AT for
LRU
Approve AT for
LRU
Perform final
check
Final debriefing
Transport to
client
Output
Test data
Testers analysis
Approved AT
Time/Queue
Test data
Testers analysis
AT for LRU
Approved AT for
LRU
Unit ready for
debriefing
Service report
Configuration list
Certificate of
Conformity
Transport Request
CBM-protocol
Spind (Ind. Tracking)
Customer
TDA for SRU
Planner
Test Manager
TDA
Assembler
SPM
Client

Appendix 7 – Ishikawa diagram (2 pages)

Part 1 (In the production)

Part 2 (in the organization and subcontractors)