An Analysis of the Kitting Process at Electrolux Mariestad

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Abstract

In order to meet goals set by the Electrolux Group, the factory in Mariestad has been changed significantly with the introduction of two new assembly lines. Kitting has been implemented along with a new material replenishment system. Several new products have also been introduced and these three elements have caused a rather chaotic situation at Mariestad in the beginning of 2011.

The main purpose of this thesis is to analyze the effectiveness in the kitting process for the assembly line and give suggestions for improvement. The goal is then to reach a conclusion that improves the effectiveness of the kitting and therefore the efficiency of the whole assembly operation.

In order to reach this goal, specific data was gathered and analyzed with regard to kitting efficiency and complexity. A special program was built and installed on the kitting stations which collected important data about the kitting. The data was then analyzed in Excel and used in a simulation of the kitting area. An extensive complexity analysis was also done, from an article and product point of view.

The results show that there is a strong correlation between the efficiency of the kitting and the size of the articles to be kitted. Bigger articles take longer time since they more boxes to reach the desired batch size of the kit. An interesting connection is found between kitting time and batch size, where the kitting time per article would decrease with an increased batch size, but only up to a certain point where it would start to increase again. The results from the complexity analysis give an insight into how article and product complexity affect kitting.

The results show that there is room for improvement. The suggestion for Electrolux is to get articles which take the longest time to kit, pre-kitted from suppliers. A complexity analysis from the production side is also recommended as it would benefit the whole production process.
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<th>Description</th>
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<tbody>
<tr>
<td>AB</td>
<td>Aktiebolag</td>
</tr>
<tr>
<td>AMW</td>
<td>Automatic Warehouse</td>
</tr>
<tr>
<td>ANC</td>
<td>Article Number Code</td>
</tr>
<tr>
<td>EMS</td>
<td>Electrolux Manufacturing System</td>
</tr>
<tr>
<td>GUI</td>
<td>Graphical User Interface</td>
</tr>
<tr>
<td>IT</td>
<td>Information Technology</td>
</tr>
<tr>
<td>KPI</td>
<td>Key Performance Indicator</td>
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<tr>
<td>LCD</td>
<td>Liquid Crystal Display</td>
</tr>
<tr>
<td>NRFT</td>
<td>Not Right the First Time</td>
</tr>
<tr>
<td>PDCA</td>
<td>Plan - Do - Check - Act</td>
</tr>
<tr>
<td>PNC</td>
<td>Product Number Code</td>
</tr>
<tr>
<td>TMU</td>
<td>Time Measurement Unit</td>
</tr>
<tr>
<td>WIP</td>
<td>Work In Progress</td>
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Introduction

1.1 Background

1.1.1 Electrolux

Electrolux was formed in 1919 when Elektromekaniska AB merged with Swedish AB Lux in order to give Elektromekaniska the sole sales rights to AB Lux vacuum cleaners. Focusing on vacuum cleaners at first, Electrolux quickly expanded and in 1925 it added refrigerators to its product line. These refrigerators were the first ones to be able to operate without a pump, a new operational design by two students at the Royal Institute of Technology (KTH). The company did not stop there and in the next decades it introduced washing machines, dishwashers, food service equipment and other appliances. Electrolux also expanded quickly through several mergers and acquisitions, especially after the 1960s. As a result, Electrolux has several brands under its belt including, AEG, Elektro Helios, Husqvarna and Zanussi, to name a few. In its 90 year history, Electrolux has gone from being a sales company, focusing on home sales, to being one of the top 5 companies in consumer durable goods, according to Forbes [Electrolux, 2011].

1.1.1.1 Electrolux Mariestad

In today’s global market, competition is constantly increasing and the focus on profitability and lowering cost has led to an increase in outsourcing and the movement of factories to low-cost countries. Electrolux is no stranger to this development and has in recent years seen increased competition in the home appliance market. This has made Electrolux realize that in order to maintain its position as the world leader in its industry, it has to constantly evaluate its situation and make changes if needed. This
has then led to a significant restructuring in the last 5-10 years and the movement of production facilities in Western Europe (Germany, Italy, Sweden etc.) to more low-cost parts of the world (Eastern Europe, South America etc.) [Chopra, 2009].

The Electrolux factory in Mariestad is the last one in Sweden to produce refrigerators and freezers, mainly for the Nordic market. It also produces combi-style refrigerators/freezers and mobile cell refrigerators for industrial purposes. Due to demands from the Electrolux Group, the factory has undergone significant changes in the year 2010 and 2011. The purpose of these changes was to meet several goals and standards set by the Electrolux Group. These goals are, to name a few:

- Reduce facility space by 40%
- Reduce WIP by 50%
- Increase productivity by 15%
- Reduce indirect manning by 20%

To meet these goals the layout of the factory has been changed significantly. Two new assembly lines have been set up, with one focusing on refrigerators and the other one on freezers. The old assembly lines were phased out in the first half of 2011. By doing this, Electrolux Mariestad freed up much of space which it plans to rent out to local suppliers in the future, thus improving the effectiveness of material replenishments. These are long term plans though and a big part of this space will serve as a warehouse for Electrolux and Electrolux Logistics. In addition to the new assembly lines, Electrolux Mariestad has introduced a new material replenishment system where a train does milk runs at regular intervals instead of a lineside stocking. Several new products have also been introduced and these three elements have caused a rather chaotic situation at Mariestad in the beginning of 2011. The factory layout can be seen in Figure 1.1.
Figure 1.1: The figure shows the factory layout. The new assembly lines are located a little left of the centre. The old assembly lines were located were it says "Free space".
1.1.2 Complex Project

The Complex project is known as Complex Support for Operation and Man-hour Planning in Complex Production. It is a research project funded from Vinnova’s called “Sustainable Production Strategies” within the programme “Production Strategies and Models for Product Realization”. Future production will be located in plants that flexibly and efficiently can produce new products, complying with environmental requirements. New sustainable production and products, e.g. new hybrid engines, will affect the whole production flow by increasing complexity and dramatically increase the number of components and variants. This project will develop generic models and methods to support strategies, planning, managing, and optimizing of complex production. The added complexity is studied and a definition of complexity is developed, along with methods to manage complexity, competence, and information requirements. Results will contribute to modeling and IT-support tools for calculation of the total requirement of indirect and direct man-hours in production. The principal investigators and project leader is Swerea IVF (management) and Chalmers, in collaboration with Volvo Cars, Electrolux, Stoneridge Electronics and Volvo Technology. The project is carried out from January 1st 2010 to 30th of June 2013 with a total budget of 12 MSEK, where 6 MSEK is funded from Vinnova. [Gullander, 2011]
1.2 Purpose

The main purpose of this thesis is to analyze the effectiveness in the kitting process for the assembly line and give suggestions for improvement.

1.3 Goals

The goal of this thesis is to reach a conclusion that improves the effectiveness of the kitting and therefore the efficiency of the whole assembly operation. In addition, the subject of complexity within manufacturing systems and how it concerns kitting and vice versa, will be discussed.

Tasks:

- Identify efficiency Key Performance Indicators (KPIs) of the kitting process.
- Identify flaws in the kitting process.
- Develop suggestions for improvement based on the KPIs and flaws of the kitting process.
Frame of Reference

2.1 Material Handling

Material handling is an important aspect in any production. Although it does not add directly to the value of the products being produced it constitutes a great share of the cost of production. Material handling is defined by [Kumar, 2008] as follows:

Material handling is the function of moving the right material to the right place, at the right time, in the right amount, in sequence, and in the right position or condition to minimize production costs.

According to the American Society of Mechanical Engineers (ASME), material handling can be considered to have five different dimensions which classify the matters which fall under material handling. The five dimensions are movement, quantity, time, space and control.

2.1.1 Material Feeding Systems

The assembly systems are moving towards a higher degree of parallelisation at the same time as many product lines require more and more part numbers due to growing diversity of variants. Each of these factors result in difficulties with feeding materials in the traditional way, i.e. that one unit load of each part number is placed at the corresponding assembly station. Therefore, other principles of material supply systems have been developed [Johansson, 1991].

Material supply systems can be categorised in many ways. [Johansson, 1991] distinguishes between systems in regard to the selection of part numbers exposed to the assembly stations and the way in which these part numbers are sorted at the station. The categorisation can be seen in Figure 2.1.
Figure 2.1: The figure shows categorisation of different material supply systems.

[Johansson, 1991] goes on to say that supply systems can be divided into two types of systems. First, systems where all part numbers allowed according to existing product specifications and work division are exposed at the assembly stations and second, systems where a selection of part numbers is exposed at a time. This is a selection related to the production schedule and means that only the part numbers necessary for a fixed part of the schedule are exposed.

The supply systems can be categorised into those where components with the same part number are held together and those where parts intended for one assembly object are held together.

This division gives three principles:

1. Continuous supply
2. Batch supply

These three systems can all exist simultaneously in one system.

2.1.1.1 Continuous Supply

Continuous supply refers to the case where material is distributed to the assembly stations in units suitable for handling and where these units are replaced when they are empty. With continuous supply the operator often gets the material needed in supplier packaging, but if they are too big they might need to be repacked. When continuous supply is solely used at the
assembly all part numbers needed for producing every occurring product over a long period are available at the assembly station [Johansson, 1991].

Problems when using this material supply system are related to an increase in the number of feeding points and cycle time. An increased cycle time usually means that more part numbers need to be exposed at each assembly station which implies a need for more space. [Johansson, 1991]

2.1.1.2 Batch Supply

In batch supply systems the material is supplied for a number of specific assembly objects. The batch of materials can be a batch of the necessary part numbers, or a batch of these part numbers in the requisite quantities. [Johansson, 1991]

Batch supply differs from continuous supply in the sense that fewer part numbers have to be exposed to the assembler and that different part numbers are exposed at different points in time. Repacking is only necessary if the supplier package is inappropriate. The remaining material is returned to the store after completion of the batch of assemblies, unless it is to be used in the next batch. Once at the assembly station, the small parts are handled in the same way as for continuous supply [Johansson, 1991].

2.2 Kitting

In manufacturing, kitting is the activity of making kits out of components and/or subassemblies and delivering them to workstations in predetermined quantities in specific containers.

A *kit* is a specific collection of components and/or subassemblies that together (i.e. in the same container) support one or more assembly operations for a given product or "shop order" [Bozer and McGinnis, 1992].

In the manufacturing industry, kitting is implemented to solve the issues of:

1. Lack of space
To further understand kitting and its purpose, one has to realize that it interacts with many subsystems within the assembly station. It has to be defined with regard to the operations it serves and the different kinds of kits that exist. But first, a small example to help understand kitting: A refrigerator door is an end product for the factory that manufactures it. At the Electrolux assembly plant however, it is a component. If the door is assembled with a handle before being sent to the assembly line, then the door and the handle are a subassembly. On the other hand, if these two parts are delivered to the assembly line together, not fastened together, then they make up a kit.

### 2.2.1 Kitting Operations

Three types of kitting operations were identified by [Bozer and McGinnis, 1992]. They are:

1. Kit-to-customer
2. Kit-to-manufacturing
3. Kit-to-maintenance

In kit-to-customer, a selection of parts are grouped together and then shipped to the customer. An example of a company that makes use of kit-to-customer is IKEA, which lets the customers assemble the final product. Kit-to-manufacturing on the other hand is when a selection of parts are grouped together in specific containers, which are then delivered to workstations to support assembly operations. An example of this is when the kitting operation at Electrolux delivers fans, kitted in specific containers, to the refrigerator assembly line. The third type of kitting operation, kit-to-maintenance, is when a maintenance person does its own kit of supplies and
spare parts before going to a service location. An example of this is when a TV repair person goes to a service location and has to decide what supplies to bring (screws, electronic parts etc.).

### 2.2.2 Types of Kitting

Bozer and McGinnis identified two kinds of kits in their study [Bozer and McGinnis, 1992]; stationary kits and travelling kits. A stationary kit is delivered to a workstation and stays there until it is used up. Therefore, the product being assembled travels through the assembly line while the kit stays at the workstation. Figure 2.2 shows a flow diagram of a stationary kit. A travelling kit, however, travels with the product through the assembly line until it is used up. There are two types of travelling kits; one where the kit and the product travel together in a specific container through the assembly process and another one where they are separated and travel in parallel through the assembly line, each in their own container. Figure 2.3 shows the flow diagram for a travelling kit. One should note that, regardless of the type, it is not common that kits include all the parts that are needed to assemble one unit of the end product. The main reason for this is the complexity or size of the product.

![Flow diagram of a stationary kit](image)

**Figure 2.2:** The figure shows a flow diagram of a stationary kit.
2.2.3 Kitting Location

In general, the kitting operation can be in two places: within the factory site or outside it. If placed within the factory site, the kitting process can be located in a central picking store or in decentralized areas close to the assembly stations. These are called material markets or satellites [Brynzer and Johansson, 1995]. A central picking store makes it possible to benefit from economies of scale, by making many different kits in the same area. It also opens a chance for the integration of the kitting area with other parts of the factory site, thereby reducing unnecessary material handling. A downside is a possible lack of communication because of the location of the kitting area. Figure 2.4 shows a flow diagram of a centralised picking store and Figure 2.5 shows a flow diagram of a decentralised picking store. Kitting can also be performed by a supplier outside of the factory site. This often results in a lower direct cost but the trade-off is an increased lead time and a more complicated production plan.
Figure 2.4: The figure shows a flow diagram of a centralised picking store.

Figure 2.5: The figure shows a flow diagram of a decentralised picking store.
2.2.4 What to kit?

When designing a kitting process, one of the first questions that comes into mind is what items\(^1\) should be kitted. Size restriction affects what parts should be kitted, components that are too big for pickers to handle cannot be part of the process. The parts that are often kitted are runners or repeaters taking up substantial processing time. High value parts can also be suitable for kitting because it gives better damage control [Schwind, 1992].

2.2.5 Kitting personnel

Kitting can either be done by people or robots. People are more suited when the parts to be kitted vary in size and number. Also, given the stochastic nature of some complex manufacturing systems, people are preferred. Robots can be better suited when dealing with simpler products, there is little disruption in the product flow and the production plan can be followed without many problems. When done by people, kitting can either be done by a special unit (often called kitters) or by operators at the assembly line. According to [Brynzer and Johansson, 1995] there are two benefits of having the operators do the kitting. The first one is that higher picking accuracy can be obtained when the operator is responsible for the whole job. The second one is an enhancement in overall productivity by reducing balancing problems and giving better possibilities regarding job design. The upside of having dedicated pickers is that the operators can focus almost fully on value-adding work. The non-value-adding work of preparing the kits, such as searching for and walking to and from parts, is removed. This also benefits the issue of learning, mentioned as one of the five main issues that kitting is implemented to solve. The operators now only have to learn the assembly work and the pickers focus on the kitting.

2.2.6 Advantages and Disadvantages of Kitting

While reading literature on kitting, one can see that different authors often point out the same advantages and disadvantages of kitting. In the beginning of this chapter, five things were pointed out as the main issues that kitting is implemented to solve.

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\(^1\)Item and article are considered the same thing throughout this thesis.
Below are some of the advantages of kitting, grouped under the five main issues named above, followed by the disadvantages.

### 2.2.6.1 Advantages

#### Lack of Space

- By implementing kitting, a lot of space that goes into storing material near assembly work stations is freed up [Bozer and McGinnis, 1992] [Medbo, 2003].

- Freeing up space results in a better organized shop floor and this directly affects the other four main issues (Quality, Flexibility, Material handling, Learning) [Bozer and McGinnis, 1992] [Medbo, 2003].

- Free space also means better control over WIP since subassemblies and parts can be stored centrally.

- Inventory costs could be reduced due to integrated storage and assembly [Seller and Nof, 1986].

#### Quality

- Faulty components are spotted earlier in the process, thereby preventing possible hickups or even stops at the assembly line [Seller and Nof, 1986] [Bozer and McGinnis, 1992] [Medbo, 2003].

- Parts are stored in closed packages until they are used in kits, minimizing the possibility of damage [Schwind, 1992].

- The kits are presented to the assembly work stations in the right order according to the production plan, ensuring correct assembly [Schwind, 1992].

#### Flexibility

- An improved visibility over the parts on the floor and their flow makes product changeover easier [Bozer and McGinnis, 1992] [Medbo, 2003].

- Less WIP results in shorter lead times [Medbo, 2003].
• The free space (compared to before) makes the whole assembly area more flexible [Schwind, 1992].

Material Handling

• Control over the flow of material is better [Ding, 1992].

• Pickers do not need to search for parts since the parts that belong together come in a kit. This results in a shorter searching time and increased productivity [Ding, 1992] [Medbo, 2003].

• Kitting reduces material handling since parts are sent in groups to the floor [Seller and Nof, 1986] [Ding, 1992] [Medbo, 2003].

Learning

• The complexity of the overall process is reduced, resulting in an easier understanding of it [Medbo, 2003].

• The learning curve for assembly workers is less steep since the kits are easier to learn [Ding, 1992] [Medbo, 2003].

2.2.6.2 Disadvantages

• Kitting is generally a non value-adding activity [Bozer and McGinnis, 1992].

• A fault in the kitting process can result in a complete stop of an assembly line [Bozer and McGinnis, 1992].

• Missing parts result in half-finished kits. This increases material handling along with the need of storage space and reduces the kit efficiency [Bozer and McGinnis, 1992].

• When kitting in advance, storage space requirements are likely to increase [Bozer and McGinnis, 1992].

• Kits that contain defective parts must be re-kitted.

• Picking parts is repetitive work that is likely to be tedious in the long run. This can result in poor work morale.
Components that may fail during (or as a result of) the assembly process will require special consideration or exceptions [Bozer and McGinnis, 1992].

Increasing material handling of parts increases the probability of damaging them. This means that all parts are not suited for kitting [Brynzer and Johansson, 1995].

### 2.3 Complexity in Production Systems

As consumers have more and more demands on variety and quality of the products that they buy, the complexity behind these products proliferates. What increases complexity in the world of manufacturing are so-called complexity drivers. They increase the number of product variants, shorten product cycles, and increase the complexity of production systems [Fässberg et al., 2011].

When designing such a production system, one has to have an overview of many different parameters. Some of these parameters drive the complexity of the system, making it necessary to control them. [Fässberg et al., 2011] has identified the main complexity drivers, as:

- Regulations
- Market requirements
- Product
- Changes
- Layout
- Routing
- Planning
- Organisation
- Process steps
- Information
• Work environment

The main driver and cause of complexity is mass customisation, which is connected to all of the above mentioned drivers. In order to control these drivers and minimize the complexity of the production system, the focus has to be on developing generic models and methods to support strategies, planning, management and the optimization of complex production [Fässberg et al., 2011]. It is also important to focus not only on the tasks of the production system but to also think of the complexity from the eyes of the workers. What may seem simple and un-complex to the people designing the system may be complicated to the people working in it. This is a very important task since an increase in complexity in a production system means that more can go wrong, making it more difficult to prevent breakdowns.

According to [Fässberg et al., 2011], production complexity management needs to address the following:

1. Global perspective/external challenges
2. Abstraction level: company/plant, cell, station, task level
3. Time perspective: Short, medium, long term
4. Individual perspective: Function/role/work task

It is important, in this regard, to view the complexity of the whole system and avoid optimizing parts of it without looking at the whole picture. By focusing on one part, it is possible that the complexity of it is transferred to another part of the process, resulting in a zero decrease in complexity of the production system. This misses the point of the task, which is to decrease the complexity of the whole system.

2.4 Lean Production

Lean production or the Lean philosophy has been growing in popularity with production companies. Lean manufacturing is a concept whereby all production people work together to eliminate waste [Kumar, 2008]. According to [Slack et al., 2004] the goal is to develop an operation that is faster, more dependable, produces higher quality products and services and, above all, operates at low cost. A company which
devotes itself to the lean mentality can subsequently become more flexible and more responsive by reducing waste [Carreira, 2004].

Toyota has been at the forefront of the implementation and development of the lean thinking. They have made it clear that it is very important to have the workers participate in decision making to improve for example production processes.

The Toyota Way goes well beyond this; it encourages, supports, and in fact demands employee involvement.[Liker, 2003]

2.4.1 Lean Philosophy

According to [Slack et al., 2004], elimination of all forms of waste is the most significant part in the lean philosophy. Waste can be defined as any activity that does not add value to the product. The first step to eliminate waste is to identify it. Toyota has identified seven types of waste. Those types can be identified in different operations according to [Liker, 2003].

1. Overproduction. Producing items for which there are no orders. The wastes which generate overproduction are overstaffing and storage and transportation costs because of excess inventory.

2. Waiting (time on hand). Workers merely serving to watch an automated machine or having to stand around and waiting for the next processing step, tool, supply, part, etc. Some even have no work to do because of stockouts, lot processing delays, equipment downtime, and capacity bottlenecks.

3. Transport. Carrying a work in process (WIP) long distances, creating inefficient transport, or moving materials, parts, or finished goods into or out of storage or between processes.

4. Inventory. Excess raw material, WIP, or finished goods causing longer lead times, obsolescence, damaged goods, transportation and storage costs, and delay. Also, extra inventory hides problems such as production imbalances, late deliveries from suppliers, defects, equipment downtime, and long setup times.
5. **Motion.** Any wasted motion employees have to perform during the course of their work, such as looking for, reaching for, or stacking parts, tools, etc. Also, walking is waste.

6. **Over Processing.** Taking unneeded steps to process the parts. Inefficient processing due to poor tool and product design, causing unnecessary motion and producing defects. Waste is generated when providing higher-quality products than is necessary.

7. **Defects.** Production of defective parts or correction. Repair or rework, scrap, replacement production, and inspection mean wasteful handling, time, and effort.

### 2.4.1.1 Kaizen

Kaizen is not a one-time project; it is a process and a state of mind for continuous improvement that supports waste elimination [Burton and Boeder, 2003].

Kaizen is not readily defined, due to the fact that its meaning and usage in production can be very broad. According to [Burton and Boeder, 2003] Kaizen is a gradual, incremental, and continual improvement of activities so as to create more value and less non-value-adding waste. Continuous improvement can be associated with many different tactical initiatives. For example if there are daily improvements, even in small amounts, carried out in every job and function of the business, then eventually these small amounts accumulate into very large gains. The success of a kaizen depends on the total commitment of the workforce to increase efficiency and reduce cost.

### 2.4.1.2 5S

5S is a lean tool which facilitates teamwork [Liker, 2003]. The 5S stand for:

- **Sort.** Sort through items and keep only what is needed while disposing of what is not.

- **Stabilize (orderliness).** "A place for everything and everything in its place"
- **Shine (cleanliness).** The cleaning process often acts as a form of inspection that exposes abnormal and pre-failure conditions that could hurt quality or cause failure.

- **Standardize (create rules).** Develop systems and procedures to maintain and monitor the first three S’s

- **Sustain (self-discipline).** Maintaining a stabilized workplace is an ongoing process of continuous improvement.

These 5S are a series of activities for eliminating wastes that contribute to errors, defects, and injuries. According to [Liker, 2003] in the 5S improvement method the fifth S, sustain, is the hardest. It is the one that keeps the first four S’s going by emphasizing the necessary education, training, and rewards needed to encourage workers to properly maintain and continuously improve operating procedures and the workplace environment. This effort requires a combination of committed management, proper training, and a culture that makes sustaining improvement a habitual behaviour from the shop floor to management.

According to [Carreira, 2004] the 5S system supports a philosophy of operating. The philosophy that this system supports is one of discipline, efficiency, and attention to detail.
Method

3.1 Research Process and Practical Studies

3.1.1 Course of Action

The thesis work began with an introduction tour of the Electrolux factory site in Mariestad, with a special emphasis on the new assembly lines. After the introduction, meetings were set up with key personnel within the factory in order to get a grasp of the situation. Since the focus of the thesis was to be material handling, one of those meetings was with the leading material handling engineer at Electrolux Mariestad. At that meeting it was decided that kitting would be the subject of the thesis. The factory was having great problems with kitting and the material handling division was very interested in seeing an efficiency analysis on the kitting operations. This subject was also a good fit since the kitting was a separate operation, consisting of three kitting stations, and kitting also has an interesting connection to production complexity.

After having spent enough time at the kitting floor to understand it’s workings the authors moved to the data collection. Which was based on the question: How can one measure kitting efficiency? The first step was to collect data that was being written on a whiteboard, close to the kitting stations, but not stored. The next step was to collect data on the efficiency of all three kitting stations. A big data collection would be needed and the manual way of collecting the data was soon ruled out. Instead, a program was written and set up on all kitting stations that measured the efficiency of each station. A description of the program is found in Chapter 3.2.

In order to investigate the relationship of kitting with complexity, data was also pulled from Electrolux databases and analyzed in Excel. This is described further in
Chapter 3.5 and Chapter 5.3.

After collecting the data an analysis was done in Excel and a simulation model was built in Extend simulation software. The model was intended to compare different solution suggestions and generate output data that could be used in the results and analysis. The data was analysed and the kitting time for the current situation was compared with one where ANCs would come pre kitted.

Throughout the thesis work, from the first meeting and introduction at Electrolux, the authors have continuously been studying literature along with writing the thesis. This was done to even the workload and make sure that sufficient time was available for result analysis in the later parts of the thesis work. A flow diagram of the course of action can be seen in Figure 3.1.
Figure 3.1: The figure show a flow diagram of the course of action taken during this thesis work.
3.1.2 Simulation

To find ways of optimizing the kitting process and simulating different situations which could lead to an improvement in the system a simulation model was made with Extend the simulation software. In order to simulate, an extensive data set is required for the model to be similar to the current situation at the kitting stations, and to be able to simulate ideas for improvement. Three situations were deemed interesting to simulate.

1. The current situation

2. Simulate if articles that take the longest time to kit come pre-kitted in corresponding boxes from supplier.

For this simulation it was assumed that there were three stations doing the kitting. A production schedule for one week from Electrolux was used. A sample production schedule can be seen in Table A.1 in the Appendix.

1. The PNCs and corresponding ANCs that are included in this schedule are collected and placed in an Excel sheet with their corresponding min, max and most likely values for the ANC calculated from the program discussed in 3.2.

2. When the program starts PNC items go through a timer block in Extend which records the total time of the kit when the PNC has been kitted.

3. A delay block simulates the time it takes for ANC to arrive in front of the kitter. This delay is generated randomly using the triangular distribution (3.1.3) where estimates for the min, max and most likely values are based on what has been witnessed on the kitting floor.\(^1\)

4. Because the kitter only works on one ANC at a time a "gate" in Extend is used so the program only lets one ANC through at a time.

\(^1\)The person responsible for the automatic warehouse was contacted and he said that Electrolux only has a record of when the ANC are ordered and not when they arrive so no data was readily available.
5. A delay process where the kitting occurs happens next. The delay value is generated using the triangular distribution. The minimum, maximum and most likely values are from the data that was collected.

6. When the ANCs have been kitted, the time data, utilization of the kitter, information regarding which ANC have been picked and corresponding PNCs, are sent to an Excel sheet for further analysis.

A flowchart with descriptions of processes in the simulation program can be seen in Figure 3.2.
Following outputs are collected in an Excel sheet which is later used for analysis purposes:

- Information regarding what ANC is being kitted.
- Total kitting time of a batch of ANCs.
- Simulation time for the process of the ANCs arriving from automatic warehouse.
- The time it takes to kit one item of an ANC.

### 3.1.3 Data Collection

#### 3.1.3.1 Applicable Distributions

According to [Gustavson, 2010] applicable distributions that can be used in a discrete event simulation are not as many as those that can be used in a continuous events simulations. In fact there are three that can be readily applied to manufacturing systems. For our simulation, the triangular distribution has been chosen. More information about the other distributions can be found in the appendix.

For a random $x$ with $a < x < b$ and $a$ as the minimum, $b$ as the maximum and $m$ as the mean of a certain data set, the triangular distribution is defined as follows

\[
f(x) = \begin{cases} 2(x-a) & \text{if } a \leq x \leq b \\ \frac{2(b-x)}{(m-a)(b-a)} & \text{if } m \leq x \leq b \end{cases}
\]

(3.1)

(3.2)

The triangular distribution provides a stochastic estimate using the minimum, maximum and most likely times that are obtained by examining a data sample. Since the triangular distribution has a finite value it suits a simulation model where extreme occurrences are not of a particular interest.

### 3.2 Kitting Program

It was observed that the data collection would become an issue, because of time, if it was to be done manually. It was therefore decided to make a program which the
Figure 3.2: The figure shows the flow chart of the simulation.
Kitting personnel could use simultaneously with their work, preferably in a programming environment which could be installed at the kitting stations. The programming was therefore done in the Visual Basic environment in Excel. When programming the initial program, the following factors were kept in mind:

- Easy to understand graphical user interface (GUI).
- Easy to operate GUI.
- Record all the data necessary for later analyzation.
- Program in an environment which could be installed at the kitting stations.
- Have corresponding ANCs appear when a certain PNC is picked.
- Status to show that a measurement is taking place.
- Take as little time as possible from the total kitting time.
- Autosave regularly.
Figure 3.3: The figure shows the GUI of the program with corresponding numbers for the description.

The GUI for the program can be seen in Figure 3.3.

1. The kitting personnel begin by selecting the PNC which is going to be picked from a droplist.

2. After choosing the correct PNC a list of corresponding ANCs that are to be
kitted populate the list. The kitter chooses the ANC he/she is going to kit and selects how many items are going to be picked.

3. When having selected the correct ANC the kitter either chooses or enters the number of articles he/she is to kit.

4. When the pallet arrives at a kitting station, the kitter presses the start button. He/she then goes on to pick the items into boxes and places them on a train wagon.

5. After pressing the start button, ”Pågår” appears in the status box. This is information for the kitter to know that the measurement has started.

6. After he/she has placed all the items in boxes, placed the information sheets on the boxes and sent the pallet away he presses stop and the status box shows an empty box. This cycle is then repeated for the next ANC. Since the PNC’s corresponding ANCs are on the screen he/she only needs to select the next ANC that he/she is to pick from the list.

The following data is collected with the kitting program:

- Timestamp when the kitting starts. The timestamp is in the format e.g. 14:34:22.
- Timestamp when the kitting stops.
- PNC number.
- ANC number.
- How many items he/she is picking of the corresponding ANC.
- What kitting station is kitting this ANC.

After running the program for a week, a feedback regarding how to make the use of the program simpler was received from the operators. A search function was added where they could enter the beginning of the PNC number or the whole number and the corresponding PNC would appear on the screen.
3.3 Kitting Information Whiteboard

In the kitting area there was an information whiteboard where the following information was written, listed are those that are of interest on the whiteboard:

- Which assembly line the kit was going to
- PNC
- Batch size
- Kit start time and kit end time
- Scheduled train start time
- Train start time and train end time

Since this information was not being stored, a camera was put in place so that the employees could take a picture of the data on the whiteboard before it was erased. Using the pictures the information was gathered and entered in an Excel spreadsheet. The whiteboard can be seen in Figure 3.4.

Figure 3.4: The figure shows the whiteboard that was used to write down data from the kitting processes.
3.4 Required Number of Observations

When analyzing the acquired data from the kitting area, Equation 3.3 was used to calculate the required number of observations. This equation is derived from standard deviation of taken observations [Salvendy, 2001]:

\[ N' = \frac{20 \sqrt{N \sum X^2 - (\sum X)^2}}{\sum X} \]  

(3.3)

Where \( N' \) is the required number of observations, \( N \) is the number of observations and \( X \) is the value of the observations. A 95% confidence level and a ±10% precision was used. This means that the chances are at least 95 out of 100 that the sample mean or the average value for the element will not be in error more than ±10% of the true element time.
3.5 Complexity Analysis

After being advised by the supervisor, it was decided early in the thesis work that a complexity analysis was something that should be done. The complexity analysis was twofold: one part analysing the complexity behind the items in the products and the ones parts analysing the products and how they are connected.

3.5.1 Article Analysis

The first part involved choosing the refrigerator model that was to be produced the most in 2011, and analysing the articles that it shared with the refrigerators that made up the top 75% of the production. An Excel document that included the PNCs that made up 75% of the predicted production for 2011 was pulled from a database. It also included all the article within these PNCs. The structure of the items in the database is such that each item is assigned a certain level. These level numbers correspond to the position of the item within a subassembly, where level 0 is the highest and level 8 is the lowest. This means that an item with the level number 1 can be the mother of a subassembly that contains items with the level numbers 2-8. Table 3.1 shows how the items are represented in the database. Figure 3.5

<table>
<thead>
<tr>
<th>Level</th>
<th>Article Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MONT, ANV, DISPLAY LCD</td>
</tr>
<tr>
<td>2</td>
<td>LCD MODUL KPL, MONT</td>
</tr>
<tr>
<td>3</td>
<td>LCD-MODUL KPL</td>
</tr>
<tr>
<td>4</td>
<td>KRETSKORT KPL, LCD</td>
</tr>
<tr>
<td>5</td>
<td>KRETSKORT, LCD</td>
</tr>
<tr>
<td>6</td>
<td>GLAS, LCD</td>
</tr>
<tr>
<td>4</td>
<td>KOMPONENTBÄRARE, LCD</td>
</tr>
<tr>
<td>3</td>
<td>DEKORGLAS, LCD, TRYCKT</td>
</tr>
<tr>
<td>4</td>
<td>LOGOTYPE</td>
</tr>
<tr>
<td>4</td>
<td>LOGOTYPE</td>
</tr>
<tr>
<td>4</td>
<td>DEKORGLAS, LCD</td>
</tr>
</tbody>
</table>

Table 3.1: The table shows how the articles are represented in the database.
Figure 3.5: The figure shows the same data as in Table, represented in a horizontal hierarchy tree.
The result of this analysis is a matrix that shows which subassemblies (items with the level number 1) are common between the most produced refrigerator and the others that make up the top 75% of the production.

3.5.2 Product analysis

In the second part the products were divided into product families, with refrigerators grouped together and freezers grouped together. A procedure from the book *Creating Mixed Model Value Streams* by [Duggan, 2002] was followed to create these product family matrixes. This procedure is about grouping products together into families based on which processes they share. According to [Duggan, 2002], it is best to consider a product family as a group of products that pass through similar downstream processes. The procedure used to create these product family matrixes at Electrolux is as follows:

1. The products are placed in the rows.
2. The processes are placed in the columns.
3. The downstream processing steps are identified and the upstream processing steps are removed from the matrix.
4. The product family matrix is sorted visually, so products with similar downstream processes are grouped together.

Due to the amount of products and product variants, this procedure was done by using an Excel algorithm. The product list was also shortened by removing the variants and only including base models. The product families were then further refined by using a work content criteria determination. According to [Duggan, 2002], the general rule is that

The total work content of the downstream process steps for each part in the product family should be within 30 percent of each other.

After this had been done, the end product was a so-called product family matrix which is a table that contains a list of processes in the columns and a list of products in the rows. This can be seen in Table 3.2.
Table 3.2: The table shows one full product family, coloured red, and a part of another product family, coloured blue. The numbers in the table correspond to the time each PNC spends at a station (MONT-XX), in the TMU time unit. The last column shows the deviation of the range of work content of each PNC from the one that spends the least time at all of the stations. This is a zoomed-in view of the product family matrix and not all stations are depicted.

<table>
<thead>
<tr>
<th>PNC</th>
<th>MONT-58</th>
<th>MONT-26</th>
<th>MONT-27</th>
<th>MONT-36</th>
<th>MONT-38</th>
<th>Total</th>
<th>Range of work content</th>
</tr>
</thead>
<tbody>
<tr>
<td>9278710-XX</td>
<td>1538</td>
<td>2286</td>
<td>2251</td>
<td>1580</td>
<td>1558</td>
<td>62305</td>
<td>1.34%</td>
</tr>
<tr>
<td>9278711-XX</td>
<td>1538</td>
<td>2286</td>
<td>2251</td>
<td>1670</td>
<td>1656</td>
<td>62631</td>
<td>1.86%</td>
</tr>
<tr>
<td>9278712-XX</td>
<td>1815</td>
<td>2286</td>
<td>2251</td>
<td>1678</td>
<td>1656</td>
<td>61467</td>
<td>0.00%</td>
</tr>
<tr>
<td>9278713-XX</td>
<td>1815</td>
<td>2286</td>
<td>2251</td>
<td>1580</td>
<td>1558</td>
<td>62317</td>
<td>1.36%</td>
</tr>
<tr>
<td>9278714-XX</td>
<td>1815</td>
<td>2286</td>
<td>2251</td>
<td>1580</td>
<td>1558</td>
<td>62976</td>
<td>2.40%</td>
</tr>
<tr>
<td>9271501-XX</td>
<td>1718</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>50505</td>
<td>3.48%</td>
</tr>
<tr>
<td>9271505-XX</td>
<td>1815</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>50302</td>
<td>2.93%</td>
</tr>
<tr>
<td>9271509-XX</td>
<td>1399</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>50171</td>
<td>2.68%</td>
</tr>
<tr>
<td>9271510-XX</td>
<td>1431</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>53532</td>
<td>0.79%</td>
</tr>
</tbody>
</table>
Current Situation

4.1 General Problem Description

Electrolux Mariestad introduced two new assembly lines in January 2011 and implemented a new material distribution system to them in the form of milk runs, done by trains. The plan was for the new assembly lines to gradually take over the assembly work from the old lines and in week 18, the old lines would be completely shut down. Along with that, a variety of new products have been introduced, further complicating this process. These three big factors have made the situation in Electrolux Mariestad rather chaotic in the last few months and production stops have been rather frequent. All these changes meant that the factory was evolving constantly as the implementation of the new assembly lines progressed.

The kitting floor was no stranger to the evolution and over the span of the thesis work it changed several times. This made the evaluation harder since measurements taken at two points in time could have been done under different working conditions. This also kept the employees very busy which has at times affected the thesis work. Getting to meet key personnel was sometimes difficult, due to them being busy. Data collection was also troublesome at times, some employees were under pressure because of the workload and frequent breakdowns in the factory. This made them doubtful that they would have time to use the program written for the kitting stations. Their skepticism is understandable, given the situation at the factory over the past few months and all went well in the end. The authors are very grateful for all the help that they have received and the positive attitude by which they were met.

Discussions with the material handling engineer, the kitting floor manager as well with key personnel were especially helpful in grasping their view of the problems.
The kitting operation had been struggling with the pace of the new setup and a few things were pointed out in causing these problems. The main problem was that some items were probably not suited for kitting and should come pre-kitted. This was also stated as a future goal for the factory, having articles arrive pre-kitted to the factory. There had also been problems with the automatic warehouse (AMW) that supplied the kitting area, where the IT system showed the wrong amount of material available in the warehouse.

4.2 Electrolux Manufacturing System

In October 2005 Electrolux started with the project Electrolux Manufacturing Systems (EMS). They launched it as ”Our Way to Excellence” to help them stay ahead of the competition. For the first five years of the project they have celebrated many successes in all of their locations around the world. They consider the most important factor in these achievements to be the input from the Electrolux people. [Electrolux, 2010]

When EMS began we explained that it was an evolving system. Part of this evolution has been the addition of new tools and techniques that help us improve operational performance.

In order to achieve the Electrolux vision of becoming the world leader in our chosen markets, we must continue to use the tools and techniques in our daily activities.

EMS is an integral part of the group strategy to achieve this goal and will become even more important to us in the coming years
— The Global EMS Core Team [Electrolux, 2010]

4.2.1 The EMS Model

There are three core elements which the EMS is structured around:

- Stability

- Process Improvement
• Culture Change

These are represented by the three wheels which can be seen in Figure 4.1, [Electrolux, 2010].

![Figure 4.1: The figure shows the three core elements that EMS is structured around, represented by wheels.](image)

According to a booklet about the EMS system from Electrolux [Electrolux, 2010], stability is the foundation for further improvement. "It provides us with safe, efficient, standardized processes with minimum waste." Stability also gives the ability to measure performance improvement. Electrolux uses process improvement to achieve better operational performance. Culture change involves engaging every member of the Electrolux team, to create a common culture that could give Electrolux an advantage over their competitors.
4.2.2 Plan - Do - Check - Act

Electrolux uses the Plan - Do - Check - Act (PDCA) cycle to help them applying EMS. It is a known management tool which is both simple and effective. It allows Electrolux to learn from and verify the effectiveness of the improvement process.

1. Plan – Electrolux identifies concerns or problems and gathers information to provide a better definition of the issue. Using the data that they have collected it is then possible to set objectives or targets for improvement. In order to improve performance it is necessary to analyze the cause of the issue and then to develop solutions to address the concern.

2. Do – In this step they implement the solution.

3. Check - The Check phase can be thought of as a learning step and involves evaluating the results of the improvement process. Questions such as, did the solution have an effect? Did it meet their expectations?, are asked. If the objectives set were not achieved, then they go to the Plan stage again with the knowledge gained from the improvement process and a new cycle of the PDCA begins. If the expectations are met then it is possible to continue to the Act phase.

4. Act - Is the final step and it is used to verify that the cause of the problem has been permanently removed. The solution can then be standardized, so that it becomes the new way of working.

4.2.3 Stability Element of the EMS

The Stability Element is a collection of tools for further improvement for Electrolux. It is made up of three principles.

1. Advanced Safety principle. The most important aspect of the Stability Element is the safety of team members. The tools for this element are designed to improve the levels of safety in a facility.
2. The Measurement principle. It contains tools to help establishing focus for improvement. It also helps present complex information clearly and to confirm improvement.

3. The Stability Basic. Set of tools that aims to give Electrolux safe, efficient, standardized processes with minimum waste. The Stability Basics tools are used together in a coordinated way that is known as 5D "Built In Quality" System Elements.

4.2.3.1 5D "Built in Quality" System Elements.

The 5D "Built in Quality" System Elements provide a structure to use the Stability Basics tools together in a coordinated way, in order to get the maximum benefit from their application. The elements of 5D are quality control Procedure, 5S condition, skill control through the use of a skills matrix, standardized work, problem solving and quality performance in "Not Right the First Time" (NRFT). The 5D is assessed through NRFT level of an area and the levels of excellence are defined as the amount of NRFT achieved in an area. Due to the big changes in the kitting area many aspects of the EMS has been put on the shelve while trying to be able to keep up with the production. The authors were told in discussions with key personnel that when order will be restored in the area the important aspects of the EMS will be implemented again.

4.3 Kitting

With the introduction of the new assembly lines, Electrolux also implemented a new material feeding system. Almost all of the material that is fed to the assembly lines now kitted, with a few exceptions such as compressors and small screws which use the other material feeding systems discussed in Chapter 2.1.1. For some of these exceptions they use kanban system, e.g. for small screws. There are approximately 1000 screws in one box and two boxes at each assembly station which uses the screws (similar boxes can be seen in Figure 4.2). When a box becomes empty the operator places the box on a tray where a train operator picks it up and delivers it to the material handling floor. The box is then filled and delivered to the operator when it
is ready. This can be defined as kanban since the box acts as a signal that e.g. certain type of screws need replenishment. The old assembly lines made use of lineside storage

Figure 4.2: The figure shows a box which is used for smaller material. These boxes are also used for the kanban system.

but in order to save space and meet the demands of the Electrolux Manufacturing System, kitting was introduced. The kitting is done according to a weekly production schedule. This schedule can be reviewed and changed with short lead time. The kitting area is a centralized picking store (2.2.3), consisting of three kitting stations (see Figure 4.3) which kit-to-manufacturing (see 2.2.3), each with one employee (called kitters). The kitters order and receive most of the material from the AMW to each station. Not all material is available in the AMW and each picker therefore has to leave his station and pick those items on the floor. The kitting is done to routes that the trains follow and there are four routes called Blue, Green, Red and White. Trains travelling the Blue route delivers batch material to the freezer assembly line, while the ones travelling the Green route deliver batch material to the refrigerator
assembly line. The trains travelling the Red route deliver doors to both lines and the ones travelling the White route deliver 2-bin material to both lines\(^1\). The kits are stationary kits (see 2.2.2), consisting of batches where 20 articles is the common denominator regarding size. This means that each batch can hold 20, 40 and 60 (and so on) articles. The finished kits are stored on wagons that are connected to the train when it is time for them to be distributed. Since each kit at Electrolux consists of 20 or more identical articles, each wagon that the train carries can be thought of as a kit of its own, holding different articles for the assembly line.

![Kitting station at Electrolux Mariestad plant](image)

Figure 4.3: The figure shows a kitting station at the Electrolux Mariestad plant. The TV screen shows what ANC is in front of the kitter and behind it, the conveyor from the automatic warehouse can be seen.

\(^1\)A new route, called the yellow route, is scheduled to be introduced and it will deliver material to the mobile cell refrigerator assembly line.
4.3.1 Kitting problems

Problems regarding the kitting are listed below:

- The kitters sometimes have to leave their stations and pick items on the floor.

- It is rather difficult for new personnel to learn the ways of working on the kitting stations. There is no real documentation or standardised form of work, they only way that they learn is from more experienced kitters.

- The kitting operations haven’t been measured in any way.

- There have been some problems with the AMW, concerning the wrong information about the amount of articles present in a pallet.

4.4 Complexity

As mentioned in 2.3, the main driver behind complexity is mass customisation. This is also the case at Electrolux, where the number of product variants drive the complexity of the product system. Currently, Electrolux is manufacturing four different product types at Mariestad:

1. Refrigerators
2. Freezers
3. Combi-style refrigerators
4. Mobile cell refrigerators

Within these four product groups, there are 164 different product number codes (PNCs). This means that there are 164 different product variants manufactured at Electrolux Mariestad. This is quite a number but there has been a big improvement in recent years; in 2006 there were 350 PNCs in production and just in January 2011 there were 199 PNCs. So although the complexity level is high now, it was even higher before.
4.4.1 Complexity Problems

Even though the number of PNC’s has decreased, the main problem regarding complexity is still the number of variants, especially from a kitting point of view. The more the variants, the more different articles go into them. An example of an article that is made complex is the drawers that go into the refrigerators and freezers. Since Electrolux has many brands (Electrolux, AEG, Husqvarna etc.), these drawers have the brand logos on them. So even though they are the same article per say, they have to be specially kitted for each brand.

Another problem with complexity is the difference in the definition of a base model between the product development and production floor. There is a lack of communication between these two departments, perhaps resulting in too much complexity in the design of the products. Although the product development department has divided the products into product families from their own point of view, no such effort has been made at the production side.
Results

In this chapter the results from our analysis of the kitting at Electrolux are presented. The data collected using the program built for the kitters (3.2) is used in this section.

For the time analysis, median, is used instead of average to remove the influence of extreme measurements. Figure 5.1 illustrates the difference. The figure shows the comparison between average and median kitting times for every ANC kitted at the kitting stations. From the ANC with the longest median time farthest left to the ANC with the shortest time median farthest right. The spikes in the figure show that the average for some ANCs are not valid. This is due to a failure when the kitter has not stopped the program at the correct instance. From this it can be seen that the median is better applicable for the analysis of the data.
Figure 5.1: The figure shows the comparison between average and median kitting times for every ANC kitted at the kitting stations.
5.1 Results From Kitting Time Analysis

Using Equation 3.3 in Chapter 3.4 on the data gathered shows that the required number of observations was not met. The result can be found in Table 5.1. The table shows the ten most common ANC in the data collection. It is in the authors opinion that the current data set is however very useful and below is an analysis of this data collection.

<table>
<thead>
<tr>
<th>ANC</th>
<th>ANC Description</th>
<th>N</th>
<th>N'</th>
</tr>
</thead>
<tbody>
<tr>
<td>208387301</td>
<td>AVDUNSTNINGSSKÄL</td>
<td>50</td>
<td>203</td>
</tr>
<tr>
<td>265104802</td>
<td>DÖRRFACK KPL</td>
<td>39</td>
<td>85</td>
</tr>
<tr>
<td>20848601</td>
<td>AVDUNSTNINGSSKÄL</td>
<td>38</td>
<td>176</td>
</tr>
<tr>
<td>208604102</td>
<td>DÖRRFACK, TRP</td>
<td>36</td>
<td>224</td>
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<tr>
<td>223205611</td>
<td>AVDUNSTNINGSSKÄL</td>
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<td>307</td>
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<tr>
<td>264600601</td>
<td>FLASKHÅLLARE</td>
<td>31</td>
<td>207</td>
</tr>
<tr>
<td>265104902</td>
<td>FLASKFACK KPL</td>
<td>31</td>
<td>238</td>
</tr>
<tr>
<td>208582304</td>
<td>TRÅDHYLLA, -FLASK</td>
<td>30</td>
<td>116</td>
</tr>
<tr>
<td>265104702</td>
<td>SMÖRFACK KPL</td>
<td>28</td>
<td>57</td>
</tr>
<tr>
<td>205760556</td>
<td>SLADDSTÄLL KPL</td>
<td>28</td>
<td>1305</td>
</tr>
</tbody>
</table>

Table 5.1: The table shows the Required number of observations for kitting time analysis. Where \( N \) is the number of observations and \( N' \) is the number of observations required.

The kitting at Electrolux Mariestad, as discussed in Chapter 4.3 is done in batches with twenty articles as the denominator. It was therefore interesting to examine what effect batch sizes have on the kitting time. Figure 5.2 shows the comparison of kitting times for different batch sizes. Kitting with batch size of twenty articles has the longest average kitting time per item while the shortest average time is when the batch size is forty items. When the batch size increases again the average kitting time increases as well. The reason for the batch of twenty articles takes the longest is probably due to the effect that the kitter does not get into to a rhythm and when he/she prepares the kit he/she uses similar time to prepare the boxes as he does when the batch size is forty. For batch sizes of forty the kitter seems to become more routinized and therefore results in him/her being able to kit with more efficiency. As
the batch sizes become larger it can take more time to prepare the boxes for the kits and therefore the average time increases. Another reason could be that when kitting big batches the kitters stop rushing since the repetition can be tiring. The average times for each batch and the number of measurements for each batch size can be seen in Table 5.2.

<table>
<thead>
<tr>
<th>Batch Size</th>
<th>No. of Measurements</th>
<th>Time Per Batch Median [s]</th>
<th>Average Time Per Item [s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>379</td>
<td>160</td>
<td>8.00</td>
</tr>
<tr>
<td>40</td>
<td>399</td>
<td>242</td>
<td>6.05</td>
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<tr>
<td>60</td>
<td>25</td>
<td>382</td>
<td>6.37</td>
</tr>
<tr>
<td>80</td>
<td>44</td>
<td>602</td>
<td>7.52</td>
</tr>
<tr>
<td>120</td>
<td>11</td>
<td>916</td>
<td>7.63</td>
</tr>
<tr>
<td>Other</td>
<td>31</td>
<td>228</td>
<td></td>
</tr>
</tbody>
</table>

Table 5.2: The table shows the comparison of average kitting times for different batch sizes.

Figure 5.2: The figure shows the comparison of kitting times between batch sizes.
Table 5.3: The table shows the comparison of kitting times for different types of ANCs. These are the ANCs which are the most time consuming per item of all the ANCs that are kitted.

Looking at the time it took different ANCs to be kitted, it was noticed that the ANCs which took the longest time to kit per item were mainly placed in a box of five items. Table 5.3 shows the ANCs which took the longest time to kit. Most of the ANCs in the table are the same type of item, Ventgallar (e. Vent cover) and Flaskfack (e. Bottle tray). Due to their sizes, shape and the fact that only 5 fit in a box it should not come as a surprise. Both are ANCs that can be difficult to stack in the boxes they go into. The column furthest right in Table 5.3 shows the deviation from the median for all the data. The deviation is very large and the room for improvement for these articles is great.

The median for all ANCs can be seen in Figure 5.3. The red line corresponds to the median for all time measurements. The tallest spikes above the red line correspond to the items listed in Table 5.3. It can be seen that by having these ANCs pre kitted by the supplier can result in substantial reduction in kitting times.
Figure 5.3: The figure shows the median for different ANC times. The red line represents the median for all ANC kitting times.
In Table 5.4 one can see the comparison of kitting times for different types of boxes the ANCs go into. As discussed above, the fewer items that go into each box, the more time it takes to kit. This is because the kitter has to prepare more boxes for the ANCs.

<table>
<thead>
<tr>
<th>Number of Items in Box</th>
<th>No. of Measurements</th>
<th>Time Per Item Median [s]</th>
<th>Time Per Item Total Median [s]</th>
<th>Deviation from Total Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>191</td>
<td>12.10</td>
<td>7.05</td>
<td>29.08%</td>
</tr>
<tr>
<td>10</td>
<td>247</td>
<td>9.10</td>
<td>7.05</td>
<td>29.08%</td>
</tr>
<tr>
<td>20</td>
<td>484</td>
<td>4.58</td>
<td>7.05</td>
<td>-35.11%</td>
</tr>
<tr>
<td>40</td>
<td>11</td>
<td>2.27</td>
<td>7.05</td>
<td>-67.73%</td>
</tr>
<tr>
<td>125</td>
<td>4</td>
<td>5.14</td>
<td>7.05</td>
<td>-27.13%</td>
</tr>
<tr>
<td>250</td>
<td>4</td>
<td>2.13</td>
<td>7.05</td>
<td>-69.88%</td>
</tr>
<tr>
<td>400</td>
<td>3</td>
<td>6.75</td>
<td>7.05</td>
<td>-4.26%</td>
</tr>
</tbody>
</table>

Table 5.4: The table shows the comparison of kitting times for different types of boxes the ANCs go into. The deviation from the total median is shown in the farthest right column.

Figure 5.4: The figure shows the comparison of kitting times for different types of boxes the ANCs go into.
A comparison between kitting times between different kitting stations can be seen in Figure 5.5. It shows that some kitters appear to work faster than others. It could also be because some kitters can be kitting items that require less time to kit.

Figure 5.5: The figure shows the comparison of stations with regard to kitting times.
Figure 5.6 shows a comparison of efficiency between the stations. This efficiency is a measurement of how much of the time the kitting program was in the PÅGÅR state, during the days that it was used. This can maybe be seen as an indicator of the real efficiency of each kitting station, that is how much of the working time the kitters actually spend time kitting articles.\footnote{Note that even though one station spends more time kitting articles than another, it doesn’t mean that it kits more articles or does a better job. Since some kitters felt uncomfortable using the program in stressful situations, the kitting program wasn’t used at all times.}

![Comparison Between Stations](image)

Figure 5.6: The figure shows the comparison of efficiency at the stations.
As mentioned in Chapter 3.3 a data was written on a whiteboard. Results from this data can be found in Table 5.5 and Table 5.6.

In Table 5.5 the results for the average kitting time and the average waiting time can be seen. According to this the average waiting time is longer than what Electrolux believes to be the case, which was between one and two hours.

<table>
<thead>
<tr>
<th>Measured Item</th>
<th>No. of Measurements</th>
<th>Seconds</th>
<th>Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Train Time - Average</td>
<td>99</td>
<td>2662</td>
<td>44</td>
</tr>
<tr>
<td>Deviation From Scheduled Train</td>
<td>90</td>
<td>429</td>
<td>7</td>
</tr>
<tr>
<td>Departure - Average</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5.5: The table shows the average train time and deviation from scheduled train departure time.

<table>
<thead>
<tr>
<th>Measured Item</th>
<th>No. of Measurements</th>
<th>Seconds</th>
<th>Minutes</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kitting Time - Average</td>
<td>248</td>
<td>4700</td>
<td>78</td>
<td>1,31</td>
</tr>
<tr>
<td>Waiting Time - Average</td>
<td>113</td>
<td>15116</td>
<td>252</td>
<td>4,20</td>
</tr>
</tbody>
</table>

Table 5.6: The table shows the average kitting time and the average waiting time.
Table 5.7: The table shows the required number of observations for average kitting and waiting time, $N$ is the number of observations and $N'$ is the required number of observations.

Table 5.7 shows that enough number of observations were made for this data to be valid except for deviation from scheduled train departure.
5.2 Results From Simulation

As mentioned in Chapter 3.1.2 the goals were to simulate the current situation and when material comes pre-kitted from supplier, using the production schedule for one week. In the second situation it was assumed the ten ANCs which take the longest time to kit (seen in Table 5.3) come pre-kitted in their corresponding boxes. The production schedule was modified so that it resembled this situation. The results can be seen in Table 5.8. The deviation is extensive and suggests that by having ANCs pre-kitted from supplier, Electrolux could save valuable time.

<table>
<thead>
<tr>
<th>PNC</th>
<th>Time - Before [s]</th>
<th>Time - After [s]</th>
<th>Difference</th>
</tr>
</thead>
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<td>922643125</td>
<td>1745</td>
<td>286</td>
<td>-83.58%</td>
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<tr>
<td>922164125</td>
<td>683</td>
<td>127</td>
<td>-81.37%</td>
</tr>
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<td>922643325</td>
<td>4808</td>
<td>1940</td>
<td>-59.65%</td>
</tr>
<tr>
<td>927090420</td>
<td>3482</td>
<td>1571</td>
<td>-54.88%</td>
</tr>
<tr>
<td>927140525</td>
<td>1000</td>
<td>458</td>
<td>-54.24%</td>
</tr>
<tr>
<td>922643436</td>
<td>8143</td>
<td>3768</td>
<td>-53.73%</td>
</tr>
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<td>3970</td>
<td>1959</td>
<td>-50.65%</td>
</tr>
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<td>927140220</td>
<td>15648</td>
<td>8062</td>
<td>-48.48%</td>
</tr>
<tr>
<td>922643036</td>
<td>4877</td>
<td>2531</td>
<td>-48.10%</td>
</tr>
<tr>
<td>927150620</td>
<td>21971</td>
<td>11717</td>
<td>-46.67%</td>
</tr>
</tbody>
</table>

Table 5.8: The table shows a comparison of kitting time simulated with current situations vs. when the ANCs which take the longest time come pre-kitted from supplier.
5.3 Complexity Analysis

This chapter will go through the results of the Complexity Analysis.

5.3.1 Article Analysis

The results from the complexity article analysis can be seen in Table 5.9. Due to the size of the article analysis matrix, the results were summarized and presented in Table 5.9.

The method behind this analysis and its results can be used to analyze the relationship of articles between PNCs and hopefully reduce the article complexity by making more articles common between products. An example of articles that increase the complexity at Electrolux are the drawers that go into the refrigerators and freezers, as was mentioned in Chapter 4.4.1. The drawers have to be specially kitted for each brand (Electrolux, AEG, Husqvarna etc.) and coupled with the fact that the products are produced in batches as small as 20, this results in a high tempo for the kitting staff. Since the kitting is only supposed to be about two hours in front of the production, small errors can lead to big problems such as production stops.

5.3.2 Product Analysis

The results from the Complexity Product Analysis can be seen in Tables 5.10 and 5.11. Due to the size of the product family matrixes, the results were summarized and presented in these tables. The complete product family matrixes can be found in the Appendix, Tables A.2 and A.3.

As mentioned in Chapter 4.4.1, no effort has been made at the production site of Electrolux Mariestad to analyze the products from a complexity point of view. The results of the Product Analysis show that such an analysis can be very helpful. The results are that the refrigerators should be divided into five different families and the freezers into six different families. It was mentioned in Chapter 3.5 that the general rule of thumb was that the total work content of the downstream process steps for each part in the product family should be within 30 percent of each other. This rule
Table 5.9: The table shows the results from the complexity article analysis.

was followed as can be seen in tables 5.10 and 5.11. This rule is not set in stone and can be modified according to the user’s needs, depending on how many product families are preferred. A limit of less than 30 percent would create more product families, while a limit greater than 30 percent would create fewer.

These results can be used to improve the production at Electrolux Mariestad. Regarding kitting, it could be used to optimize the way the production plan is set up. This would mean, for instance, that products in the same product family would follow each other in production. This would directly improve the flow of the kitting process, since it would decrease the jumps between unrelated products and increase the production of similar products (with similar articles to be kitted) after each other.
The product family matrix also gives an insight into how much time each product spends at each assembly station (this can be seen in Appendix, Tables A.2 and A.3). That knowledge can be used in order to improve the line balancing where the time per station can be decreased or increased. Kitting can, for example, be used to decrease the time a product spends at a station. This could be done by moving an element of an assembly operator’s work to the kitting area.

| Table 5.10: The table shows the results from the complexity product analysis for freezers. |
|---|---|---|---|
| **Freezer Product Families** | **Average Work Content** | **Average Range of Work Content** | **Max Range of Work Content** |
| Product Family 1 | 45253 | 7.19% | 14.30% |
| Product Family 2 | 47546 | 4.04% | 10.44% |
| Product Family 3 | 43647 | 4.08% | 8.61% |
| Product Family 4 | 52484 | 0.54% | 1.04% |
| Product Family 5 | 42815 | 3.98% | 5.47% |
| Product Family 6 | 46146 | 6.92% | 15.47% |

| Table 5.11: The table shows the results from the complexity product analysis for refrigerators. |
|---|---|---|---|
| **Refrigerator Product Families** | **Average Work Content** | **Average Range of Work Content** | **Max Range of Work Content** |
| Product Family 1 | 62339 | 1.39% | 2.40% |
| Product Family 2 | 50718 | 3.60% | 8.79% |
| Product Family 3 | 46063 | 11.68% | 22.81% |
| Product Family 4 | 46917 | 12.10% | 24.49% |
| Product Family 5 | 44199 | 9.78% | 16.07% |
Conclusions and Discussions

6.1 Discussions

This thesis was done at times where Electrolux Mariestad was going through extensive changes in their production. It is the authors’ opinion that it was a valuable experience to be able to witness and be part of those changes. Problems will always arise when making big changes in production and the kitting area was no exception to those changes. During the time of this thesis work the kitting area was constantly changing. For example the authors could notice something in the kitting area that could be improved and spend time to think of suggestions, only to find it fixed the next week.

Below are some thoughts on the kitting that the authors would like to suggest changes to.

- It was mentioned that the pickers sometimes have to leave their stations and pick items on the floor. This disrupts the balance of the kitting area. The optimal solution would probably be that all of the material that is kitted is received from the automatic warehouse.

- It is rather difficult for new personnel to learn the ways of working on the kitting stations. There is no real documentation or standardised form of work, the only way that they learn is from more experienced kitters. This means that if the experienced kitters are away from work for some reason, there is a big chance that the productivity of the kitting stations will suffer greatly. The lack of documentation and a standardised way of work means that the pickers can have their own ways of doing their work. This is bad from a lean point of view and makes it harder to get the stations as effective as possible.
• There have been some problems with the AMW, where wrong information about the amount of articles present can occur. This means that the pickers can end up not receiving enough articles for a kit. It could also result in a delayed kit which in a worst case scenario can delay the whole production.

• The main problem regarding complexity is still the number of variants, especially from a kitting point of view. The more the variants, the more different articles go into them. An example of an article that is made complex is the drawers that go into the 50 refrigerators and freezers. Since Electrolux has many brands (Electrolux, AEG, Husqvarna etc.), these drawers have the brand logos on them. So even though they are the same article per say, they have to be specially kitted for each brand. This, coupled with the fact that the products are produced in batches as small as twenty, results in a high tempo in the kitting environment. Since the kitting is only supposed to be two hours in front of the production, small errors can lead to big problems such as production stops.

6.2 Conclusions

The results presented in the previous chapter show that there is plenty of room for improvement at Electrolux Mariestad when it comes to kitting. The results of the analysis and the simulation model coincide with the theory and the ideas of those working at Electrolux on where the problems lay.

Kitting time analysis shows what ANCs are the most time consuming to kit for the pickers. This information can help Electrolux decide on what ANCs should be pre-kitted. It is interesting to note that the kitting time per item decreases between batch sizes of 20 and 40 and increases again between 40 and 60.

It could be seen that some kiters work faster than others. This shows the importance of standardising the kitting process. It is important to find the reasons for one station being able to kit faster than the others and have the kiters learn from each other.

The results gathered from the data on the whiteboard gives an overview of the average kitting time along with average time it takes for the trains to deliver to their routes. From the simulation model it can be seen that by having some of the ANCs pre
kitted from supplier can improve the kitting process extensively. The simulation model shows that even if only ten of the ANCs that take the longest time to kit come ready to be picked in correct boxes it can decrease the kitting time of some PNCs of up to 80%. During the authors’ last days at the factory it was understood that negotiations with some suppliers were underway and new pallets were replacing old ones. The new pallets that will come with pre kitted material from suppliers can be seen in Figure 6.1.

Figure 6.1: The figure shows the new pallets with boxes for pre kitted material. The kitter would instead of picking one item at a time, pick one box with for example ten items.

The results from the complexity analysis show how article and product complexity affect kitting. The more different articles and product variants there are, the more the complexity. An example of article complexity are the drawers that go into refrigerators and freezers. These drawers have to be specially kitted for each brand since they bear the logo of each brand, otherwise they look the same. Electrolux should strive to make more articles common between products as this would simplify the kitting process. The results from the product analysis show that the refrigerators and freezers can be
grouped in to distinct families in order to improve the production. The production side at Electrolux could use this method and its outcome to optimize the production plan and by that directly influence kitting in a positive way, making the kitting flow better.

6.3 Further Research

It would be interesting for Electrolux to look into having the kitters kit the most common articles to a supermarket during their idle time. This could increase the efficiency of the kitting process, reduce idle times of kitters and also improve flexibility.

The automatic warehouse is also an area of interest. There have been problems when kitters order many ANCs at the same time and this has caused delays in the AMW resulting in the kitters waiting to long for the articles. An optimization of this process would be useful for Electrolux.

The train routes as they are done now are managing to keep up with production. However if production capacity increases the current train routes might not cope with increase in capacity. An optimization of how the trains deliver material to the assembly line and their routes might be of high value for Electrolux.
Bibliography


Electrolux. Ems guideline, October 2010.


P. Gullander. Complex support for operation and man-hour planning in complex production, 2011. URL \url{http://extra.ivf.se/complex/}.


Appendix A

Appendix title

A.1 Simulation
<table>
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<th>Band</th>
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<th>SNR</th>
<th>KvKvant</th>
<th>Datum</th>
<th>LTakt</th>
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<td></td>
<td></td>
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Table A.1: The table shows an example of a production schedule. Columns from left: Assembly line, short PNC, PNC, PNC description, first three numbers in the serial number, quantity, the date it is to be produced (Year 11, week 18, day 1 is 11181).
A.2 Complexity Analysis
Table A.2: The table shows all the product families from the Complexity Product Analysis for freezers. It also shows some of the assembly stations each product goes through, theoretical assembly time at the corresponding stations, total work content for each PNC and deviation from total work content within each product family.
Table A.3: The table shows all the product families from the Complexity Product Analysis for refrigerators. It also shows some of the assembly stations each product goes through, theoretical assembly time at the corresponding stations, total work content for each PNC and deviation from total work content within each product family.