LOGISTICS OF A NEW PRODUCTION

MAN Diesel & Turbo, Frederikshavn

EXPORT TECHNOLOGY WITH SPECIALIZATION IN GLOBAL BUSINESS ENGINEERING

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STUDENT REPORT

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Synopsis:
This thesis was conducted in collaboration with MAN Diesel & Turbo, Frederikshavn. The focus has been on the internal logistics and part supply to the future production.
Through interviews, observations and literature reviews, shortcomings were detected in the current procedures.
Further analysis resulted in suggestions to improve the situation. Communication needs to be established between the production and the warehousing departments; the company should make demands to suppliers concerning packaging and delivery amounts; lineside supply should be reduced based on consumption rates.

Danish abstract

Denne rapport er resultatet af det afsluttende diplomingeniørprojekt på uddannelsen Eksportteknologi med Specialisering i Globale Forretningssystemer på Aalborg Universitet. Projektet er udarbejdet i samarbejde med virksomheden MAN Diesel & Turbo, frederikshavn i perioden 1. december 2017 til 18. januar 2018. Projektet er en forlængelse af den studerendes tidligere praktikophold hos virksomheden. Praktikken omhandlede primært produktions-forberedelse, hvor dette projekt omhandler intern logistik.

Virksomheden er ved at etablere en ny produktion, hvor der manuelt skal samles 12-cylinder skibsmotorer. Fremstilling af disse motorer skal foregå ved linjeproduktion, som er inddelt i seks samlestationer. Til at administrere det omfattende projekt, er der indført Work Breakdown Struktur som ledelsesstil. Denne metode bruges til at styrke samarbejde mellem afdelinger og sikrer en detaljeret opdeling af arbejdsopgaver.

Logistikafdelingen er en vital del af projektet og fokus i rapporten er denne afdeling og deres indflydelse på den nye produktionslinje i Frederikshavn. Da logistikafdelingen påvirkes af beslutninger taget i de andre deltagende afdelinger, er samarbejde og kommunikation vital.

Denne rapport er delt op i to; i den første del etableres forståelse for den nuværende og den kommende situation for den nye produktion og de logistiske parametrer, der er tilknyttet, for at identificere om der er nogle mangler ved de metoder, som bruges af virksomheden. I den anden del af rapporten analyseres fundene fra den første del og der præsenteres løsningsforslag til de mangler, der er blevet påvist.

I første del af rapporten findes der frem til, at der er specielt tre problemstillinger, der kræver opmærksomhed. Disse problemstillinger danner grundlag for analyserne i anden del af rapporten og de dertilhørende løsningsforslag.

Den første problemstilling omhandler kommunikation mellem produktionsafdelingen og lagerafdelingen. Virksomheden ønsker at planlægge genopfyldning ud fra produktionstiderne på produktionslinjen, men da disse tider endnu ikke er fastlagt, er der et behov for en midlertidig løsning til kommunikation. I rapporten foreslås det, at der indføres kanban til at varetage kommunikationen. Der er et elektronisk forslag, som er baseret på brug af tablets og touch-teknology, og der er et forslag, hvor der bruges fysiske kanban-kort, som indsamles periodisk.

Det andet problem omhandler indkøbsmængder. Virksomheden baserer disse på den mængde, som varerne er pakket ved hos leverandøren og fordele ved at bruge beregninger for økonomiske indkøbsmængder. Disse to parametre gør tilsammen, at der vil være stor risiko for

at virksomheden vil have høje lagre. Fokus i denne problemstilling ligger dog primært ved, at der ikke tages højde for det faktiske forbrug hos virksomheden, når der bestemmes indkøbsmængder. Dette skaber flere ulemper, blandt andet at tidspunkter for leveringer vil variere fra vare til vare og at det ikke vil være muligt at tilbyde slutkunderne fuld sporhed. Sporbarhed er en mærkesag for virksomheden, så hvis hver enkel komponent skal kunne spores tilbage til fabrikanten, må indkøbte varer fra forskellige forsendelser ikke blandes. Hvis dette er tilfældet, vil der i mange tilfælde blive varer tilovers fra forsendelserne, som skal smides ud. Virksomheden er en stor kunde hos leverandøren, og står derfor i en stærk position til at forhandle om størrelsen af de indpakninger, som varerne kommer i.

Den sidste problemstilling knytter sig til den foregående og berører mange af de samme emner – her handler det dog om intern levering. Virksomheden planlægger, at den samlede indkøbsmængde af visse dele skal lagerføres ved produktionslinjen. De samme principper om kun at efterspørge, det man har behov for, gør sig også gældende i denne problemstilling. Løsningsforslaget underbygges af teoretisk viden fra LEAN filosofien om at varer skal leveres på det rette sted, på det rette tidspunkt og i den rette mængde.

Preface

This report reflects the results of the Bachelor of Engineering Thesis performed by Johanne Munk studying Export Technology with specialization in Global Business Engineering at Aalborg University. The thesis is done in collaboration with the company MAN Diesel & Turbo, Frederikshavn and completed in the period December 1st 2017 till January 18th 2018.

The thesis is an extension of the student's previous internship at the collaboration company. While the internship concerned production preparation for a future production, this thesis will focus on logistics connected to the new production. The report has two main parts; the first establishes the current and the future situation of the new production and the connected logistics to reveal any shortcomings of the methods used by the company, while the latter analyzes the findings from the first part and provides suggestions to how the shortcomings can be improved.

Acknowledgements

For this report to be completed a word of thanks goes to supervisor Kim Nørgaard Jensen at Aalborg University for initiating the project and guidance and counselling throughout the period. The company MAN Diesel & Turbo, Frederikshavn for making company collaboration on this project possible. Inger Gylden, Head of Logistic Systems and Material Management at MAN Diesel & Turbo, Frederikshavn for collaboration, consultations regarding the company's future use of vendor managed inventory, and supplying quantitative data. John Henrik Jensen, Warehousing Section Manager at MAN Diesel & Turbo, Frederikshavn for guided tours at the company and clarifying consultations.

Table of Contents

1. Introduction

This report reflects the final semester project and is an extension of the previous internship at MAN Diesel & Turbo, Frederikshavn. As the internship, this project has the future production line and appertaining ramp-up project, BRO 4 MAN175D, as its fulcrum. While the internship concerned production preparation, this project has a different theme.

During the internship an interest for the internal logistics surrounding the coming production line arose, along with a wish to explore different areas of the education. The physical layout of the production and parts presentation have been determined by the collaboration company, however, flow and communication regarding parts between warehousing and production has not. It is decided that some parts are delivered to the assembly line in pre-packed kits for distinct operations, while others in larger amounts in kanban-racks.

But there is still much to discuss and many agreements to make concerning flow of parts to the production line, communication regarding this, and quantity and timing of deliveries.

2. Initial analysis

Through knowledge obtained during the internship and subsequent conversations with employees at MAN Diesel & Turbo, Frederikshavn (MDT FRH) the interest for handling delivery of parts to the assembly line became greater. To understand the processes concerning this topic, this chapter will analyze the current situation of the ramp-up project and how the company expects the new production to function in the future. The analyses will concern the ramp-up project, the production, the logistic function, and descriptions of the different collaborations within the project. The company is planning to use vendor managed inventory for some parts so this chapter will also contain a description of this method and how the company is planning to use it.

The topics will be accompanied by theoretical knowledge obtained throughout the education to uncover any shortcomings in the approaches used by the company.

2.1 Company description

To establish the overall setting for this thesis the collaboration company and the concern, which it is a part of will be described. To fully understand the immediate environment of which the analyses are based the ramp-up project for the new production at MDT FRH will be elaborated. The product and the future production will also be described to form an understanding of the conditions of which the logistics function is subject to in terms of parts, lineside deliveries and transportation.

2.1.1 MAN SE

The following descriptions of the company is based on former knowledge obtained during the internship (Munk, 2017). MDT FRH is a part of the main concern MAN SE, which is a part of the conglomerate Volkswagen Group that owns a range of car and truck companies. The history of MAN SE dates back to 1758 where iron foundries fused and later developed into engine factories. The product portfolio has developed through time in pace with technology and demand, and have among other contained steam and diesel engines, steam turbines, trucks and busses (MAN SE, 2017a). The organization structure is depicted in Figure 1. The blue boxes show the direct line between Volkswagen Group and the ramp-up project for the new production at MDT FRH and the three following subsections will describe these interrelations. The grey boxes show the remaining parts of the concern and will not be described further.

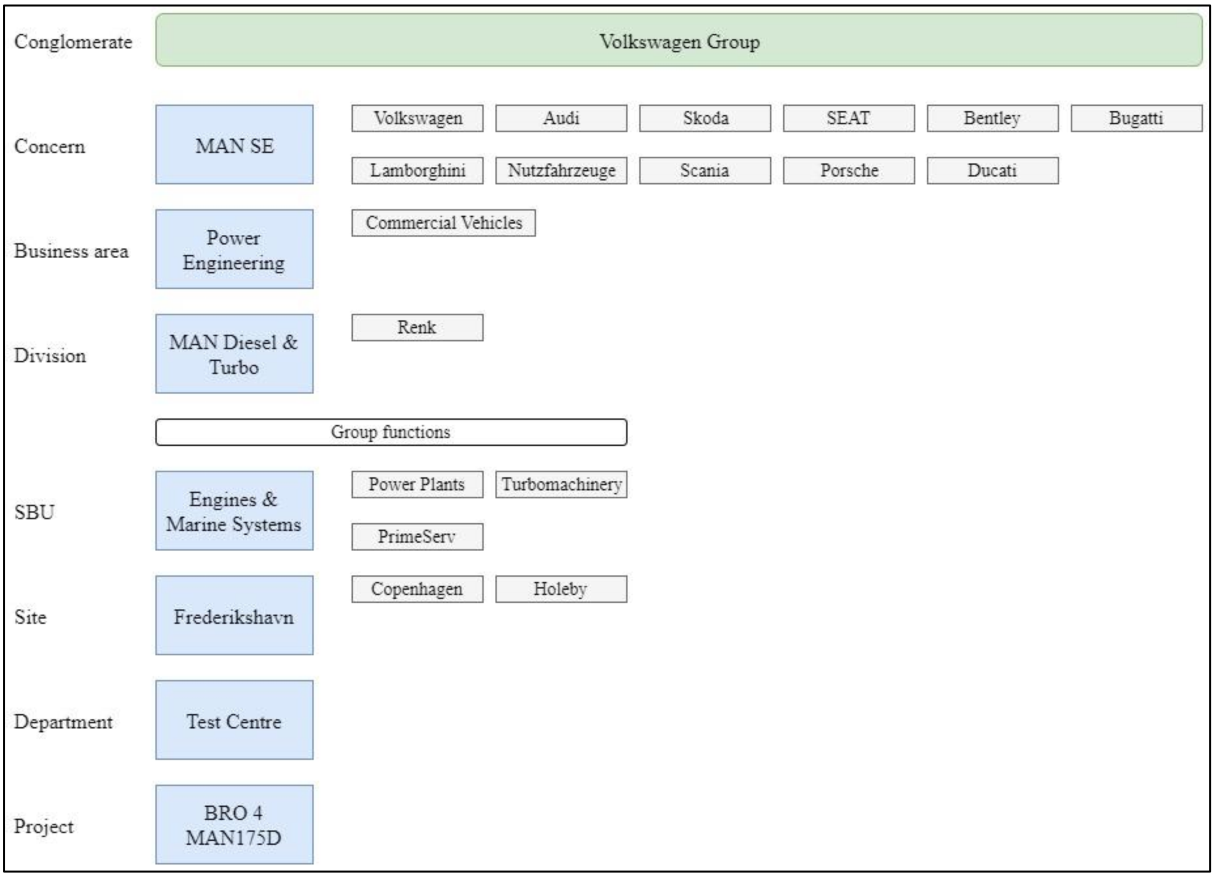

Figure 1. Organization structure (Munk, 2017)

2.1.2 MAN Diesel & Turbo

MAN SE addresses two business areas - Power Engineering and Commercial Vehicles. MAN Diesel & Turbo operates in the field of Power Engineering and is divided into four strategic business units, where three of them manufacture engines and turbomachinery for both maritime and stationary purposes and the last business unit is the global after sale service unit PrimeServ.

2.1.3 MAN Diesel & Turbo, Frederikshavn

MDT FRH is a part of the strategic business unit Engines and Marine Systems. This unit manufactures engines for maritime application, propellers, propulsion systems and turbochargers. In Frederikshavn, the focus is on propellers, control systems, testing of engines and research and development is these fields. As of July 2018, assembly of diesel engines will also be a part of the portfolio (MAN Diesel & Turbo, 2018).

The ramp-up project for the new production is managed by the Test Centre. This department tests existing products and contributes to the development of new products. The work performed in the Test Centre contributes to the service and knowledge once engines have been installed in the vessels (Nordjyske, 2011). In the following, the ramp-up project BRO 4 MAN175D will be described.

2.1.4 The ramp-up project - BRO 4 MAN175D

When establishing a new production many departments and functions have to work together and the project BRO 4 MAN175D has been initiated to manage the ramp-up project. In MDT FRH a Work Breakdown Structure management approach has been implemented to create a clearer overview of the project. It has been broken into six main functions which again is divided into smaller work areas. Within each work area specific work packages have been defined. The six main areas are Logistics, Quality, Production, Customs/Import/Export, Controlling, and IT, and is depicted in Figure 2. The reason for using this approach is to ensure that every activity necessary to complete the project is clearly identified and no activities are missed.

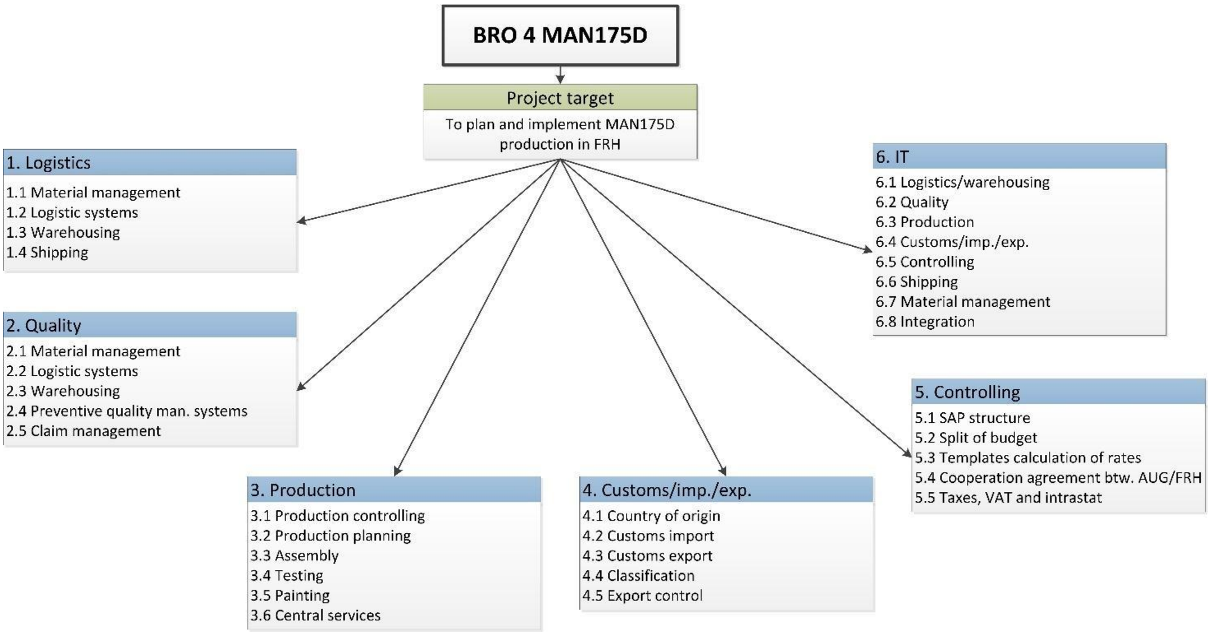

Figure 2. Structure of the ramp-up project BRO 4 MAN175D (Munk, 2017)

When the project is broken down into smaller pieces of work it is easier to manage schedules, budgets and responsibilities. A task is easier to define if it is small and it will be easier to schedule and accomplish (Nicholas & Steyn, 2012). At MDT the defined work packages are printed and visually accessible at the production site on whiteboards for all stakeholders of the project. For each work package the task, time to perform the task and responsibilities among other things are defined, as well as a track status of the task. In this way, all parties know who is doing what, and how well it is going.

2.1.5 The product

The coming production in Frederikshavn will produce one product with few additional modules. The product is a high-speed 12-cylinder diesel engine for motive power in super yachts, smaller ferries and tugboats. Alongside the engine the company also offers complete propulsion systems containing engine, propellers, and integrated operating system. The engine can also be used as *genset* (engine-generator set) to generate power on board vessels (MAN175D, 2014). The drive behind development of this new product has come from market demand and will complete the company's product portfolio. The development is done in close dialog with customers to make sure that the product fits needs and expectations. The product is made from standardized modules to shorten lead time, but additional modules can be integrated to make a customer specific end product (DieselFacts, 2014).

Figure 3. The 12-cylinder MAN175D engine (MAN Diesel & Turbo, 2018)

2.1.6 The production

In MDT FRH the engine will be manually assembled from 6741 parts (standard product) distributed into 2369 part numbers. Before initiating the ramp-up project in Frederikshavn, feasibility studies were carried out of where to locate the production. Denmark, Germany and India were options, however, in Germany new facilities should be build and India has problems with maintaining quality levels. Denmark was chosen because facilities already existed and knowledge still remain from the last time engines were produced at the site. Based on expected demand and space requirements an assembly line consisting of 6 workstations will be implemented in MDT FRH. The production will be line assembly where the initial aim is to finish one engine each day.

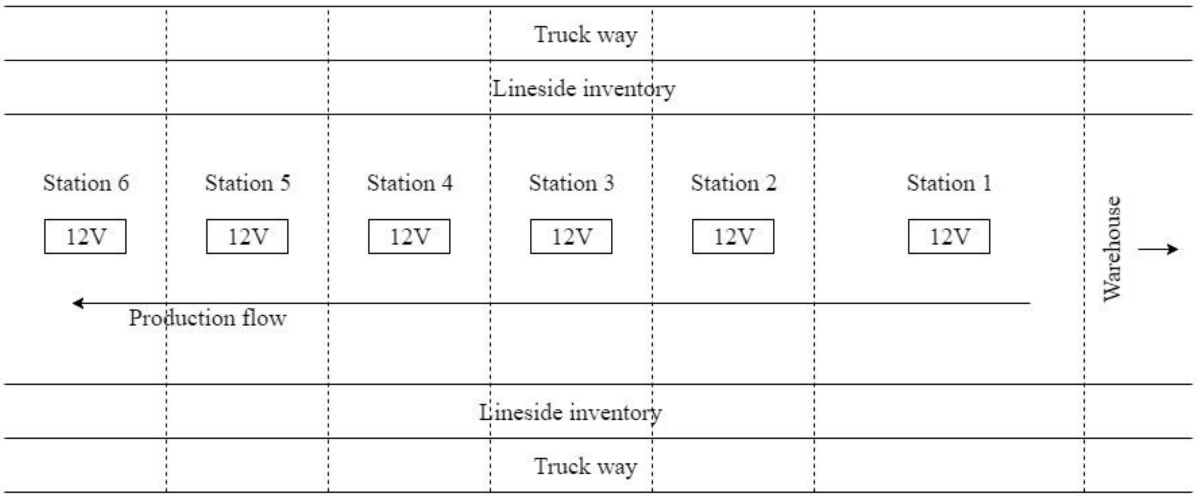

Figure 4. Layout of the production facility

The total work content of assembling an engine will be divided equally into the six workstations. Each workstation will contain work content that can be done in one day.
During the internship at MDT FRH one of the tasks was to balance the six workstations. With the estimated total work content and the six stations it is theoretically possible to balance the assembly line to make each station finish its work within one day. However, precedence of operations and special equipment may make it difficult to balance the stations in reality. When the assembly line is established additional work still have to be done with the balancing. The initial time studies are estimates and based on a single sample. Additionally, new tools and equipment will be installed which will also change the operation times.

The purpose of an assembly line is to equally divide the total work content between the stations. In this way each station will finish its work at the same time and is able to send forward the product to the following station simultaneously. At MDT FRH each workstation will contain work elements that can be done in one day. This makes the takt time 7,4 hours, which is the average Danish working hours per day.
During the internship the tasks included documenting processes and balancing the work stations. The processes were only performed once meaning only one sample constitutes the time study and is therefore deemed rough estimates. With the estimated total work content, it is theoretically possible to balance the assembly line to make each station finish its work within one day. In Appendix A is the result of the balancing performed by using the Kilbridge &

Wester method (Groover, 2008). It depicts stations 1-5 can be smoothly balanced, whereas there is a lot of excess time in station 6. The excess time can for instance be used if the operator functions as a water spider. However, preferred work precedence and location of special equipment makes it more complicated to balance the work stations. In Figure 5, the balancing used as a starting point by the company is depicted. The work content of each station is still within the required takt time but varies greatly.

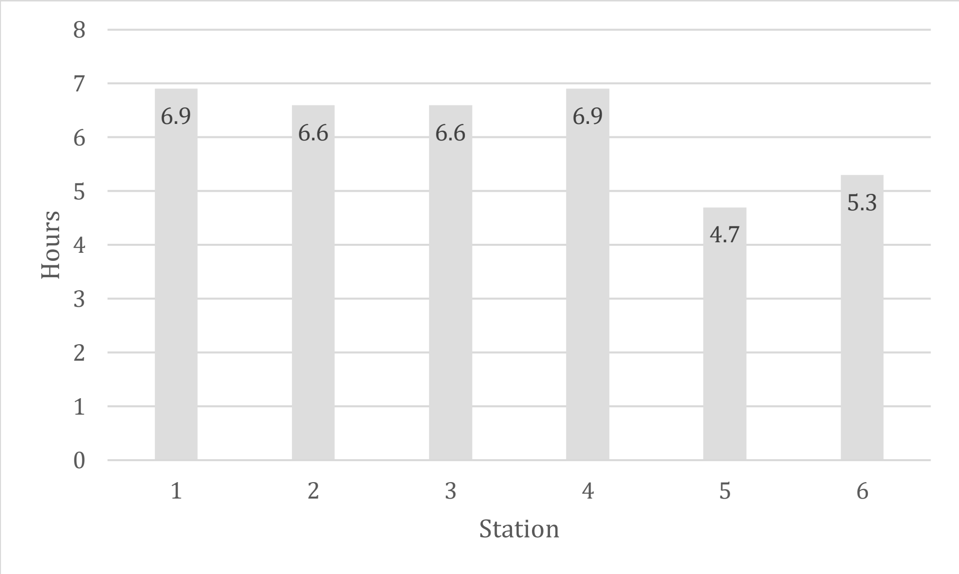

Figure 5. Current balancing of the assembly line

The purpose of takt time is to keep manufacturing flow in pace with demand. It is the rhythm of the production. Once the takt time is set, operations should be planned so that the timing of production output is as close as possible to that time. The takt time also sets the pace of the supporting processes such as the delivery of parts. When the takt time is determined it is possible to make a leveled production schedule so the production runs occur on a regular scheduled basis. With a leveled schedule, every operation follows a uniform pattern that will be easier to follow than a constant changing pattern. With a smoothly running production following such a pattern it is easier for the logistics department to schedule their supporting processes (Nicholas, 2011).

2.2 Inhouse logistics

This section will contain descriptions of the logistic functions of the ramp-up project with focus on the warehousing department (see Figure 2 in section 2.1.4 for clarification) since this will handle the goods internally. The description will concern how the warehousing will function when the production of MAN 175D is established and how the collaboration between other departments works during the ramp-up project and afterwards. Introductory to this subject five key points of interest to obtain effective logistics will be presented to keep in mind when reading the subsequent sections.

2.2.1 Effective logistics

"*Logistics is a process which interfaces and interacts with the entire company and with external companies, vendors, customers, carriers and more*" (LDT Management, 2018).

As stated by the quote, logistics plays a great role in a company. It is composed from many functions to make operations run smoothly, continuously and interrelated. There are five key issues to effective logistics; Movement of product, Movement of information, Time/service, Cost, and Integration.

Movement of products must emphasize flow, not just moving items to, from or between locations. It should complement the company strategy and be consistent with the overall objectives. In the case of MDT FRH the logistics function must emphasize the LEAN principles of the right item at the right place at the right time. This involves purchased items and items delivered to the assembly line. A smooth flow of items will assist a smooth production flow. With items flowing instead of just moving may help decrease the need for inventory.

With the movement of products comes the *movement of information*. To ensure the flow, it is important to know placement pf products, the inventory levels and the possible need of action. Timely and accurate information is vital for decision making. Information must be shared between a number of functions and departments, both internally and externally. Information concerning incoming orders must be shared between sales department and production department, information concerning production orders between production and warehousing, information concerning incoming shipments between purchasing and warehousing to name a few. Sharing information with external partners is just as important to create a smooth flow. This will help suppliers to know what to deliver when, carriers what to deliver and customers when to expect order fulfillment.

In a rapidly changing and global marketplace *time and service* is key to competitiveness. In order to respond to customer requirements and keeping the position in the industry components must be ordered and delivered completely, accurately and timely. As well as orders must be filled completely, accurately and timely. Logistics is the link ensuring this flow. Internally with items transported between operations and extending the flow externally to concern the supply chain. This should be the main driver of the logistics function.

The efficiency of the logistics is often measured by *costs*. However, only focusing on costs may cause a risk for sub optimization that can be damaging for the overall operation. It is key to determine the service required and from there on work on the costs. When the required service is determined it is possible to improve the surrounding processes with the aim of minimizing costs while still maintaining the service.

The key for the four above mentioned to work is *integration*. Integration between internal departments, between the company and its customers, and integration between the company and the suppliers. Though it is a difficult task. Each function of the organization must be as effective as possible and specialize in core competences, but it must do so according to the surroundings to create the flow. The efficiency of a warehousing department will only matter if it complements the production department, and effectively manufactured goods can only be truly valued if the shipping department functions likewise.
The integration goes beyond company borders. Close collaboration with customers ensures that needs are fulfilled and the service meets the expectations. Letting suppliers know what the company is doing and why will make the supplier able to specify own production and schedules to enhance the cross-company flow and ability to meet the demand more timely and accurately.

2.2.2 Warehousing department

Managers from the current logistics department handles the matters of logistics for the new production. At the moment, the warehousing department seems a well-functioning department with a sense of responsibility, autonomy and growth. Communication and integration between functions, such as warehousing, classification and shipping ensures development of new solutions pleasing all parties and contributes to a higher efficiency. Various initiatives have been executed, e.g. a warehouse vending machine has been implemented to increase speed of picking small parts. An experienced employee can make up to 200 picks per hour with this solution. Earlier, the department has established that on average 30 picks can be made per hour. This is due to the wide range of items where some are large and needs special handling. As well as improvements of the physical attributes of the warehouse, initiatives are also carried out with the software system in use. If employees have experienced shortcomings of the system or come up with ideas for improvement, new functions have been defined and integrated.

Even though the warehousing department is well functioning now, several changes following the new production that will decrease the efficiency. The two major changes include employment of new staff members and implementation of a different IT system.
The company will not be able to manage the warehousing with the current number of employees and therefore more employees are required. These new employees must be trained to operate the warehousing system at MDT FRH. The current employees also need training due to implementation of a different MRP-system. As described in section 2.1, MDT FRH is part of a larger concern and for the new production it is decided to use the same MRP-system as the main company in Germany. Both companies are using MRP-systems from the same supplier but different versions of the system. At first, the new system needs to be defined and applications implemented and then the daily users will need training in operating this system. The new system configuration also changes some of the physical handling of the items at the warehouse. Currently picking and tracking is done electronically through hand scanners and tablets or monitors, whereas in the new production physical picking lists will be printed and picking is only registered electronically when all items on a list have been picked.

2.2.2.1 Collaboration with other departments

As described earlier the existing warehousing department is well integrated with other collaborative functions but in the new production the collaboration is going to be even more explicit. To make the ramp-up project running smoothly, as well as the future production, the collaboration between departments will be great interest. To illustrate how vital an effective warehousing department is to maintain a smooth flow of operations this section will describe its relations and collaboration with the remaining departments of the BRO 4 MAN175D (see Figure 2 in section 2.1.4 for clarification of functions). Many decisions made in the other departments affect the work of the warehousing department.

Quality

The quality department decides which parts must go through in-house quality check before consumption, which parts should be classified, and handles defects. The method and frequency are not yet decided. It can either be samples from each batch or entire batches used as samples. When the method has been decided it is the responsibility of the warehousing department to transport the parts to and from the quality department. Likewise, with classified parts and defects, the quality department notifies the warehousing department who will handle the transportation. Parts that needs classification must be transported from the warehouse to the classification area, and defects must be collected from the assembly line and a new part delivered.

Production

During the ramp-up project the production department and the material management function collaborates on determine which parts are to be delivered to which locations at the assembly line. When this has been determined, the warehousing department will know how many parts and the sizes of these each engine produced needs, and can thereby determine how to handle the parts in the warehouse.

Transportation of parts from inventory to the assembly line also depends on the assignment of parts to operations and on the takt time of the assembly line. When knowing what part is needed where at what time, the warehousing department can schedule the delivery of parts. As the production is going to be line assembly, lead times will be of great focus and therefore parts need to be delivered to the assembly line LEAN-style with the right parts, at the right place, at the right time. For this reason, the collaboration with the production department needs to be tight and daily meetings between the two department will be carried out. This will ensure greater communication and better possibility to prevent misunderstandings to happen between the two functions.

Customs/import/export

The collaboration with this department mainly concerns parts where country of origin of a part is of interest. Some customers will not accept a product with parts from certain countries. As with the quality department, this department determines the parts in question, communicates the knowledge to the warehousing department who handles the transportation of these parts. The warehousing department will be able to deliver the special parts to the right location at the right time to make sure it is installed in the right engine.

IT

Much collaboration happens with the IT-department during the ramp-up project. As mentioned earlier, a new version of the MRP-system is to be implemented. The new version will be adapted to the Danish way of usage which results in a lot of functions that need to be designed specifically to this system. The warehousing department is in close dialogue with the IT-department to ensure that the new functions fit the purposes. A topic of collaboration has been designing the labels for the boxes containing parts and for the shelves. The labels have been defined and designed from scratch by the employees and do now fit the intended use. After production start in the summer of 2018 the collaboration and dialog will continue with this department to remedy flaws and improve the applications and use of the system.

2.2.3 Categorization of parts

The new production will have a dedicated warehouse where the parts will be divided into two main groupings - “kit-parts” and “kanban-parts”. The kit-parts will be handled internally by the warehousing department while the kanban-parts will be handled by a vendor managed inventory solution. This section describes the handling method for the kits as well as the layout of the MAN175D warehouse, and in the following sections methods for handling the kanban-parts will be presented.

2.2.3.1 Handling of kit-parts

The kit-parts got their name from the way they are to be presented at the assembly line. Previously, all operations necessary to assemble a MAN175D engine have been documented as well as every part used for the specific operations. Based on these documentations kits with the necessary parts have been designed to fit specific operations. The kits are presented in standard sized plastic pallets with customized foam filler with holes shaped like the relevant parts. This is implemented to increase both productivity and quality. The time of the assembly worker is the most valuable and delay in one station will equally delay each of the following stations. Presenting parts so they can be picked and assembled at the product immediately reduces the time for walking and handling for the assembly worker. This method of parts presentation will prevent errors of picking the wrong part or overlooking a part. In this way every item for a specific operation is presented together and only when the kit is empty it is certain that all items have been assembled. Since items are handled before entering the assembly line the risks of defects in the filled kits is minimal reducing lost production time caused by handling defect items (Baudin, 2002).

The parts used in the kits are handled in-house by the warehousing department, where the parts are delivered by the supplier at a receiving area. From here, the parts are picked and placed in

stock - both physically and electronically. When parts are placed in stock and registered they can be picked for kits and delivered to the assembly line.
Standard MRP-system is used to manage the flow of kit-parts. The sales department creates a sale in the system (where a wanted delivery date might be presented). The MRP-system generates a proposal for a production order based on knowledge concerning the production and the production schedule. An employee manually confirms if the proposed production order is manageable. When the production order has become effective a picking order, based on the bill of materials for the requested product, is generated for the warehousing department. When the items are picked from stock, barcodes are scanned and registered in the MRP-system and based on the consumption of items a purchase order will be generated (Slack et al., 2013).

2.2.4 Layout of the warehouse

To make the warehouse more effective and able to accommodate the wishes of a LEAN production it has been designed thereafter. The warehouse is divided into two main areas - one for parts and a buffer area for kits. The area for parts is divided into three areas as well.
In one side there are shelves that can be reached from both sides enabling picking from one side while placing parts from the other. Pallets will be on the bottom and top of the shelves and smaller parts, that does not require picking equipment, will be located in reachable height of the shelves. The shelves will vertically be divided into sections complementing the respective stations in the assembly line. With this design it is possible to pick parts for multiple kits at the same time without the employees being in the way of each other.
In the middle of the warehouse is a designated area for completed kits ready for delivery functioning as the warehouse outbound buffer. When all parts are picked for a kit it is placed in the area and from here it can be transported to the assembly line.
On the other side of the warehouse there will be areas and shelves for larger parts that does not fit into standardized shelves and pallets. This will include parts such as the crankcase and the crankshaft.
In the front of the warehouse will be a reception area designated for the MAN175D production. Here incoming parts will be received and registered, undergoing quality inspection or classification if needed, and then placed on stock.
The area between the warehouse and the assembly line will be a buffer area to store mostly empty kits and by times also completed kits if the warehouse department needs to work ahead of schedule.

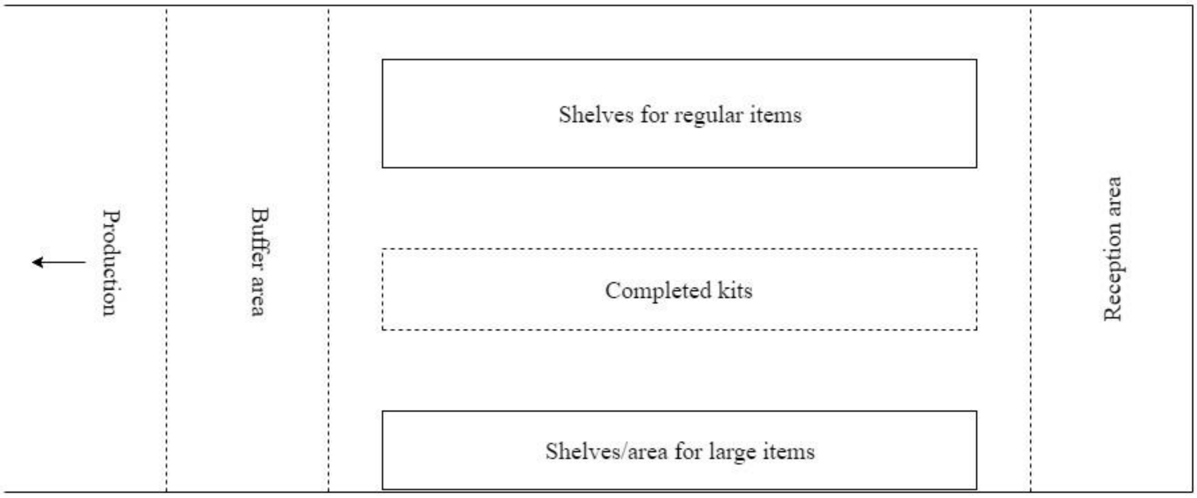

Figure 6. Layout of the warehouse facility

The transportation of kits is done by a small train with a capacity of five kits. The train will drive back and forth between the warehouse and assembly line picking up empty kits at the line, placing them in the buffer area, driving into the warehouse to pick up completed kits and deliver these at the assembly line. The kits will function as a modified two-bin system where an empty kit placed in the warehouse buffer area will function as the signal for replenishment. In a system like this the two bins are full at production start. In this case, one full kit at the assembly line and one full kit at the warehouse outbound buffer. When all items from a kit has been used the empty kit is replaced with a full kit and the empty kit transported to the inbound buffer area at the warehouse. In this way the warehouse outbound buffer with full kits functions as the assembly line inbound buffer as well. The reason for this to be possible is the long lead time between usage of two identical kits. This time will be used for transporting the full kit to the assembly line (Nicholas, 2011).

2.3 Handling of kanban-parts

For approximately half of the parts going into a MAN175D, MDT FRH is planning to implement a vendor managed inventory solution. The division of parts is based on size of the items, since they are to be presented in small containers fitting a lineside kanban-rack. To understand such an arrangement, vendor managed inventory will be described as well as the intended use by MDT FRH.

Parts constituting a MAN175D engine	
Total number of parts	6741
Total number of part numbers	2369
Number of kanban-parts	3485
Kanban part numbers	434
Kanban-locations	705

Table 1. Parts constituting a MAN175D engine. The high number of kanban-locations is due to identical parts being used in multiple operations

2.3.1 Vendor managed inventory

Vendor managed inventory, or VMI, is an approach to inventory management where collaboration between supplier and customer is different from traditional ordering processes. The supplier takes responsibility for maintaining the customer's inventory. This business model requires the customer to provide information to the suppliers about a product and the suppliers then have responsibility to maintain inventory of the product (The Balance, 2016). Different from traditional inventory management is that in VMI the supplier can base their own upstream supply chain through access to relevant information from the customer. The need for communication and reaction upon this is reduced since the suppliers can see the demand real time and thereby anticipate fluctuations better and respond timelier. With a more streamlined supply chain the possibility of running out of stock will decrease, inventory across the chain will be reduced, and service levels are likely to increase for all customers (Datalliance, 2017).

2.3.2 VMI at MDT FRH

MDT FRH is going to implement a 2-bin VMI solution using E-kanban. This allows for communication between operations not located next to each other or in this case two different companies. The parts are presented in kanban-boxes and when these boxes are emptied by the assembly worker he/she places it on a designated shelf. This functions as regular withdrawal kanbans, but in this case an empty box authorizes withdrawal from the supplier's outbound finished goods buffer to replenish an inbound buffer at the assembly line (Nicholas, 2011). On the boxes there will be RFID-tags (radio-frequency identification) and an electronic reader will be placed to read the tags when a box is placed on the shelf. The data from the tag will be received by the supplier who then knows which parts to replenish for next shipment. The initial idea is that replacement of parts will happen twice a week. The supplier's removal of the boxes will generate a purchase order from MDT FRH that will be registered at the supplier as a sales order that must be fulfilled. The purchase order is created in the MRP-systems at both companies through EDI (electronic data interchange). When the order is registered and approved by the supplier an order confirmation is electronically sent MDT FRH to inform the warehousing department of incoming parts. The goods are received at the warehouse and the quality check is handled in house. When the check is performed the warehousing employees places the filled boxes in the kanban-racks at the assembly line. MDT FRH will not allow non-employees at the assembly area and therefore parts are delivered at the warehouse and not directly at the point of use.

2.3.3 Agreements between MDT FRH and supplier

Before a buyer-supplier relationship like this can work many agreements have to be made. Some of these are how often parts are to be replaced, what the quantity of parts each delivery will comprise, information sharing and prizing. However, these agreements have not yet been specified, but an outline has been formed to how they will be. The initial thought is that parts will be delivered twice a week, but this will be finally determined when the production flow is stabilized. The quantity of parts delivered depends of various factors and are to be calculated. A requirement is that the quantity delivered must be divisible by the number of parts in the suppliers' packages to minimize handling and repacking. Say for a given part the standard amount in one package delivered by the supplier is 100, then the amount purchased by MDT FRH must be divisible by 100. The purchase amount is based on forecasts for the end product and a calculated reorder point. To minimize material handling and storage space at MDT FRH the amount purchased will constitute the amount of parts in the bins at the assembly line.

The kind of information given to the supplier is decided to be forecasts for the end product and knowledge concerning the immediate needs for parts from MDT FRH. Until production and demand have stabilized the supplier will be given forecasts each month but will change into quarterly forecasts afterwards. Through the RFID-tags on the empty boxes, the supplier will know the demand for parts for the next delivery.

The prizing of parts is currently a special matter and is likely to change over time. At the moment MDT FRH buys parts from suppliers, then these parts are delivered to the VMI collaborator company that will handle deliveries to MDT FRH. In the long term the VMI collaborator will handle purchasing of parts and communication with parts suppliers.

2.3.4 Benefits of VMI

MDT FRH hope to minimize the use of own resources when implementing VMI. With an arrangement like this many functions will be placed at the supplier and thereby releasing in-house resources to maintain other functions. The assembly line is based on LEAN principles and the company wishes to implement this across the entire making of a MAN175D engine. With the benefits from VMI warehousing and purchasing operations will be more automated and will contribute to a smoother flow throughout the supply chain. With VMI and increased information sharing the supply chain is less likely to experience bullwhip effect or amplification of forecasts. With the bullwhip effect companies tend to buy increasingly larger lots the further upstream the company is located to prevent stock outs, leading to an inefficient supply chain. Amplification happens when each company in the supply chain produces own forecasts based on the forecasts produced by the subsequent downstream customer. When peaks in demand occurs managers will adjust forecasts accordingly and if every company in the supply chain does so, the amplification effect will increase for every step upstream and may cause either great over- or underproduction (Hopp, 2003). Increasing information sharing, improving forecasts and reducing batch sizes will induce a more efficient line of supply and enabling more efficient inhouse operations.

Even though a VMI solution will be more expensive than handling the parts in question in-house, this solution is deemed to be more beneficial by the company. Resources can be utilized elsewhere, the flow of parts between supplier and MDT FRH will be enhanced, the amount of parts on stock will decrease which leads to lower holding costs and tied up funds and less risk associated with inventory.

2.3.5 Concerns about VMI

The main concern for MDT FRH about this kind of relationship is handing over the responsibility. This is a great change of how things are usually done at the company and it requires a great deal of mental change.

However, the company is not quite ready to hand over all responsibility. Former experiences have made the company keep an inhouse quality inspection upon arrival of parts. The concern lies not with the quality of the parts but with the quality of deliveries. To keep the assembly line running smoothly at all times it is important that the right parts are delivered. Therefore, this check will mainly focus on whether it is the right parts that have arrived at the right quantity.

To ease the radically new approach it is important that the transformation process is managed properly and employees are kept motivated. Employees should be consulted, encouraged and appreciated until the change have become part of the everyday work (Slack et al., 2013).

2.4 Initial findings

This section concludes on the initial analysis of MAN Diesel & Turbo, Frederikshavn, the warehousing department and the future collaboration regarding parts supply which leads to certain areas of focus. These detected areas will form the basis for the problem statement and appertaining research questions.

The future production at MDT FRH will be line assembly consisting of 6 assembly stations, each with dedicated work content. The desire is to establish a lean production capable of finishing one end product every day, working on six engines at a time (one at each station). This will be achieved through leveled work content for each station, allowing the engines to move one station forward all at once. However, this is not the situation with the current balancing of the assembly line. If handled properly, this will not affect the work of the warehousing department since they work in parallel with the assembly line. A two-bin kanban-system will compose the supply method for kits and the idea is to collect empty kits with a transportation train and afterwards replacing them with an identical kit. The problem with this is not the method, but how it is handled. There has not been established a method for communicating needs for replenishment, which may cause confusion for warehouse employees, lack of parts supply and excessive runs with the train. A well-managed flow of information will enhance flow of products.

The company is planning to implement vendor managed inventory for some parts to reduce risk of holding stock, reducing inventory, and to release resources from the warehousing department to maintain other functions. An issue yet to be processed is purchasing of parts for the vendor managed kanban-parts. This task will be carried out by the purchasing department and will be based on economic order quantities and packaging quantities from the supplier and not by the consumption rate of the assembly line. The purchase amount must be divisible with the number of parts in the packages delivered by the supplier, which may lead to excessive inventory and irregular delivery intervals.

The last issue processed in this thesis is closely related to the previous and concerns the quantity of parts in the lineside kanban-boxes. Instead of adapting the same method as of the kits, which contains only parts to supply one operation, the kanban-boxes will be filled with the purchase amount, which may be rather large. The company seeks a lean production and beneficial principles from the lean philosophy can be applied to the lineside parts supply as well. The lean philosophy emphasizes among other things reducing inventories and supplying the right parts at the right time, quantity and place. Large lineside buffers are contradictory to this and may hide or cause problems.

3. Problem statement and research questions

The three detected issues from the initial findings will form a joint problem statement for the problem analysis in which the three will be addressed separately along with appertaining suggestions for improvements:

> *What will the effects be if the company implements the current ideas and which possible solutions are applicable to induce improvements?*

The problem statement revolves around research questions for each issue and they are as follows:

1. How does the unbalanced assembly line affect the warehousing department and how is demand for replenishment communicated?
2. What are the effects of purchasing based on convenience of supplier instead of own production rates and how does this affect inventories and the warehousing department?
3. How does large lineside buffers comply with the LEAN philosophy and how does it affect inventories and the warehousing department?

3.1 Delimitations

The processes of establishing a new production with everything it includes is highly complex and includes much collaboration between both inhouse and outhouse parties and concurrent engineering. Thorough analysis of all aspects requires extensive knowledge and a great deal of resources. To limit the scope of the thesis certain limitations have been formulated.

- Focus lies only on the warehousing department and the logistics function of the ramp-up project, and problems arising in other areas connected to the future production will not be addressed
- Any specific company policies regarding capacity or purchasing have not been taken into consideration
- Accompanying this, the matter of safety stock is not addressed due to it being deemed an internal matter still to be determined by the company
- The possibility of altering agreements and the effects thereof with the VMI collaborator company is considered out of scope for this project

4. Method

This chapter describes the methods and empirical data used to form this thesis and answer the problem statement.

As no problem was presented by the company to initiate the thesis the initial analysis focuses on establishing the current and future situation and comparing this to theoretical knowledge on the matter. Since the thesis revolves around a future production instead of an existing one, the problem analysis also exploits theoretical knowledge to explain possible outcomes.

4.1 Initial analysis

The initial analysis elaborates on the current situation of the future production and the logistics functions thereof. Qualitative primary data is used to establish the ideas of how the warehousing department will function and collaborate with other departments. Theory on the matters is applied for further explanations of methods used at MDT FRH.

4.2 Problem analysis and suggestions for improvement

The problem analysis attempts to answer the problem statement and the related research questions. The problem analysis is based on the findings from the initial analysis and the answers are mainly based on theoretical knowledge obtained throughout the education. Quantitative data supplied by the company is supporting the analysis and the findings.

The problem analysis leads to the suggestions for improvement and these are based on the same knowledge.

4.3 Empirical data

Both primary and secondary data compose the empirical data used in this thesis. The primary data is qualitative data collected through experiences and observations from the internship and through interviews with employees at the company. The qualitative secondary data used is primary theoretical literature presented throughout the education and the quantitative secondary data is a spreadsheet presenting the kanban-parts used in the production of a 175D engine (Heaton, 2004).

4.3.1 Primary data

The primary data is directly obtained and collected by the student through the qualitative methods of interview and observation. Exploratory questions are asked to gain better understanding, and descriptive questions have been asked as a way to match what is being observed to what is being explained. The interviews during meetings have been strict with prepared questions, while interviews conducted during guided tours at the company have been more unstructured and functioned like conversations rather than interviews (Gubrium & Holstein., 2001).

Background knowledge gained from experience and observation during the internship forms the basis of understanding the company, the ramp-up project and the production function of this. Approaches where the student was both participating and non-participating have been used. Participating in the daily work of the company during the internship and non-participating during meetings.

The observations during the guided tours were performed with a non-participant approach, but with descriptive interviewing to collect additional information regarding the observed (Eriksson & Kovalainen, 2008).

4.3.1.1 Evaluation of primary data

It is believed that the employees interviewed at MDT FRH have the knowledge and competencies to answer the questions. The interviewees are part of the management in their respective fields and is trusted to have thorough understanding of their departments and surroundings, and is therefore deemed credible. The answers given may be somewhat subjective since they are based on the interpretations of the reality the interviewees experience. But since the ramp-up project is still in embryo the information forming the basis of its surrounding knowledge should be the same.

The observations made by the student during the internship and the experience gained in that period will be subjectively interpreted, but it contributes with a different kind of objectivity than that of employees at the company. Not being permanently employed does not add the same sense of responsibility and gives the possibility to experience things with a less biased view. Observations made during guided tours may not give a representative image of the performance, since employees were interrupted and asked to show how they work, which in some cases may show either higher or lower performance. But it is believed that what and how they were doing their job was represented trustworthy.

4.3.2 Secondary data

This type of data is collected earlier by someone else, meaning that the student does not have firsthand knowledge about collection method and related issues. The secondary data used for this thesis is represented both qualitatively and quantitatively.

The qualitative secondary data is obtained through reviews of litterature presented throughout the education or used in previous semester projects.

The quantitative data is a spreadsheet provided to the student by the company. It contains a list of kanban-parts, in what assembly station they are used, and in what quantity they are used. The parts are registered using the bill of materials and consumption of parts is calculated from this. The division of parts have been done manually by an employee and is based on the size of the component.

4.3.2.1 Evaluation of secondary data

Literature written by acknowledged authors and approved for study curriculum by the university is deemed valid and trustworthy.

Validity and reliability of the quantitative data is more difficult to establish, since the parameters are created manually. The parts and quantities thereof should be reliable since the numbers stems from the bill of materials, but if the analysis was performed again a different division of parts into categories may be used and changing the numbers accordingly.

5. Problem analysis

This chapter seeks to answer the formulated problem statement by analyzing the topics of the related research questions. The production not being established yet, the theoretical nature of this thesis applies for the problem analysis as well. Knowledge of the topic in question will be compared to theories on the matter to expose the potential magnitude of the issue. Based on the current situation at MDT FRH and the applied theoretical knowledge suggestions for improvement will be presented with a practical approach to the specific situation.
Each of the three issues alongside the appertaining improvement suggestion will be presented and processed separately.

5.1 Unbalanced assembly line

In the initial analysis is was established that the assembly line is not balanced, and that the production times are based on single sample rough estimates. In itself, this will not cause any trouble for the warehousing department when replenishing kits, since the function of parts supply works parallel with the assembly line. Delays on the assembly line do not cause parts supply to be delayed. However, uncertainty and irregularity of production times will cause uncertainty at the warehousing department and thereby affect the quality of the service provided if not handled properly.

The time used by the assembly workers is the most valuable and supporting processes must not be a cause of delays. The quality of the service provided by material handlers is much more important than the efficiency with which they provide it. The first focus should be on providing effective support to the assembly line, and second focus on doing so efficiently (Baudin, 2002). For the warehousing department at MDT FRH to be able to provide effective parts supply of high quality they need the right conditions to perform. When the assembly line is established, the company is planning to use the takt time and production times for proactive planning for the supply of kits to the assembly line.

Using forecasts and/or future sales orders a production plan for end products is determined and based on this production plan it is calculated when and how many components are required to realize the production plan. The production plan along with the bill of materials forms the subsequent material planning. Using this method, the material planning will be based on dependent demand since the planning is formed on the basis of demand for end products. This means that the future pull of parts from the warehouse will be known both concerning demand and timing in terms of consumption on the assembly line. Based on this demand and knowledge concerning replenishment time (time used on picking and preparing parts and deliver the kit to the assembly line) an order can be released to the warehouse.

This method requires high quality of knowledge concerning consumption and timing. MDT FRH only excels in one of those - consumption. All kits have been designed based on the bill of materials and process documentation, but due to the estimated and still uncertain production times the timing of replenishment is still uncertain. A way to overcome this situation is to implement reactive management of parts supply to the assembly line. Using this method, replenishment is initiated by actual consumption instead of forecasts. The timing of replenishment is determined so the remaining items will satisfy demand in the period from replenishment is ordered until it is delivered for consumption (Michelsen, 2010).

In the case of MDT FRH the time between consumption of two identical kits is long enough for the reorder point to be zero. Producing one engine each day means that a kit is consumed only once each day. When there are zero parts left in the kit it must be replenished before the same operation is performed on the next engine. This gives a replenishment time of approximately 7,4 (working) hours.

With a total of 82 operations divided into 6 stations and a long distance between the warehouse and the assembly line there is a need for managing the timing and sequence of replenishment of kits. When the production times are not established it will be a difficult task to know when materials are needed, and when an empty kit can be collected and make space for a new one.

5.1.1 Suggestion

The irregularity of production times and thereby consumption time of kits does not form a problem for the warehousing department however, the management of it does. Ways of communication needs to be established for the warehousing department to know when kits are empty and need to be replenished.

The suggestion is to introduce methods of kanban until production times have stabilized and replenishment can be scheduled accordingly. Since the distance between the warehouse and the assembly line is large it will be suitable to either introduce an electronic form of kanban or determine intervals to collect kanbans.

During the internship a concept for an electronic kanban-system for managing replenishment of kits was developed.

The concept emphasizes visibility and minimum handling and is designed as an application for an MRP-system. Communication between the assembly worker and the warehousing department will take place using monitors or tablets with touch technology. A monitor/tablet will be located at each assembly station. The idea is that every lineside location for kits is represented on a blueprint drawing on the monitor. When the operator empties a kit he/she simply touches the imaged location at the blueprint. The touch will alter the color representing the location to let the operator know that replenishment is ordered. The gathered information from the assembly line will form the scheduling for the warehousing department. Associated with the lineside location will be the specific kit. These have already been determined by the company and will constitute the picking list. A regular first-in-first-out approach can be applied to make sure that the kit emptied first will also be replenished first, or any otherer clustering of orders that will suit the scheduling. The choice of method should consider the risk of stock-out at the assembly line, minimize transportation and layout of the warehouse. Though, this method requires software developing and extra expenses. If it is only a temporary implementation, it may not be beneficial.

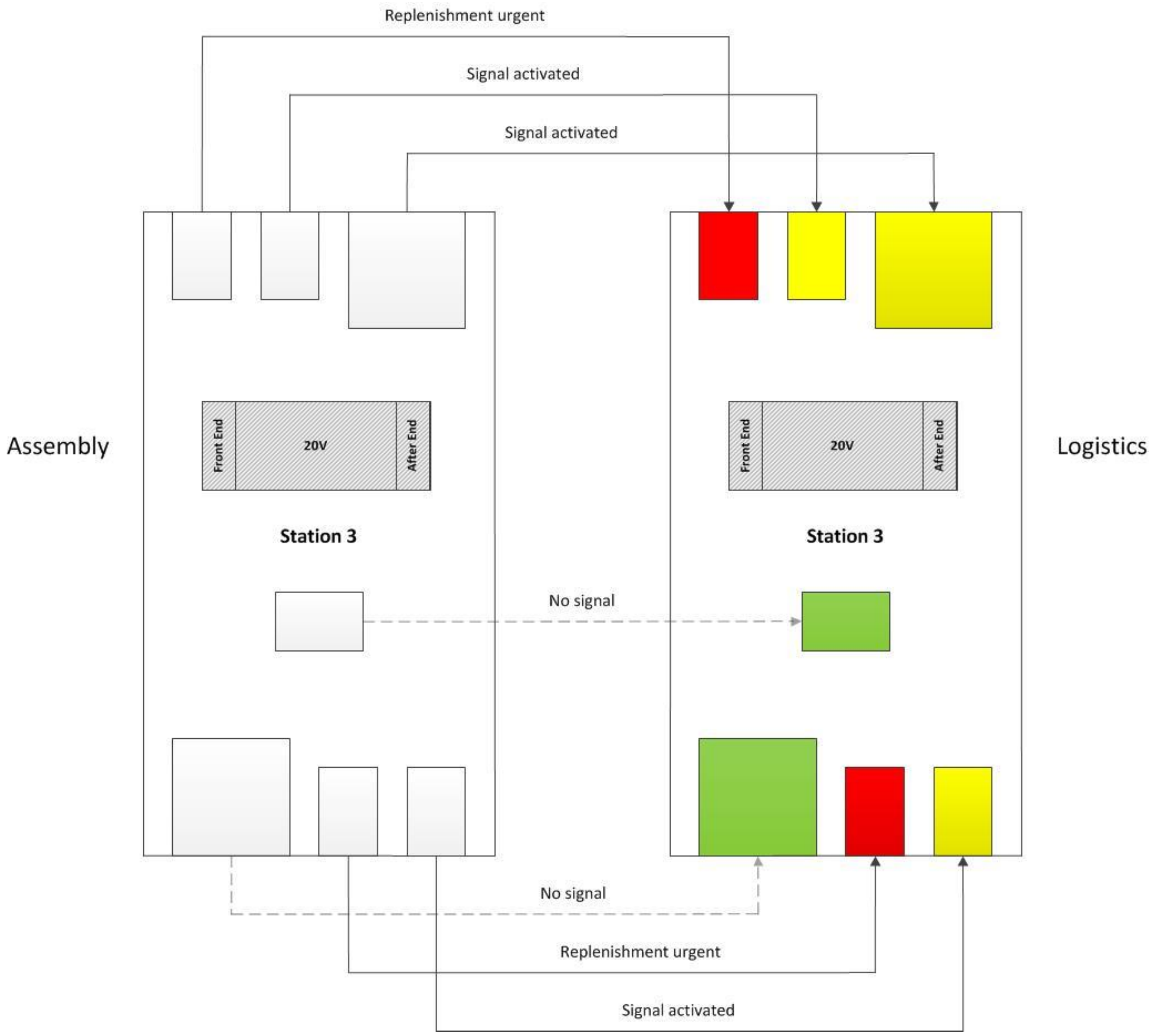

Figure 7. Visual conceptualization of electronic replenishment communication

A less expensive method is using physical kanban-cards. Each set of kit will share two different kanban-cards. One card will signal replenishment and the other card transportation. The replenishment card should follow the route between the warehouse outbound buffer and the assembly line inbound buffer. The replenishment card will be attached to the filled kit and transported to the assembly line. When the kit is emptied by the assembly worker, the card is detached from the kit and placed on a nearby board designed for the purpose. The board should be divided according to urgency of the replenishment. A first-in-first-out principle can beneficially be applied, since the order of consumption of kits is always the same and replenishment must follow the same order. The cards should be collected by a dedicated employee at fixed time intervals in so-called milk-runs (Nicholas, 2011). In every milk-run the cards are collected and attached to the corresponding empty kit in the buffer area at the warehouse. This card gives the authorization for the kit to be moved to the main area of the warehouse to be re-filled.

On the empty kit in the warehouse buffer area is a transportation card. When a replenishment card is collected during the milk-run and attached the kit at the warehouse, it will replace the transportation card. The transportation card authorizes collection of empty kits at the assembly line, and is forwarded to the employee maintaining this task. When the empty kit is collected from the assembly line, the transportation card is then attached to this kit and the process can be repeated.

In this way the kanban-cards will dictate the sequence of replenishment ensuring that the correct kits are replenished and that it only happens when inventory locations at the assembly line is empty. By doing the milk-runs in fixed intervals and categorize kanban-cards according to urgency, the transportation train only has to drive round the assembly line when it is needed. The categorization prevents timing errors of the replenishment.

5.2 Purchase amounts

Established through conversations with employees at MDT FRH several parameters are taken into account when determining purchase quantities. It is based on forecasts for the end product and a reorder point. In addition to this the purchase department uses calculations for Economic Order Quantity (EOQ) to establish the most feasible purchase amount. This amount is then compared to the number of items in the packages delivered by the VMI supplier company by which they must divisible.

Using this method, the supply of parts to the warehouse will be based on the convenience of the supplier, and not by the actual need at MDT FRH. In lean assembly one of the principles is to deliver the right amount at the right time, and the method used at MDT FRH does not comply with that.

Not purchasing based on actual consumption and needs may lead to excessive inventory that in itself constitutes waste, but also covers up other issues. Inventory is carried to prevent interruptions in material flow caused by equipment failures or delivery delays by suppliers, instead of performing preventive maintenance or work on the supplier relationship. Inventory is carried to cover defects, instead of making suppliers responsible for quality of parts and improving product design and production processes. Reducing inventory will reveal such problems and forces improvements.

Reducing inventory will also reduce the direct costs related to inventory, which can be very high. The holding costs increase with the size of the inventory, and the capital needed to acquire the items cannot be used elsewhere and this forms an opportunity cost (Nicholas, 2011).

To illustrate the problem with the purchasing amount, calculations are carried out for some of the kanban-parts used in the assembly of the engine. In Appendix B is a full list of the kanban-parts and amount used in a single engine. This sheet forms the basis of the calculations.

The first calculation illustrates amount of inventory for a specific part if using the method of MDT FRH. As an example, the amount of the part 06.22140-1213, a cylinder pin, is 24 per engine. If the packages from the supplier contains 10 pieces and the company is purchasing based on this, they will order 240 parts per delivery. This means the company will hold enough inventory to satisfy several days of production, leaving the excessive parts waiting for consumption, occupying space and tying up capital.

Another example is part 06.01013-1213, a hexagon head screw, of which a total of 33 is used per engine. The purchase amount will be 330 if the packages contain 10 items, but even more if the packages contain larger amounts.
Using this exact part as an example shows another concern if buying large amounts suiting the supplier. The part is used in various amounts in seven different operations. This will either cause even more inventory if the method is applied every time the item is purchased or extra handling of the items if it is purchased as one aggregated amount. If large amounts are purchased and afterwards need to be divided into separate containers, unnecessary time is spent on this, and the more items are handled the larger the risk of errors become (Nicholas, 2011).

If the company wish to decrease the inventory, but still complying with supplier's amount in the packages, a smaller amount can be purchased. If the purchase amount for cylinder pins is reduced to 200 it leaves eight parts in excess. In itself, eight parts in excess does not sound of much, but this may derive another problem. Described by employees at MDT FRH the quality of traceability must be very high in the engines. Every part of the engine must be traceable back to the manufacturer if defects or breakdowns occur. This means that batches of items cannot be mixed. If they are, and a breakdown occurs, the source of the defect cannot be detected. The eight excessive items are useless and forms waste in terms of purchasing costs, handling costs, tied up capital and have taken up space in the warehouse.

The use of economic order quantity methods and complying with supplier packaging amount may also cause problems if different items are packaged in different amounts. If so, the replenishment time for the different items will vary and the schedule of each item will differ from one another. It will make the scheduling of deliveries and warehousing employees difficult and cause peak periods or idle periods. The reorder points for different items will differ and make the amount of stock for items different. This will make it difficult to estimate if a half empty shelf is an indication of immediate shortage or the amount can satisfy for several days (Nicholas, 2011).

Table 2 depicts the principles behind the issues using this method. The part number and the parts per engine is based on the spreadsheet provided by MDT FRH, while supplier package amount and purchase amount are fictional numbers used for illustration. The lead time represents number of days the purchased amount will satisfy demand at the assembly line. The excess parts represent the difference between demand during lead time and the purchased amount.

Part number	Parts per engine	Supplier package amount	Purchase amount	Lead time	Excess parts
06.15717-0406	4	20	20	5	0
06.22140-1213	24	10	240	10	0
06.11064-0115	3	15	15	5	0
06.02099-0439	10	50	50	5	0
06.01283-1217	15	100	100	6	10
06.15150-0104	12	50	50	4	2
06.01283-1218	16	30	90	5	10

Table 2. Conceptual illustration of issues related to purchasing based on convenience of supplier instead of own needs

The table clearly shows great differences in lead time which will cause infrequent deliveries. This makes it difficult to produce a uniform schedule of deliveries. Some days deliveries might be large, and other days small, causing peak and idle time at both the warehousing department, the supplier and possibly the manufacturer. Excess parts are also the case in some of the examples and these parts will constitute scrap if parts from different batches cannot be mixed due to traceability. The part will have formed costs of purchasing, storage and handling.

5.2.1 Suggestion

Quantities delivered should be based on consumption rates and calculated to support the assembly line for the same amount of time. This avoids imbalances of inventory and allows for regular and periodic deliveries of multiple items in matching quantities and it will even workload for the warehousing employees.

If the large purchase amounts are based on cost reduction by quantity discount it may be feasible to make framework agreements with the part manufacturers. In this way the orders can still be large and manufacturers exploit economies of scale, but deliveries will be smaller and more frequent. Instead of receiving 500 parts at once, 10 deliveries of 50 can be made. The smaller batches will reduce inventory and increase quality. If a delivery is handled wrongfully less will go to waste and if the received batch contains defects less has to be replaced.

However, by introducing smaller batches the handling increases. It is therefore important that the handling is easy and can be done quickly. This can be obtained by buyer and supplier making agreements concerning standard sized containers based on consumption rates which can be moved directly to the point of use at the assembly line. MDT FRH should have a strong case on the matter of negotiations concerning amounts in each package. The VMI supplier maintains deliveries of more than half of the parts going into a MAN175D possibly making MDT FRH a large customer. As the customer, MDT FRH is entitled to make requirements and the supplier should try to meet these requirements to not risk losing the customer.

If the company wishes to reduce number of deliveries and transportation costs, multiple containers containing the same amount of parts can be delivered at the same time. By doing so, it will be easier to manage the warehouse and it will be easy to quick-check for how many days the inventory is sufficient. It will lower the risk of deterioration of certain parts if they are kept in sealed containers and only delivered to the assembly line at time of use. Some parts, like O-rings and gaskets, may go bad over time if exposed to the environment for too long. Keeping the sealing on for as long as possible, by the warehousing employees unpacking just before use, will ensure less defects.

5.3 Quantity in Kanban-boxes

The last issue mentioned in this thesis is closely connected to the previous. Explained by employees at MDT FRH the purchasing amount will constitute the number of parts in the respective kanban-boxes. The company also wishes to achieve a lean production, but those two statements are contradictory.

Principles of the LEAN philosophy emphasize reducing inventories and reducing batch sizes. The replenishment of Kanban-parts at MDT FRH is done through a two-bin system consistent with pull production method. In pull production the containers are kept small to minimize inventory buffers, they are easy to move and items are easy to access. Increasing the amount of parts in the containers results in parts waiting, taking up space and risk going bad over time (Nicholas, 2011).

As with the previous issue of purchase amount, large buffers are more difficult to manage. They may hide other problems and they tie up capital. Knowledge on when to replenish will be difficult to obtain since the consumption rates of items are different. A box containing five parts may be sufficient supply for a week or it may be an immediate shortage.

The large number of items in the kanban-boxes may also cause problems regarding traceability. If the amount in the box does not comply with consumption items from the next box will be used. If the items assembled at the engine come from two different batches and if a breakdown occurs it will be difficult to trace the origin of the defect part. If every part in the end product needs to be traceable, identical parts from different batches cannot be assembled on the same engine. As with the illustration in Table 2 this will lead to excess parts and scrap.

5.3.1 Suggestion

MDT FRH has done such great effort regarding design of the kits and the method is applicable for the kanban-parts as well. Each kit contains the exact amount of parts to satisfy demand (assembly of one engine) and likewise each kanban-box should contain no more parts than needed to satisfy the same demand. In this case it will be beneficial to hold line-side inventory of parts for one engine. In this way, it will be easy to manage parts and facilitate counting. In the current setup, the warehousing department transport the replenished kanban-box to the assembly line. If every box only contains parts for one engine, all boxes should be replenished once every day. When the production times are established, it will be easy to create a replenishment schedule that can be used every day, since it is a single-model assembly line.

Having only the exact amount needed in the boxes, will also be beneficial for the assembly worker. As with an empty kit, an empty kanban-box indicates completion of an operation and functions as mistake proofing. With no parts left in the box it is certain that all have been assembled on the engine, and if each box contains exactly the amount needed, the end product will have total traceability.

Even though the boxes only contain the amount needed, defects are most likely detected at the incoming quality check at the warehouse and will not pose an issue. If a defect is detected at the assembly line it is possible to replace the entire box. Due to the small amount of parts in the box thorough quality inspection can be done rapidly to detect the source of the defect and, if possible, make the necessary corrections. Statistically, a large batch will contain more defects and if replacement is needed, replenishment time may be long and cause delays on the assembly line.

One of the aims of lean philosophy is to continuously reduce the number of kanban-boxes and thereby the inventory levels. When a consistent flow is created in the production and its surroundings, the number of kanban-boxes can be reduced until shortcomings occur. This gives better possibilities of focusing on the relevant improvements (Nicholas, 2011). The reduction of kanban-boxes will be easier to manage, if the number of parts in the boxes constitutes the exact amount needed.

5.3 Findings

This section answers the three formulated research questions with the findings from the problem analysis. The research equations are listed below for recollection purposes with the summarized answers. The problem statement will be answered in chapter 7, which also concludes on the overall thesis.

1. *How does the unbalanced assembly line affect the warehousing department and how is demand for replenishment communicated?*

In itself, an unbalanced assembly line does not affect the supporting processes, since these work in parallel with the assembly line. Uncertainty and irregularity at the assembly line will cause the same at the warehousing department and affect quality of parts supply, if not handled properly. Currently, no specific way of communication has been established for the replenishment of kits, which may lead to irregular schedules, late deliveries and unnecessary transportation.

The solution to overcome this issue is to establish a method for communication. The suggestions presented are both based on the methods of kanban, and includes an electronic approach and a physical one using kanban-cards. This will enable sequencing and timing of replenishments, prevent delays, and even the workload of the warehousing employees.

2. *What are the effects of purchasing based on convenience of supplier instead of own production rates and how does this affect inventories and the warehousing department?*

Using this method for determining the purchase amount may cause multiple issues. The inventory levels will be high, tying up capital and take up space. If every part in the end product must be traceable, batches cannot be mixed and MDT FRH will end up with excessive inventory that must be scrapped.

The purchase amount should be based on the consumption rate to avoid the abovementioned issues. To facilitate this, it will be beneficial if the amount of parts in the supplier packages is based on the consumption rate at MDT FRH. As a customer, MDT FRH is entitled to set requirements to their suppliers, and if not met, find another supplier.

3. *How does large lineside buffers comply with the LEAN philosophy and how does it affect inventories and the warehousing department?*

A high level of inventory in the lineside buffers are contradictory to the lean philosophy. It causes the same negative effects as the previous issue and more. It is difficult to manage inventory levels and replenishment, and counting errors are more likely to occur for the assembly worker.

The same mindset as of the kits should be applied for the kanban-boxes, which should only contain the amount needed to satisfy demand. This will facilitate better scheduling, easier managing and prevent errors.

6. Discussion

This chapter will discuss the findings from the thesis and will reflect on this. Before the problem analysis was conducted, multiple delimitations were formulated to limit the scope of the project. The effect of the delimitations may have caused inadequate findings of the analysis.

Specific company policies regarding the purchase amounts may cause the suggestion on this to be impossible to implement at the moment. If this is the case, the company should strongly consider altering the policies to gain benefits of purchasing based on consumption rate.

Not taking the safety stock into consideration will change the calculations from the problem analysis. The method will not change, but the reorder points and inventory levels will change.

Some of the suggestions require alterations in the agreements made between MDT FRH and the VMI supplier, and the possibility and the effects of this have not been examined. Changes in agreements may cause a higher prices, but will cause other benefits. Less resources will be used for purchasing and warehousing operations and inventory levels will be lowered and risk will be spread across the supply chain. If the supplier does not accept changes in the agreements, maybe it is not the correct supplier for the purpose.

The supplier relationship also constitutes another problem in pursuing a lean production for MDT FRH. One method in the lean philosophy is to make the supplier responsible for the quality of items and deliveries, releasing resources from the customer company. The inhouse quality inspection of deliveries should be unnecessary with the right supplier.

7. Conclusion

Through analysis of the logistics connected to the ramp-up project the current and future situation for the new production at MAN Diesel & Turbo, Frederikshavn were established.

Many aspects of the ramp-up project and the future production have been established and thoroughly processed by the company. This especially includes the design of the kits prepared in the warehouse.

The purpose of the initial analysis was to expose any shortcomings connected to the logistics and multiple issues were detected. Despite much effort is put into the design and preparation of kits, no method for communicating replenishment have been established. The company needs a way for assembly worker to communicate a need for replenishment to the warehousing department. This can beneficially be facilitated by a type of kanban.

The company has chosen a vendor managed inventory solution for the kanban-parts. The solution has the potential of bringing various benefits by releasing inhouse resources and reduce inventory levels. In order to obtain the last-mentioned benefit, the purchasing amount needs to be smaller than they are currently planned. As a large customer, MDT FRH has a great influence on the agreements made with the VMI collaborator. MDT FRH should make agreements designed specifically for this relationship and situation.

The kanban-parts are going to be presented by the assembly line for easy access of the assembly worker, but choices made by the company will hinder this benefit and others. The plan is that the purchased number of items will constitute the number of items in the kanban-box. Reducing the number of items in the kanban-boxes and basing it on production rate will reduce inventory and facilitate easy counting and scheduling.

Establishing a new production is a great and complex project and requires a lot of effort. MAN Diesel & Turbo has already considered many aspects of the new production, but some areas still need improvement. Many of the principles applied to the handling of kits is applicable to the kanban-parts as well. The company wishes to be lean and to be so, methods and principles from this philosophy should be applied to all operations of the production and beneficially to the supplier relationship as well.

8. Further research

In order to base the replenishment schedule on the production times, these must be documented and rather stable. When the production has matured and the flow and balancing of operations have become smoother, time studies should be conducted to improve the flow of materials to the assembly line. Likewise, time studies should be conducted regarding time for picking and delivery of parts. Those two in combination with information on sales orders will make it possible to schedule replenishments.

The matter of customer-supplier relationship has not been taken much into consideration during this project. Analysis of the current relationship supplemented with theoretical knowledge may reveal an optimum relationship. Such an analysis would help uncover different requirements, and help establish a well-founded relationship.

During the project, the student was supplied with a spreadsheet concerning the kanban-parts, which initiated an interest not pursued in this thesis – the categorization of parts. More than a hundred of the part numbers constituting the kanban-parts are only used in the quantity of one part per engine. Some of these parts are in risk of deterioration if exposed to the environment for too long, and might be more suitable for kits. The interest lies in changes of the categorization if taking more than size of the component into consideration for example quantity and shelf life.

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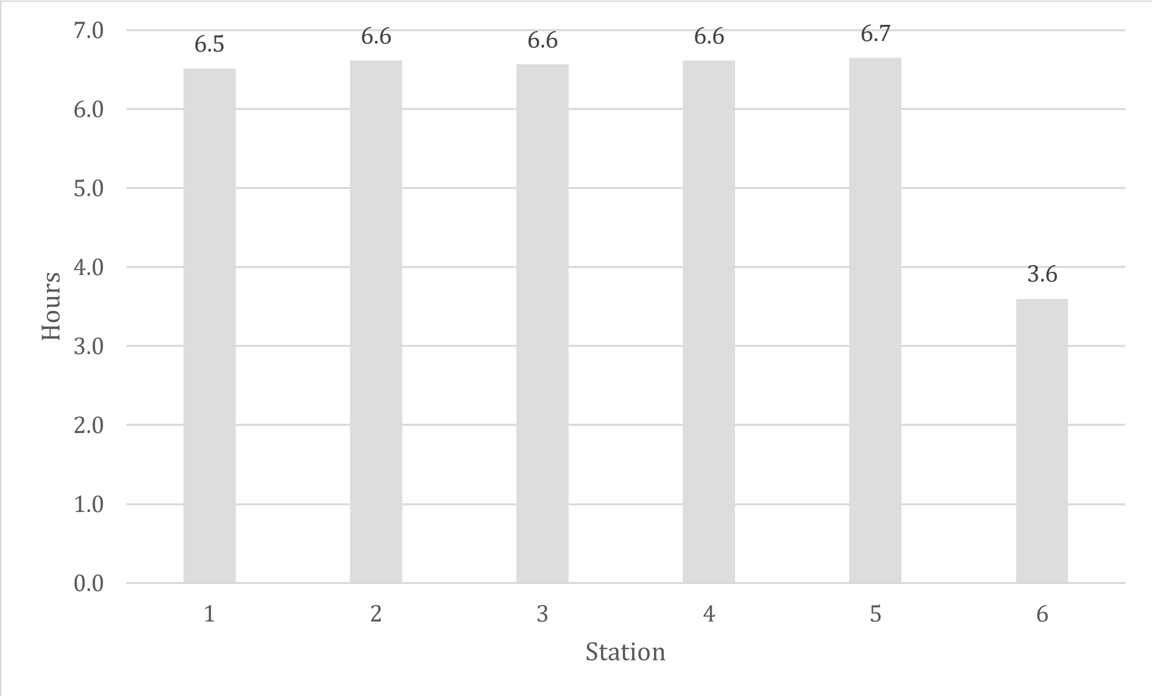
Appendix A – Balancing of the assembly line using Kilbridge & Wester method



Appendix B – Kanban-parts

The appendix is located in the attached Microsoft Excel-document and consists of two spread-sheets.

Sheet 1 constitutes the full list of kanban-parts. Each row consists of a part number, a parts description, the number of the station of which the part is used and the quantity. Next to this information, the quantity of parts has been summarized due to identical parts being used in multiple operations.

Sheet 2 shows the illustrative calculations used in the problem analysis in section 5.2. The parts used as examples are highlighted with blue in sheet 1.