Streamlining Of Bucket Elevator Foot Assembly

Examensarbete inom högskoleingenjörsprogrammet Maskinteknik

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Abstract

Skadia Elevator is a global leading provider of transportation solutions within the agricultural industry. With a rich history spanning over several decades has Skandia Elevator established itself in the industry as a pioneer and innovator consistently delivering high-quality service and products all over the world.

As the agricultural industry continues to evolve, so does Skandia Elevator. They are constantly looking for opportunities and solutions that can increase their production and benefit their company. This project looks to analyse their assembly department and the ability to streamline one of their assembly processes concerning their Bucket Elevator Foot. The end goal is to reduce the final assembly time.

To conduct this study a literature review was held in the early stages to find out the best way to approach the problem. The streamlining of an assembly process as complex as the one in this project would require pre-assemblies to be implemented which was the way to move forward. The process of assembly was documented closely from beginning to end in order to understand where the most amount of time could be found. During this, interviews were held with experienced assembly personnel to fully understand how different parts and components were connected to each other. This was crucial since it opened up for discussion with the people involved to determine in what ways pre-assemblies could be supportive for the end assembly. This resulted in a total of eight potential pre-assembly options that were listed and evaluated based on including components, storage availability and time. To finalise the process of implementation was looked at to make a decision.

Content

1. Introduction

This study has been conducted at Skandia Elevator, Arentorp, Sweden and at Chalmers Lindholmen, Gothenburg, Sweden. This section presents background to the thesis, a description of the problem itself, its purpose as well as limitations.

1.1 The company

Skandia Elevator has been a key company within the agricultural industry for years where they are widely known for their high-quality conveyor systems. They categorise their products into three different lines, L, I and H. Depending on to what extent the system will be used and what loads it will have to withstand you choose the line of your choice. This means that they supply a wide range of customers, from the local farmer to the biggest of facilities in Ukraine.

Figure 1.1 Skandia Elevator. A picture of an assembled system

1.2 Background

The background to the thesis was presented by their head of assembly. Some of their products consist of numerous components, followed by complex assembly with little instructions.Today there are 25 employees working at their assembly department and only 2 people have the knowledge of how to assemble these sorts of products which results in having to rely on their presence. This is something that is not sustainable for the company long term and was one of their main concerns today. The second part to the problem is revolving the logistics of such a complex assembly. Lack of mounting locations have been a topic within the company for long, at peak season the bigger assemblies start acting as bottlenecks for the company due to blockage of workspace. The consequences of this can then be reflected in other parts of their business such as postponed orders and having to slow down the pace of registering orders. All of which has a negative impact on the growth and success of the company.

1.3 Product line H

Skandia Elevator has their supply categorised into three product lines, L, I and H. Depending to what extent the system will be used and what loads it will be exposed to you choose a line of your preference. This thesis concerns a product of impact in line H. Product line H is described by Skandia Elevator as the product line for daily use, continual operations and year-round production. H-LINE is developed to fulfil the stringent requirements of the grain industry.

1.4 The product, Foot SEH50/23

The product this project will investigate is called Foot SEH50/23. It is a part of their H-line Bucket Elevator 50/23 which can be seen in the image below.

Figure 1.2 Skandia Elevator. Picture of a fully assembled Bucket Elevator.

The foot is an assembly itself containing 66 different parts and components. A more detailed image of the foot can be found below.

Figure 1.3 Picture of the Bucket Elevator foot. [Own picture]

1.5 Problem definition

The primary objective will be to find solutions that reduce the lead time of the product at final assembly. Making the process more efficient and streamlined will help the company get a better understanding of what could be implemented elsewhere.

1.6 Limitations

The project does not concern finding solutions for other products or product lines, it is solely focused on the foot of their Bucket Elevator 50/23. In their system it has the article number 135200 and goes under the name Foot SEH50/23.

2. Background

2.1 Current state

This chapter explains the current state of the assembly, it contains photos and information that provides a detailed description of the problem all the way from logistics to assembly.

2.1.1 Factory layout and the process of assembly

Skandia Elevator has its factory divided into different sections where different types of work is done. The biggest separation is between the sales department and the factory department, since the sales department is not of interest in this project I will solely be describing the factory department and why it is important. The following image is a complete drawing of the factory.

Figure 2.1 Drawing of Skandia Elevator. [Own picture]

The factory itself is then split up into four different sections, first we have the punching and folding department, named as 01. They specialise on two key processes, punching and bending of the plates. This is crucial in the manufacturing to create components with specific shapes, holes and features that will be used later on in the production.

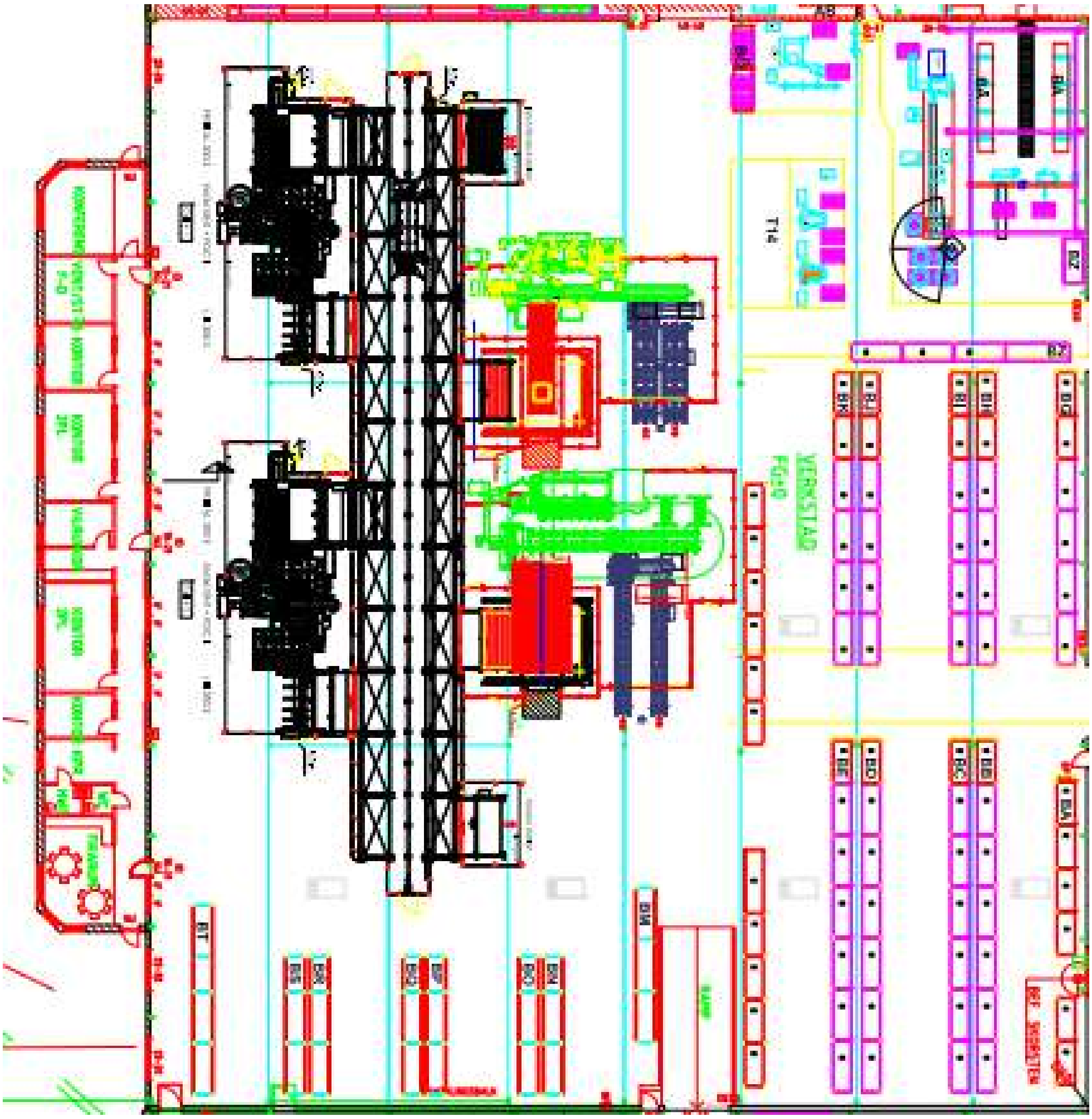


Figure 2.2 Drawing of Skandia Elevators Punching and Folding department. [Own picture].

Then we have the joining department named 02. Here the company performs the joining of parts and pieces through electrical welding among other things. This is done to simplify the job that will later be done in the assembly department. However this department will not directly be involved with the project either but is of importance to mention.

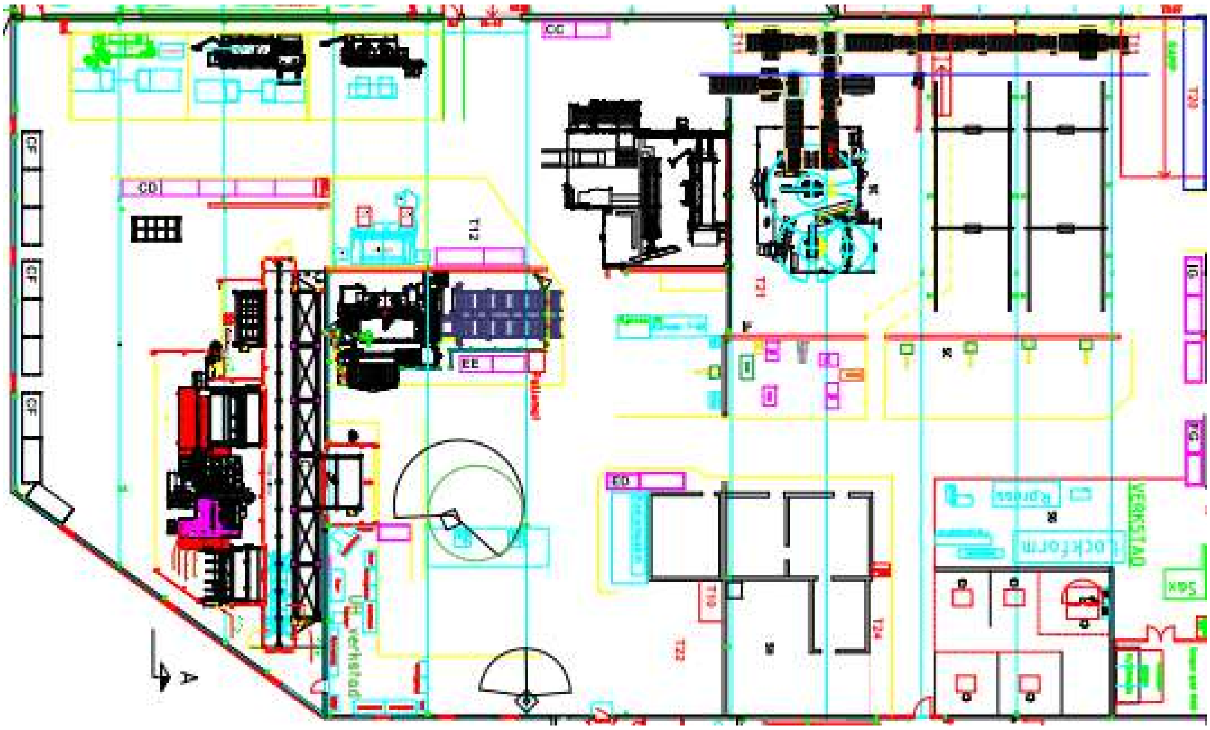


Figure 2.3 Drawing of Skandia Elevators Joining Department. [Own picture].

The next department and the most important one to this project is the assembly department named as 03. It contains 13 different assembly stations where work can be done, but the availability of necessary tools varies and therefore some products have their set stations to where they will be assembled and these stations are therefore often occupied. The company's assembly department also contains two lines.

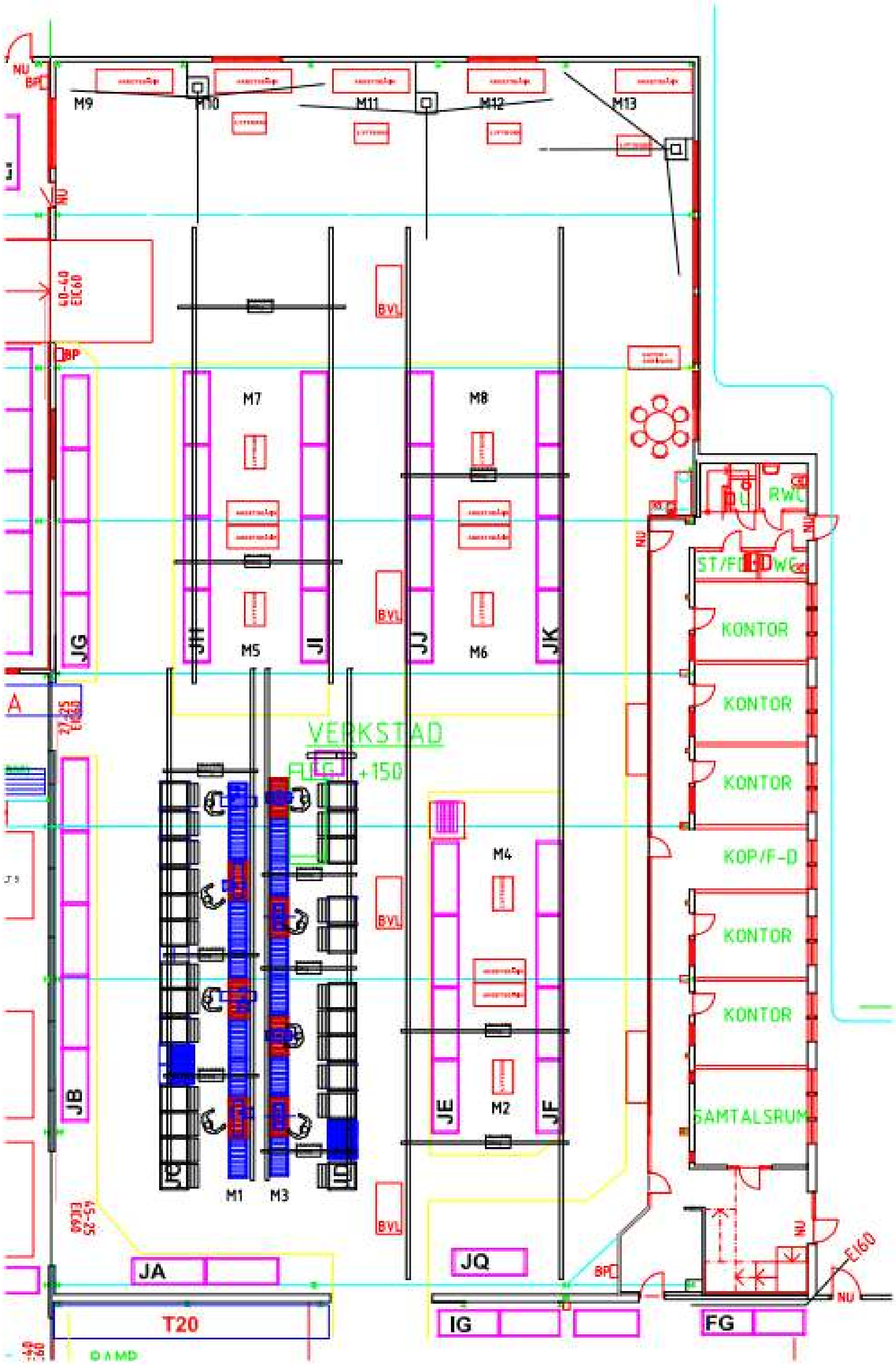


Figure 2.4 Drawing of Skandia Elevators Assembly Department. [Own picture].

The last and final department named as 04, is the warehouse. It is responsible for the storage, management, and distribution of goods and materials both within the facility but also externally.

Figure 2.5 Drawing of Skandia Elevators Warehouse Department. [Own Picture].

Another section that is not classified as a department is the logistics, for the simplicity we can call it 05 in this project. It performs all of the preliminary setting of assemblies, they are in direct contact with the assembly department and will therefore be of importance to this project. Through orders in monitor they prepare and deliver the components that are needed for the assemblers work. However the easier parts/components are located in a bureaux which the assemblers have access to. This process is something that will be more detailedly described in the acquiring components chapter.

2.1.2 Assembly stations

There are 13 assembly stations as of today that are available for work, in the drawings they are tagged with an M followed by a number. After speaking to the head of assembly he explained that they work differently and 9 of them can be viewed almost as project stations. Where most of the components are located in shelves around the station, this means that the space is very limited and so is the work that can be done there. The reasoning behind this is that the products assembled there are of constant flow and therefore having stationary shelves with the components in direct contact to the station makes the assembling much easier. The product in question for this project is not one that is assembled with high enough frequency to have its own station and therefore all of the parts have to be transported from the storage to an available assembly station. Since the space is limited for 9 of the mounting stations. There are four available locations to perform the assembly of article 135200, station M10, M11, M12 and M13.

These four stations are under high pressure, especially during summer when the company has its peak season. As can be seen on the area circled in red on the image there is theoretical space that the logistics department can use to set the different assembly jobs. During a normal year with ordinary demand this space is often fully occupied during the summer, this leads to a blockage not only for the workers but also in terms of how much work can be done. Which in a way limits the production. This is especially important for this project because the product in question is one that demands a lot of space and it also takes a lot of time to assemble.

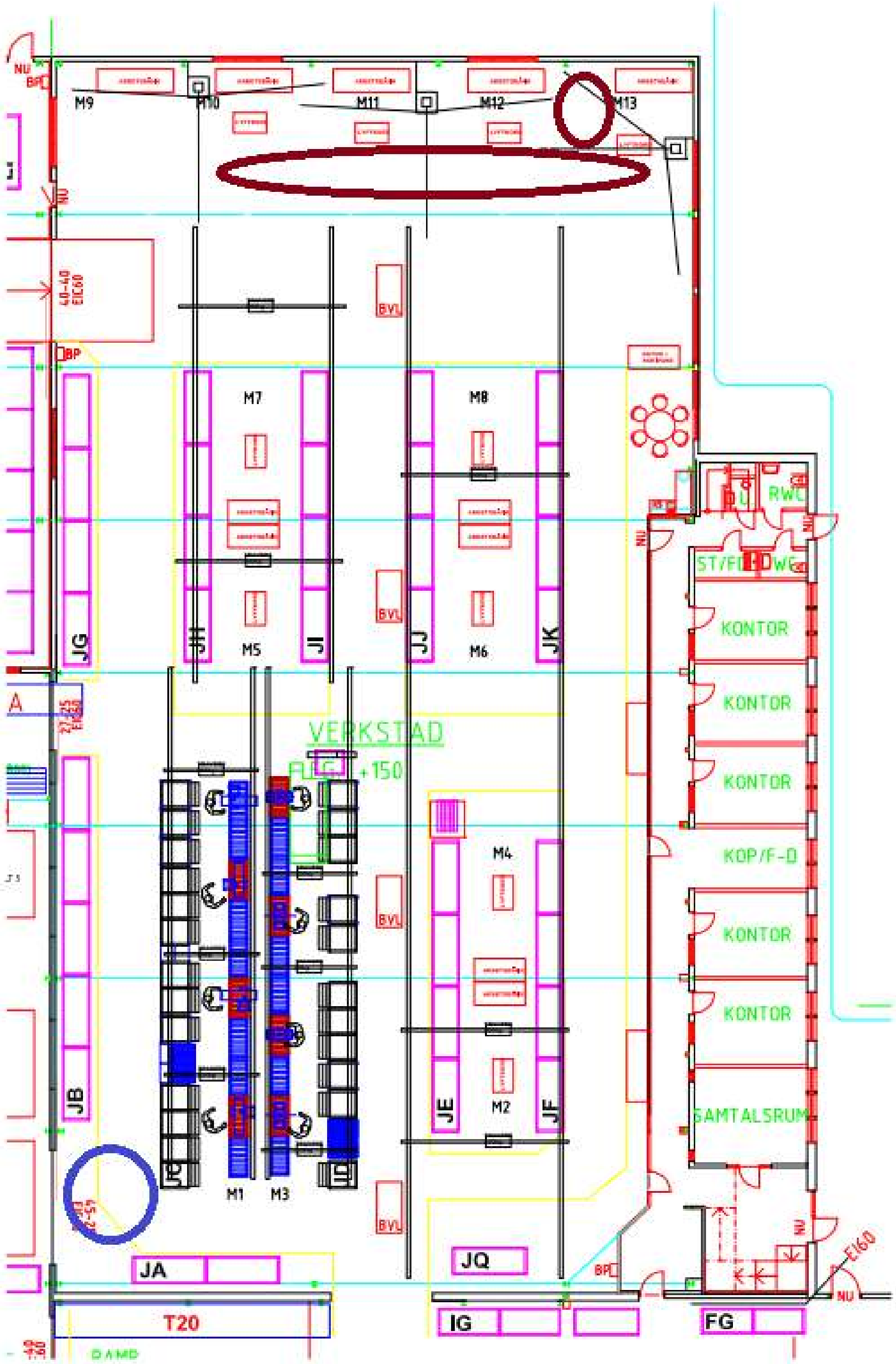


Figure 2.6 Drawing of assembly department with marked areas. [Own pictures].

2.1.3 Setting of a job

The setting of a job is today performed usually by both the assembler and the truck driver. Once an order is registered and it is set to be assembled the logistics department begins gathering the components needed. This is done at the warehouse section of the company, to reduce unnecessary movements, and manage the space within the factory; they currently have five different bureaus installed. Four of them are only available for the logistics, and one of them is available to the assembly workers. The four that are located in the warehouse section are filled with parts that the truck drivers can easily obtain through searching for the article number listed on the work card. The rest of the components are found on shelves located around the warehouse. Once all of the components have been gathered and transported into the assembly department they check themselves out from the order and list it as ready to be assembled. Now the assembly workers will see the job available in Monitor and they can start the job themselves. It is important to distinguish the job done by the logistics department and the job done by the assembly department. The reasoning behind this is to get an understanding of how much work is put into the process from both departments. This is crucial for the weekly planning of working hours that are requested from the workers to meet the demand.

For the assembly that is discussed in this project all of the components are not stored in the warehouse, but instead some of them are in the assembly department. They can then be found on shelves and in the bureaux. These components will be marked on the working card so that the assembler knows that they have to be acquired before starting.

2.1.4 Process of acquiring components

In this segment the process for the worker when acquiring the components for the assembly is explained. Ove, which is the worker that was involved, started off by going to the bureaux. The bureau is located in the bottom left of the assembly department marked with a blue circle on the drawing.

Figure 2.7 Picture of the Bureaux located in the Assembly Department. [Own Picture]

The bureaux located in the assembly department works as a storage for bolts, screws and decals etc. that are not used frequently enough to be located in shelves at the mounting stations, this due to space management. How this works is that on the assembler's working card there are components listed followed by a bureaux classification, this indicates that they have to be collected at this specific place. So Ove, who I was following, enters the item numbers listed into the computer which then tells the bureaux to provide the shelf containing the item requested. The product in question has 16 items that have to be collected from the bureaux which resulted in an additional 15 minutes of setting work for the assembler.

Figure 2.8 Picture of the items that had to be collected from the bureaux. [Own Picture].

After using the bureaux there were three additional components that had to be collected from shelves located in the assembly department. These were easily obtainable and didn’t take any extra noticeable time.

Figure 2.9 Pictures of the components in comparison to where they are located. [Own Picture].

2.1.5 Components included in the assembly

Here the full bill of material for the assembly is presented.

Article number	Head article	Article name (Swedish)
EF0210	135200	Impulsgivare
EF1604	135200	Sidolist
EF1608	135200	Renslucka
EF1620	135200	Övre Spännvinkel
EF1626	135200	Inre Glidskiva
EF1628	135200	Yttre Glidskiva
EF1630	135200	Vinkel Glidskiva
EF1632	135200	Mutterhållare M12
EF1634	135200	Mutterfixering M12
EF1636	135200	Klämlist Glidskiva
EF1638	135200	Sensorfäste
EF1652	135200	Förbindning Kassett
EF1660	135200	Spjällstyrning
EF1666	135200	Sidoskydd
EF1672	135200	Fot
EF1674	135200	Förstärkning Fot
EF2600	135200	Bottenplåt
EF2602	135200	Sida
EF2606	135200	Nedre List
EF2610	135200	Sidbindning Fot
EF2612	135200	Yttre Gavel Förhöjning
EF2614	135200	Inre Förhöjning
EF2616	135200	Inre Förhöjning För Vakt
EF2618	135200	Övre Spännbalk

EF2622	135200	Lock
EF2640	135200	Spännhjul
EF2650	135200	Gavel Kassett
EF2654	135200	Snedplan Kassett
EF2656	135200	Slitbelag Kassett
EF2658	135200	Slitbelag Botten
EF2662	135200	Liten Täckplåt Inlopp
EF2664	135200	Stor Täckplåt Inlopp
ET2490	135200	Täckplåt Remlägesvakt
BR142820	135200	Bricka Srb
BR173030	135200	Bricka BRB
DEK3060	135200	Dekal Skopor
DEK4030	135200	Dekal Romb
EF2648	135200	Axel Fot
GKF1013	135200	Kabelgenomf, m hål
GLIS106	135200	Gummilist Cello Strip
KULFY40	135200	Kullager Skf
MF12	135200	Mutter M6M-M 12
MF16	135200	Mutter M6M-M 16
MFA12	135200	Lågmutter Ml6M-M 12
MFF10	135200	Mutter M6Mf-M10 Fzb Med Fläns
MFF12	135200	Mutter M6Mf-M12 Fzb Med Fläns
MFF8	135200	Mutter M6Mf-M8 Fzb Med Fläns
MFL12	135200	Låsmuttr. Loc-King-M12
PFILT2	135200	Maskinfilt Självhäftande
PH12008	135200	Handtag Termoplast
PLM16	135200	Lyftögla M16 FZB

SFF1020	135200	6-Kantskruv M Fläns M10X20
SFF1025	135200	6-Kantskruv M Fläns M10X25
SFF1040	135200	6-kantsskruv M flän M6SF 10X40
SFF812	135200	6-Kantskruv M Fläns M8X12
SFF816	135200	6-Kantskruv M Fläns M8X16 FZB
SFF820	135200	6-Kantskruv M Fläns M8X20
SFI1240	135200	Insexskruv Mf6S M12 X 40 Fzb
SFI816	135200	Insexskruv Mf6S 10.9 M8X16 Fzb
SFI820	135200	Insexskruv MF6S 10.9 M8X20 Fzb
SFT58	135200	Gängpressande M5X8 Stål Fzb
SFT610	135200	Gängpressande M6X10 Stål Fzb
SSB1010	135200	Stoppsk. Sk6SS-M10X10 Sv
ÖGÄST12331	135200	G.Stå.M12X330 Helg Svetsad Fzb
EF2649	135200	Fixerings Hylsa SEH 50/23

2.1.6 Orientation of workspace, mounting station M13

This is a representation of how the orientation of the workspace can look after the logistics department has set the job for the assembly. The pallets located in the image consist of the components needed to make the full assembly of the Bucket Elevator Foot. Each pallet consists of several components. At this specific occasion the order was on four Bucket Elevator Foots.

Figure 2.10 Setting of the Bucket Elevator Foot at mounting station M13. [Own Picture].

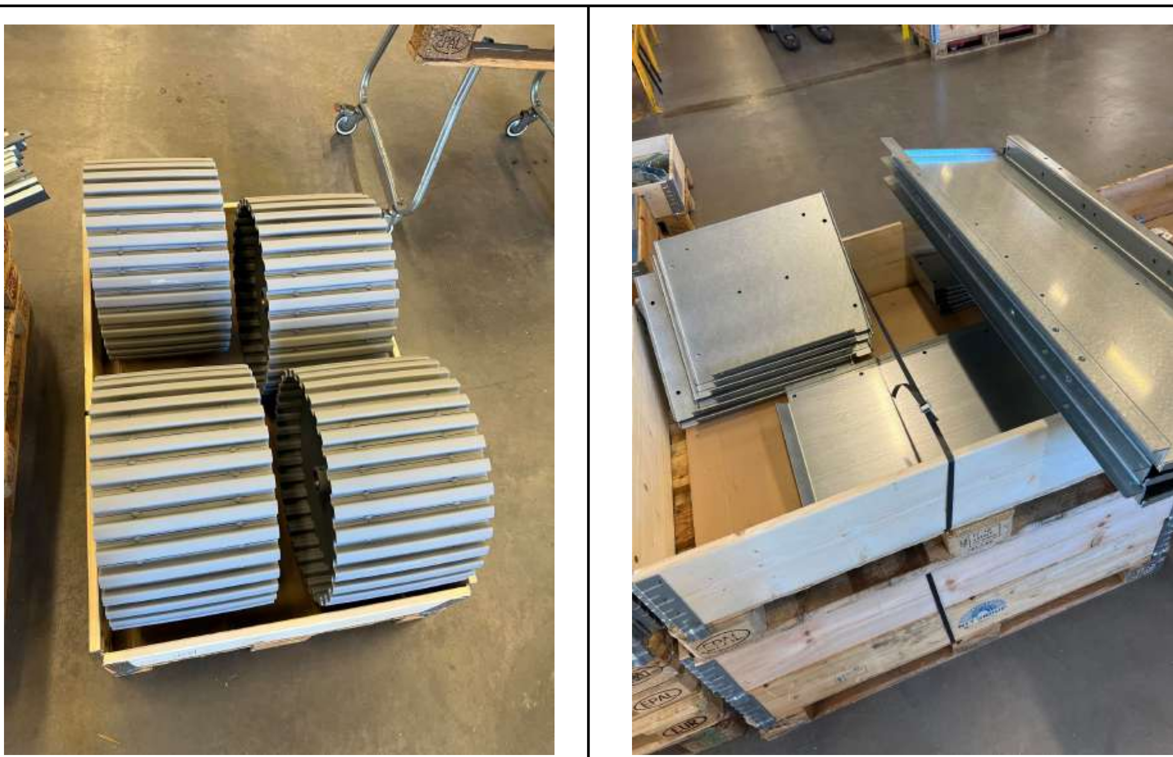


Figure 2.11 Picture of components in pallet 1 & 2. [Own picture].

Figure 2.12 Picture of components in pallet 3 & 4. [Own picture].

Figure 2.13 Picture of components in pallet 4 & 5. [Own picture].

2.1.7 Interview with assembler

After monitoring the process from logistics to the point of where the assembly starts the next step was to interview someone who is experienced with the mounting of the product. With my questions prepared, the main idea of the interview was to get a better understanding of what components were compatible to put together without interfering with the final assembly. The interview resulted in eight different kits of components called sub-assemblies. It was also confirmed that the total assembly time as of today is correct according to Monitor which states 360 minutes per Bucket Elevator Foot.

3. Literature review

This chapter presents theories of relevance revolving around the subject and definitions of the terminology used in the project.

3.1 Terminology

3.1.1 Product description

Product

A product can be described as “any item that is designed, manufactured and delivered with the intention of making a profit for the producer by enhancing the quality of life of the customer” (Torenli, 2009) . A product itself can also consist of numerous parts that when combined forms what is defined as the product. This process is often referred to as an assembly.

Assembly

The general definition of assembly is the concept of bringing parts together to form a new product. When dealing with more complex assembly constructions you can perform initial assemblies to simplify the process, often called sub-assemblies.

Sub-assembly

A sub assembly consists of bringing parts together to perform a sequential assembly that is referred to as a work piece, later on in the process it will be put together with another sub-assembly or part to form the finished assembly defined as the product.

Assembly process description

Since the process of assembly is essential in this project it is important to get a full understanding of the core elements involved. For this I decided to use the illustration made by Torenli (2009). Figure 1.1 highlights and provides an illustration of how the defined terminology is used in the process of an assembly. The process pattern in this scenario is linear and the operations follow a sequential order.

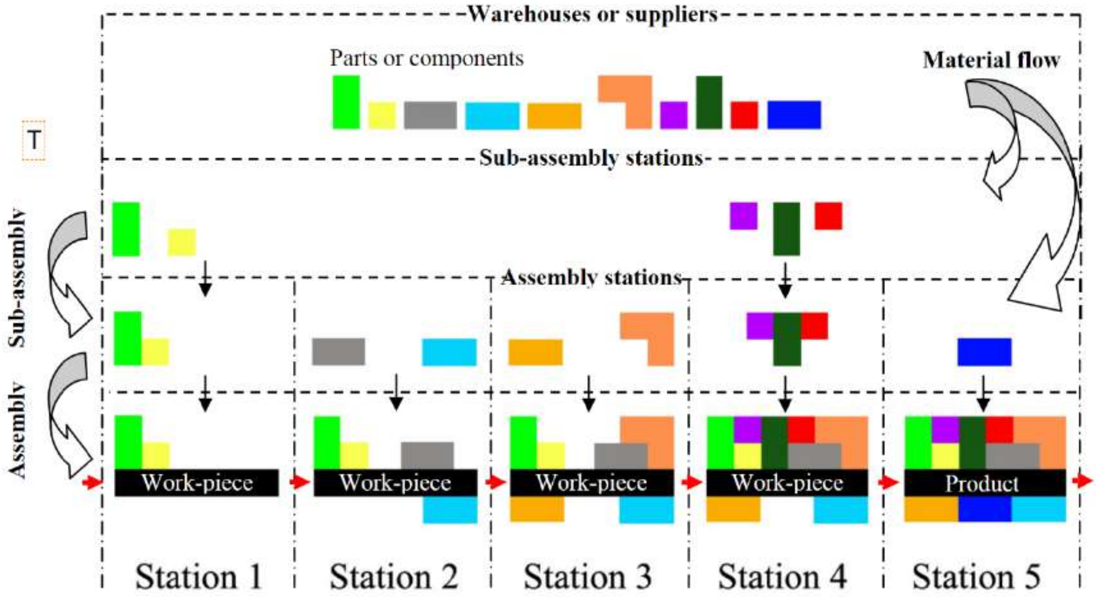


Figure 3.1 Picture of the Assembly Process. Törenli, Artun. 2009.

3.1.2 Production environment

Workstation

A workstation is a point in the assembly process where a percentage of the total work is performed. How many stations are needed and how the work is distributed among them can be of great variance depending on what is being assembled. In figure 2.1 the work stations are set up in a line, referred to as an assembly line. Every station is equipped with necessary materials and equipment to ensure that the operator can perform the work that is needed.

Product process patterns

The process of how a product is manufactured or assembled within a company is dependent on its features and the layout of the factory itself. It is therefore important to understand what characteristics are of importance when selecting one. Today there are four common manufacturing processes that are used around the world. Project process, Job shop process, Line process and Continuous process (Buzacott & Shanthikumar, 1993).

Job shop process

A job shop process is characterised by having tools, machines, and facilities with similar functions or performances located together. The separated workstations can perform different tasks of varying quantity and specification which enables the customization of personalised orders. A job shop produces a small volume of products that are not standardised.

Line process

Line process is a common manufacturing process used in connection to assembly. It is a process consisting of several stations in a sequential order connected by a conveyor belt in which parts are added at every station. By mechanically moving parts in between stations a finished product can be produced faster with reduced labour since workers can solely focus on the mounting aspect (Scholl & Becker, 2006).

3.2 Prestudy

This pre-study aims to provide a comprehensive overview of preassembly, a manufacturing process that involves assembling components or subassemblies before final assembly, in order to streamline the overall production process. The study explores the concept, benefits, challenges, and potential applications of preassembly, along with examples from different industries. By analysing the existing literature and industry practices, this pre-study aims to equip readers with a better understanding of pre assembly and its implications for improving manufacturing efficiency and product quality.

3.2.1 Objectives of preassembly

The first objective of why preassembly is applied is to streamline the production process in a company/factory. It is therefore important to understand how a preassembly can benefit the production process.

Improved efficiency

First of all it can result in improved efficiency. Preassembling in a controlled environment allows for more efficient use of time and resources. The workers can focus on the specific tasks that are provided without interruptions or problems caused by final assembly.

Enhanced quality

When preassembling components defects or issues can be found in the early stage of the process. Which results in the preventing of faulty components blocking the entire assembly process. This helps the overall streamline of the process but also provides a higher grade of quality standard.

Reduced production costs

The preassembly of components can lead to the company and production saving cost in various ways. It enables the manufacturers to optimise their workflow by their own needs which minimises production downtime and improves resource allocation. Additionally specialised providers could be of use to deliver already pre assembled components on request to reduce costs further.

Higher flexibility

It also gives room for a company to have higher flexibility. By assembling components in advance the final assembly will include less steps which results in a shorter lead time. When the workers assign themself the job they can focus on integrating these pre-assembled units into the final model rather than starting from scratch. This saves time, reduces the complexity, and improves overall assembly productivity.

Scalability

Preassembling can provide a better scalability for a production within a company. As the demand increases or decreases the manufacturer can decide on at what pace the product will be produced at. By having a preassembly that takes up less space more workstations will be available which results in the ability to ramp up the production upon request.

3.2.2 Different pre assembly techniques

There are different types of preassembly that occur in industries, in this chapter the ones of interest in this project will be described further.

Sequential preassembly

Sequential preassembly refers to a process where components or parts are being assembled in a predetermined sequence before being put together into the final product. It involves splitting the process into smaller, more manageable steps that are more effective and efficient.

Parallel assembly

Parallel assembly also called simultaneous assembly is a process approach that involves multiple assemblies occurring at the same time. Instead of doing them in a predetermined sequence one after another, it enables the concurrent assembly of different parts or modules. This means that the work can be divided into separate workspaces or cells which can operate independently. The partial assemblies are then brought together at a later stage in the process for final integration and completion.

3.2.3 Challenges with preassembly

While preassembly brings many benefits to a production process it also comes with its challenges, in this chapter some of them that are associated with the implementation are explained.

Synchronisation and coordination

The preassembly of components involves multiple workstations and workers operating together. Therefore it can be challenging both coordination and synchronising these different processes. Ensuring that the pre assemblies are done correctly, and completed in a timely manner requires effective planning beforehand. It is also of importance to have great communication and coordination amongst the workers and people involved in the entire process.

Logistics and factory spacing

The logistics and factory spacing are crucial factors that have to be considered when applying sub assemblies to a manufacturing or production environment. To ensure that implementation actually benefits the process proper planning of the logistics and storage of impacted components play an essential role in the optimization. Determining the best methods for material handling and setting up a strategy that aims to reduce waste and minimise inventory levels in advance is required.

3.2.4 Previous cases on preassembly

Re-engineering through pre-assembly, client expectations and drivers

Alistair G. F.Gibb and Frank Isack did a research on how re-engineering through pre-assembly can benefit a manufacturing environment and what the drivers and expectations of such a process are (Alistair G. & Frank Isack, 2003). Their report is based of mainly work connected to construction but there are parallels that can be drawn to a production environment and therefore some of its research can be of importance to this project. In their data collecting through interviews with clients they could categorise what was seen as the key benefits of introducing pre assemblies, this was presented in the form of a diagram.

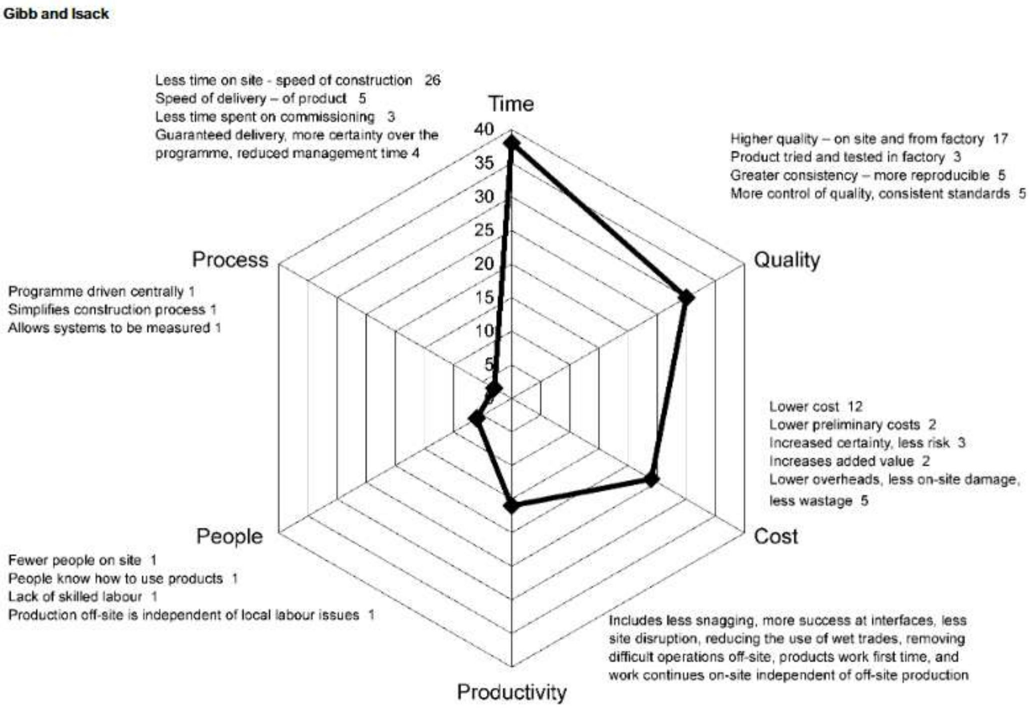


Figure 3.2 Clients' views on the benefits of pre-assembly. Gibb, Alistar. Franck, Isak. 2010.

From this diagram it is clear that time, quality and cost are the fundamental benefits when it comes to implementing sub assemblies. The cost in this case can be compared to reducing blockage in a production environment which leads to a more streamlined process that in order generates greater workflow for the company. They also mention the importance of success in the measurements as one of the main strands in re-engineering. In their study they cited some of the specific benefits due to pre assembly in different environments. Those of relevance are listed below.

- Cost of preliminaries was reduced by having a shorter construction time, a total saving of £420,000

- Shop fit-out cost and construction time reduced by 10%

- Two expansions projects could not have been achieved without the use of preassembly

- Failure rate on welds reduced from 5-10% for on-site to less than 1% with off-site preassembly

In their research they also included a chapter addressing what disadvantages clients see of implementing sub assemblies. The most common reply was the impact of overall quality, the products could often be poorly built because of contractors not being experienced enough or having the right education. They also write about people stating that the volume of products has to be justified to look at pre assemblies, but this is contradictory since they also explain complexity as a foundation to considering pre assemblies. All in all their research gives a good understanding of balancing the benefits and disadvantages with this process.

Mechanisms and rationales for the coordination of a modular assembly system, The case of Volvo Cars

Peter Fredriksson has made a study on the mechanisms and rationales that the coordination of a modular assembly system includes, and how this is applied in the case of volvo cars. His research on pre assemblies in production has shown that many benefits may arise from the dispersion of activities into a number of pre-determined assemblies. These benefits are mainly in the form of efficiency and flexibility gains. In the case of Volvo cars he refers to pre assembly activities as a module assembly unit (MAU), and the unit undertaking final assembly as final assembly unit (FAU). Each MAU is responsible for a preassembly process which results in a product module, the FAU is responsible for the final assembly process of the cars. He explains further that to cope with Volvo's short order-to-delivery-time all MAU's are located in close proximity to Volvo's final assembly line. This resulted in a good workflow as long as their production plan remains unchanged. However since volvo is a car brand with different models consisting of numerous specifications it is often hard or impossible to predict the production plan on a detailed level leading to disturbances. Therefore determining and deciding on pre-assemblies is a big challenge for them.

His research implies that the complexity of implementing pre-assemblies varies depending on the company's production and its amount of variations. In the case of Volvo cars the process will be far more complex than in the case regarding Skandia Elevator. This means that disadvantages that occur for Volvo does not necessarily have to occur for Skandia Elevator.

4. Methodology

To meet the objective of this project it is important to approach the problem with a procedure that can ensure all important aspects have been taken into account. The first thing will be to get a clear understanding of the product in question by looking at the already existing drawings and its bill of material list. Secondly, looking at the gathered data from previous assemblies will be necessary to understand the timeframe and complexity of the project. The next step is then to be present during an assembly with an experienced worker and document the different stages of the process. This is crucial for the holistic view and to gain insight into where the main problems of the process occur, and what possibilities there are. The gathered information and the data that was already available on hand will then be used in dialogues with experienced assemblers and workers within the company for a wider range of knowledge.

4.1 DMAIC

DMAIC is a methodology widely used in problem solving that has relation to process improvement initiatives. It is short for Define, Measure, Analyze, Improve and Control. It represents the five key phases of a DMAIC process. A DMAIC provides a structured framework for identifying and addressing issues within a manufacturing or production environment (Lynch et al., 2003). By implementing it process variability can be reduced and measurable improvements in quality and performance can be achieved.

4.1.1 Defining the problem

In this stage the information that has been collected so far will be used to properly define the problem. What is it that lays the foundation for it to look the way it does today?
In this segment it is also important to further define the boundaries of the project, the extent of how much work will be done will be limited to available resources and time.

4.1.2 Information gathering

This section of the chapter introduces and describes the different types of information gathering that will be used in detail.

Bill of material (BOM)

The BOM list of the product acts as an information foundation for this project. It is a comprehensive list that contains all the raw materials, assemblies, subassemblies, parts and components that are included when putting together the assembly of the product.

Drawings of the product

Drawings of the product will be looked at in the initial stage of the project to get an illustration of how the product looks both during the assembly stage but also when assembled and finished. In the drawings the general dimensions can be found but also important notes to the assembler.

Previous data of assemblies

Data from previous assemblies can be found in Monitor, which is the modern ERP system that Skandia Elevator uses. Monitor can provide information and charts over past years production and sales to get a better understanding of the future and forecast. It also stores the workers time registered on each order to where a time based approximation can be made. This will be of use in this project due to working with reducing the lead time being in the focus.

Entire assembly process of the product

Taking part in the assembly process is crucial for the full understanding of the problem and to get a view of the current state. In this part of the information gathering there will be communication with both assemblers and forklift drivers who are involved with the logistics. The process will be documented through timing different segments, writing down important information and taking photos of important sections.

4.1.3 Analyze the gathered information

This phase of the process involves in-depth analysis of the data that has been collected to identify the root causes and understand the contributing factors. Various tools and techniques will be used such as statistical analysis and process mapping to illustrate the problem. The goal is to gain insight into the underlying issues and to establish a clear understanding of the cause-and-effect relationship.

4.1.4 Improvement phase

In the improvement phase potential solutions and strategies are developed to address and solve the root causes that were identified during the analysis phase. The ideas/possibilities are evaluated and selected based on their feasibility, impact on performance, and alignment with this project's goals. Detailed plans on how the implementation can work could also be included.

4.1.5 Control phase

The control phase is about ensuring that the improvements made from previous stages can be sustained over time. It involves establishing control measures and processes that can monitor and track the performance on applied improvements.

4.2 Evaluation

In the background chapter eight different sub assemblies were formed through interviewing an experienced assembler. With the use of different evaluation measures these sub assemblies will be analysed to find out whether they are compatible to be used as a pre assembly in the future. The measures chosen for this project are based on the properties that were found important for the company.

Time

The main reason why this project was created in the first place was due to the problems of said products' lead time, an order registration is followed by a long complex assembly and therefore an important goal is to shorten the time that this process takes. Evaluating the time every preassembly can save for the final assembly is crucial for that reason.

Size/Storage

Evaluating the size of every prea-ssembly is also of importance from a logistics point of view. After putting them together they need somewhere to be stored, and for that reason it has to be efficient enough to make it valuable. In this project this aspect was evaluated as bad, ok or good.

5. Results

In this chapter the results gathered from applying the methods in the previous chapter are presented.

5.2 Data gathered from Monitor

Here data from Monitor SE Skandia Elevators ERS system is provided regarding the production of article 135200.

Year and month	Produced amount
202304	3
202303	3
202302	0
202301	3
202212	5
202211	1
202210	5
202209	1
202208	4
202207	0
202206	6
202205	3
202204	6
202203	6
202202	5
202201	2
202112	1

5.3 Data gathered when watching the assembly

When watching the assembly a timer was used to time the different segments that were found important during the process. Data was also collected to illustrate in what order components of interest were put together. This was used to form multiple tables as a description. Down below all of the eight tables are listed with an attached text outlining their ability to be stored.

Assembly 1

Sub-assembly number one consisted of five different components and took a total of three minutes and 30 seconds to perform.

Time (min)	Components (article number followed by amount)
03:30	EF1672 (2pcs), EF1674 (4pcs), SFF1025 (8pcs), SFF1020 (8pcs), MFF10 (6pcs)
	The ability to store sub-assembly one was evaluated as good.

Figure 5.1 Picture of Assembly 1. [Own Picture].

Assembly 2

Sub-assembly number two consisted of 10 different components and took a total time of nine minutes to perform.

Time (min)	Components (article number followed by amount)
09:00	EF2650 (2pcs), PH12008 (2pcs), DEK3060 (2pcs), EF2654 (2pcs), EF1652 (4pcs), EF2656 (2pcs), SFI816 (20pcs), SFF816 (4pcs), SFF812 (4pcs), MFF812 (12 pcs)

	The availability to store sub assembly number two was evaluated as ok.

Figure 5.2 Picture of Assembly 2. [Own Picture].

Assembly 3

Sub-assembly number three consisted of three different components and took a total of one minute and 20 seconds to perform.

Time (min)	Components (article number followed by amount)
01:20	EF2600 (1pcs), EF2658 (1pcs), SFI816 (6pcs)

Time (min)	Components (article number followed by amount)
	The availability to store sub assembly number two was evaluated as good.

Figure 5.3 Picture of Assembly 3. [Own Picture].

Assembly 4

Sub-assembly number four consisted of three different components and took a total of one minute and twenty seconds to perform.

Time (min)	Components (article number followed by amount)

01:20	EF1608 (2pcs), DEK3060 (2pcs), GLIS106 (530mm)
	The availability to store sub assembly number four was evaluated as good.

Figure 5.4 Picture of Assembly 4. [Own Picture].

Assembly 5

Sub-assembly number five consisted of four different components and took a total time of 4 minutes and thirty seconds to perform.

Time (min)	Components (article number followed by amount)
04:30	EF2640 (1pcs), EF2649 (2pcs), EF2648 (1pcs), SSB1010 (4pcs)
Picture missing	The availability to store sub assembly number five was evaluated as ok.

Assembly 6

Sub-assembly number six consisted of two different components and took a total time of four minutes and 30 seconds to perform.

Time (min)	Components (article number followed by amount)
04:30	EF2622 (2pcs), GLIS 106
	The availability to store sub assembly number six was evaluated as good.

Figure 5.5 Picture of Assembly 6. [Own Picture].

Assembly 7

Sub-assembly number seven consisted of 14 components and took a total of 30 minutes to perform.

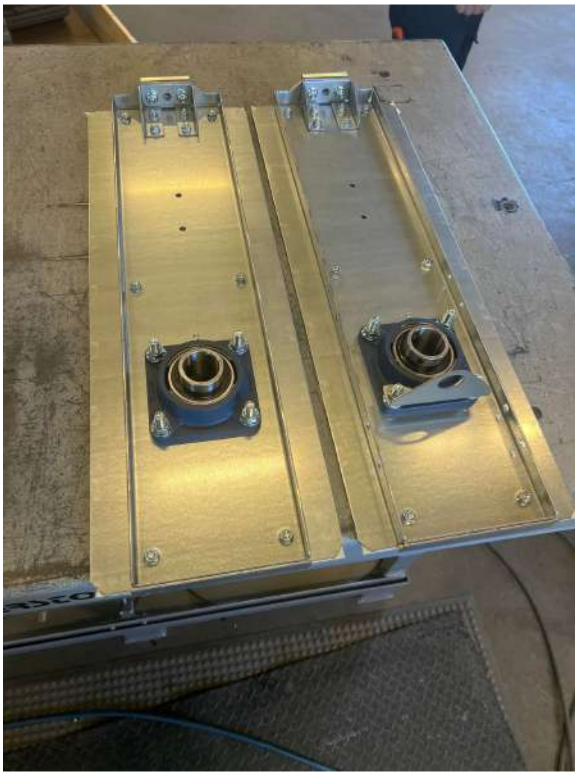
Time (min)	Components (article number followed by amount)
30:00	EF1628 (2pcs), EF1626 (2pcs), EF1630 (2pcs), EF1632 (2pcs), EF1634 (10pcs), KULFY40 (2pcs), SFI1240 (8pcs), SFI816 (12pcs), SFI820 (8pcs), SFF1040 (4pcs), SFF820 (4pcs), MFF12 (8pcs), MFF10 (4pcs), MFF8 (12pcs)
	The availability to store sub assembly number seven was evaluated as ok.

Figure 5.6 Picture of Assembly 7. [Own Picture].

Assembly 8

Sub-assembly number eight consisted of four different components and took a total of two minutes and 10 seconds to perform.

Time (min)	Components (article number followed by amount)
02:10	EF2618 (1pcs), PLM16 (2pcs), MF16 (2pcs), BR173030 (2pcs)
Picture missing	The availability to store sub assembly number eight was evaluated as ok.

Those eight sets of assemblies were the ones of interest to note down since they have the possibility to be mounted together without impacting the capability of assembling throughout the whole process. Following is an entire table of all 8 sub-assemblies.

Sub-assembly	Time (minutes)	Components (number)	Storage possibilities
1	03:30	5	Good
2	09:00	10	OK
3	01:20	3	Good
4	01:20	3	Good
5	04:30	4	OK
6	04:30	2	Good
7	30:00	14	OK
8	02:10	4	OK

Figure 5.7 Table of the sub-assemblies. [Own Picture].

The remaining part of the process was decided as not suitable for preassembly because of its inappropriate size and accessibility. Pre-assembling these parts would take away the benefits of reducing the lead time with excessive storage usage. The process was still documented and photos were taken.

Figure 5.8 Initial stages of further assembly. [Own Picture].

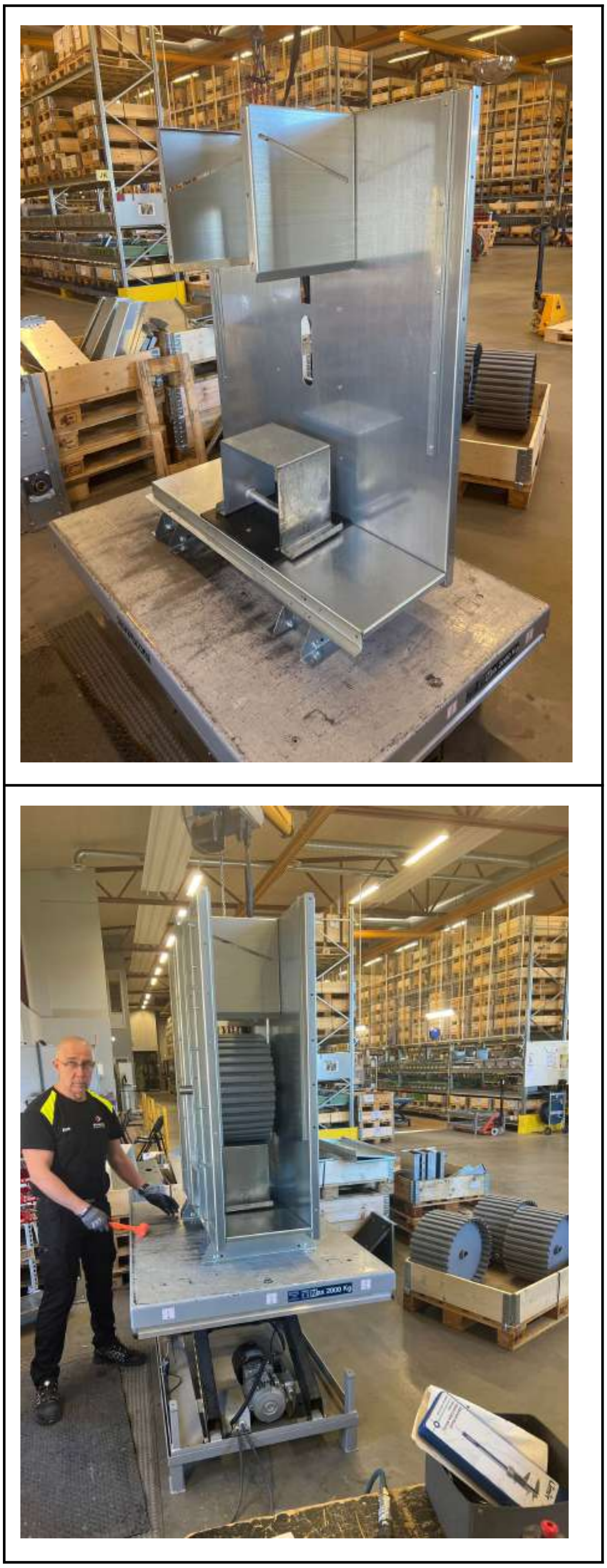


Figure 5.9 Final stages of further assembly. [Own Picture].

Figure 5.10 Final Assembly. [Own Picture].

6. Discussion

In this chapter the aim is to explore the findings. It will present a discussion regarding how the applied theory and methods affected the result and whether it fulfilled its purpose. It will also give suggestions on improvements that Skandia Elevator could consider when it comes to implementing sub assemblies into the process.

6.1 Choice of method

When approaching this project at Skandia Elevator it was clear that there were two fundamental problems that were occurring at the assembly of the Bucket Elevator Foot. Number one was the amount of space required to provide the assembler with all of the components necessary. This could already be seen when I visited the company and took the photo that can be seen in the chapter above, however their head of assembly pointed out that this is even more crucial in the summer when the company has its peak season. The lack of space at the mounting stations presents the company with significant challenges that can hinder efficient operations within their assembly department. This impacts their overall productivity, safety and workflow. The second problem was the lead time of the bucket elevator foot, with its long list of included components comes a long complex process of assembly. This is not only problematic for the worker who is assigned with the task to put the product together, but for the entire production. A long lead time can result in customer dissatisfaction, increased inventory holding costs and forecast and planning challenges. The latter which was also mentioned when speaking to their head of assembly, especially during summer.

With this information it was obvious that the process of assembling the Bucket Elevator Foot had to be simplified. The methodology DMAIC, chosen for this project, has proven to be very useful. The early stages of defining the problem was also amongst the most important parts of this project, setting boundaries and deciding on what to investigate was really important to come to a conclusion. During the measuring part Skandia Elevator was of great help and very collaborative, not only through all the information in Monitor SE but also the possibilities of recording and being in the factory at any time. The helpfulness of the workers and my supervisor at Skandia made the analysing section of the DMAIC very practical, I was provided with coworkers, a computer and necessary tools to go through and evaluate the material that I had gathered.

6.2 Solution proposal consisting of pre-assemblies

My hope and expectations going into this project was to provide a solution that enables the possibility to shorten the final assembly of the bucket elevator foot. These expectations were consistent with Skandia Elevator through the entire process of working with this project. When doing a literature review and performing interviews with workers at the company it was discovered that the possibilities of solving this problem would be through implementing pre-assemblies in the form of sub-assemblies.

6.3 Deciding on pre-assemblies

After interviewing workers and monitoring the process there was a clear difference when applying the evaluation measures. Firstly the main part of the assembly was decided on as not suitable for preassembly, however eight different sub-assemblies were found.

When deciding on what ones should be applied in theory it is quite easy, you look at the results and ur evaluations and pick the ones that provide the best numbers. But in reality there are more factors that can have an impact and therefore every sub assembly has to be reviewed one by one.

Sub-assembly number one had a mounting time of three minutes and 30 seconds effective working time, however this does not cover the time it took the logistics apartment to acquire these components and the space it blocked in the factory. One could argue that it is negligible but when this approach is taken for all the eight sub assemblies it reveals that it is of importance. Sub-assembly one does reduce the active working time by three minutes and 30 seconds but also reduces the space required for setting the job if done in advance.

Sub-assembly number two had a more remarkable mounting time of nine minutes effective working time. Also this number does not cover the time that logistics spent on acquiring and setting the job, or the impact of the space the pallet containing the components blocked. The storage opportunities of sub-assembly number two was also considered OK. Analysed solely from the evaluation properties this assembly is more attractive to the company to implement as a pre-assembly.

Sub assembly number three and four both had a short assembly time of only one minute and 20 seconds each. Comparing this to previous sub-assemblies it implies that these two would be the least effective ones seen from a time evaluated perspective. However then again you could argue that the work done by logistics and the space they require at the mounting location could mean that implementing pre-assembly of these two would benefit the company. But it wouldn’t reduce the final assembly time by a lot which was the main reason to this project.

Sub assembly number five had a mounting time of 4 minutes and 30 seconds of active working time. The storage opportunities for this pre-assembly would also be considered OK. Evaluated by selected measures implies that this would be a possible pre-assembly that would reduce the final assembly by 4 minutes and 30 seconds but also reduce the setting space and time spent by the logistics department.

Sub assembly number six had the same mounting time as number five, which was 4 minutes and 30 seconds. However this assembly only contained two components which means that is easier for the worker to handle.

Sub assembly number seven was the one that stood out the most. It had a total assembly time of 30 minutes active work and included 14 different components. This makes it the most interesting one out of the eight that was tested. As can be seen on the image the storing of this particular pre-assembly would also be seen as OK. Sub-assembly number seven would therefore be an obvious choice to implement as a pre-assembly for the bucket elevator foot.

Sub assembly number eight was also similar to number three and four. A fairly short effective assembly working time of two minutes and 10 seconds and the possibilities of storage could be reviewed as ok.

To summarise the eight different pre-assembly opportunities all of them have characteristics and properties that were of interest to this project and its end goal. However from this discussion it is clear that number two and seven stands out in comparison to the others. Therefore the suggestion would be to implement the pre-assembly of these two sub-assemblies. If the company would look to reduce the final assembly time further, sub-assembly number one, five and six would together benefit to a reduced active working time of 12 minutes and 30 seconds. All of them will also affect logistics setting time and reduced blockage of work space. Which means that in the end it is a question of how much Skandia Elevator values these aspects. The proposal based on these conclusions would be to test out the implementation of the five different sub-assemblies mentioned.

6.4 Implementing the pre-assemblies

This short chapter presents the possibilities of where and how the implementation of these pre-assemblies would work in Skandia Elevators production.

6.4.1 External providers

Skandia Elevator is a company that is working with several providers for their components and material. They also have their own section that is working closely with their assembly department to provide them with specified and custom components. In this case through a review and discussion it turned out that external providers for the pre-assemblies were of no interest because of the many downsides. It would require Skandia Elevator to transport their own material to an external provider that today doesn't exist, which is not sustainable now or or in the future. Therefore this was dismissed and would not be looked into any further.

6.4.2 Inhouse pre-assembly

Since the pre-assemblies are far less complex then the final assembly it would mean that any assembler with the right instructions would be able to perform it. As mentioned previously in this report the final assembly requires a lot of setting space and therefore the working stations were limited, however the pre-assemblies require nowhere near as much setting space and therefore all working stations are available. To produce further opportunities for these pre-assemblies they could be ordered at any time of the year when the company has spare time or in its off-season.

Through discussions two possible strategies were brought up, to either implement the pre-assemblies through own article numbers or the second option called operations. Those are two very similar strategies but the first one requires a lot more work in terms of recreating the structure in monitor and CAD. The second option instead is a form of creating working instructions in already existing article numbers such as the Bucket Elevator Foot in this case.

Skandia Elevator made it clear through discussions with their product development department that they do not want to recreate all of the structure if not necessary. Therefore the conclusion will be to test out the implementation through operations.

7. Conclusion

In this chapter the conclusions that were made are presented.

7.1 Answering the question at issue

Answering the research questions that were brought up during the project.

The primary objective was to find a solution that reduces the lead time of the product at final assembly and to streamline the process, what solution was found?

In the initial stages of this project it became clear that introducing pre-assemblies in form of sub-assemblies was the way to go. After interviews and discussion eight different possibilities were provided. They were then reviewed upon their characteristics as in capacity, complexity, and storage availability. These measurements were provided in form of articles involved, time taken for assembly and lastly how easily they could be stored in a pallet without taking up too much space.

What pre-assemblies should be implemented?

After reviewing the measurements that were provided from the eight different sub assemblies there are two that stand out. Sub-assembly number two and seven, number two consisted of 10 components, with an assembly time of 9 minutes and a storage availability that was classified as OK. Sub-assembly number consisted of 14 components and had an assembly time of 30 minutes, the storage availability was also classified as OK upon review. Those two were the most obvious ones to implement and would result in a combined reduced final lead time of 39 minutes.

There were also three other possible assemblies that could be looked into further and explored under more aspects. These were sub-assembly number one, five and six. The storage availability was good and together they could reduce the final assembly time of 12 minutes and 30 seconds which is a good amount of time. However due to the restrictions in this project in form of time and resources this conclusion is only based on the data collected in this project. There are more aspects that could be taken into account that were not discussed in this project.

How should these sub-assemblies be implemented?

After looking at both external providers and inhouse-assembly a conclusion was made, in Skandia Elevators case you can see from their logged deliveries of article 135200 that it varies from month to month. This means that the demand is not stationary and therefore the forecast of producing these pre-assemblies would have to be on point for an external provider to meet those requirements. There is also no possible external provider as of today that can do these pre-assemblies and therefore the only option I see is to perform them inhouse. This conclusion is also based on the amount of mounting stations available once the size of the assembly is reduced which opens up a lot of opportunities. So the best way of doing these pre-assemblies would be in house, through creating an operation for every pre-assembly involving all of the components. This way Skandia Elevator can register an order with the pre-assembly included when they want to produce and set it up for production in advance of the final assembly.

7.2 Continuous work

This project has discovered the possibilities of introducing pre-assemblies to article 135200 and provided a conclusion to the implementation of them. If Skandia Elevator is looking to streamline the final assembly process further they could investigate the eight sub-assemblies provided with more aspects. In this report the spacing required around the mounting stations and the logistics perspective is discussed shallowly. But as can be seen it is quite a big problem for the company and something that does make the process of assembly problematic. Especially during its peak season. Through discussions after the study was conducted it was clear that Skandia Elevator was happy with the results and would want me to work further with this. The continued work and its extent is therefore up to be decided on based on the results that will be collected through testing the concept out.

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