Design and conceptual implementation of an improved pre-batch polymer handling process

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Abstract

This thesis is a collaborative project between the division of Production and Materials Engineering and Trelleborg AB. The aim of the thesis is to analyse the current pre-batch polymer handling process, assess the current process from a Lean perspective, and provide a new handling process which is more effective in terms of capacity, operator time, forklift transportation and traceability.

The current situation was first analysed, using both quantitative and qualitative methods. In order to find the most suitable production flow, two different solutions were developed. One of which had buffer storage, and one which did not have buffer storage. These two solutions were then compared on a number of criteria and finally the production flow with buffer storage was determined most suitable. To determine the credibility of the solution, the most critical components were prototyped, with successful results.

The recommended solution leads to a reduction of forklift transportation by 69% and a reduction of time spent cutting polymer by 60%. Furthermore, the new production flow greatly improves operator ergonomics and enables the possibility of running three shifts instead two.

Keywords: *Lean, Production Improvement, Polymer Handling Process, Prototyping*

Acknowledgements

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Lastly, we would like to extend our gratitude to our supervisor at LTH, Fredrik Schultheiss, for valuable input throughout the thesis process.

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1. Introduction

1.1 Background

Sweden has a long history of successful industrial companies where a large share of production is exported. The Swedish industry has delivered innovative and successful products, which has contributed to Sweden's strong position as a global exporter of goods.

However, due to the globalization trend, the competition for Swedish industry companies are steadily increasing. According to Business Sweden [1], Asian manufacturing will continue to seize market shares from the European and North American industry in the coming decades, Figure 1. This is due to the fact that Asia is becoming more self-sufficient in terms of manufactured goods, as well as continued low wage levels compared to North America and Europe.

In order for companies to stay competitive whilst manufacturing in Sweden, they will need to increase their focus on integrating technical solutions and automating processes. According to Vinnova [2] companies will have to focus more efforts on fully utilizing technology and letting employees focus on the work which machines cannot, i.e. solving problems, developing workflow and managing production.

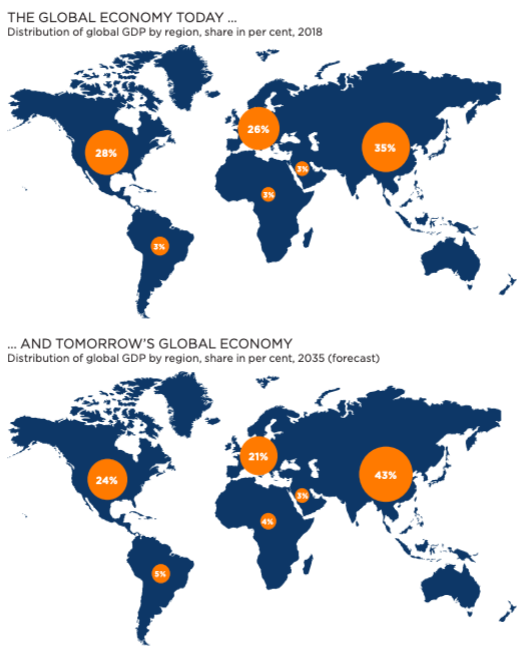

Figure 1: The global economy of today and tomorrow [1]

1.2 Trelleborg AB

Trelleborg AB is a global manufacturer of polymer solutions. They were founded 1905 in Trelleborg and have a long and successful history in the polymer industry. Currently, Trelleborg AB has a revenue of over 32 000 million SEK and employs more than 22 000 people [3].

The company supplies a wide range of products including tractor tires, tunnel seals and industrial hoses. Trelleborg AB is divided into the three business areas Industrial Solutions, Sealing Solutions and Wheel systems. This thesis will consider production at the production site in Trelleborg. More specifically, the evaluated production line is part of the department Engineered Coated Fabrics [4].

1.2.1 Engineered Coated Fabrics

Engineered Coated Fabrics (ECF) is a department belonging to the *Industrial Solutions* business area. ECF produces polymer solutions for a wide range of applications and environments. Their main industries are *Aerospace, Automotive, Healthcare & Medical*, *Defense & Safety*, *Outdoor & Recreation*, *Marine Equipment & Construction, Manufacturing & Machine Tool* and *Rail & Mass Transit* [5].

Figure 2: Headquarters of Trelleborg AB [3]

1.3 Delimitations

This thesis is focused on the pre-batch polymer handling process, where polymer is prepared before mixing. Handling of the raw materials from storage to pre-batch handling will not be evaluated. Processes after the mixing stage will also not be evaluated. The thesis will aim to reduce the time spent processing the raw polymer. A second key focus will be to increase traceability in said process. Lastly, the new workflow will be prototyped.

1.4 Goals

The objectives of this thesis are to:

- Decrease transportation of polymer that requires operator intervention with at least 20%.
- Reduce the time spent on polymer cutting with at least 50%.
- Provide a new polymer handling flow which can handle a 50% increase in production.
- Provide a solution which only needs two operators during the first shift, and one operator during the following two shifts.
- The provided production flow shall not negatively impact the changeover times between orders and between batches.
- The provided production flow's ergonomics shall be at least as good as the current production flow.
- Prototype critical hardware for the recommended solution.

1.5 Problem formulation

The overarching research question of this thesis is:

How can Trelleborg develop its pre-batch polymer handling process in order to improve on the aspects of:

- *Forklift transportation*
- *Polymer cutting times*
- *Ergonomics*

1.6 Present Production

1.6.1 The Physical layout

The production facility has two mixing lines, the *Black line* used for mixing dark and black polymers and the *White line* used for mixing white and lighter coloured polymers. This thesis will be delimited to the Black line. Given that the Black line by far is the largest in terms of production quantity, focusing on this line has the greatest potential to positively impact the production facility as a whole.

The production facility also includes a chemical preparation station. This station is used for weighing and preparing the chemicals that are mixed together with the polymer. The production flow of chemicals as well as the chemical preparation station are not included in this thesis. The production layout of the mixing department can be seen in Figure 3.

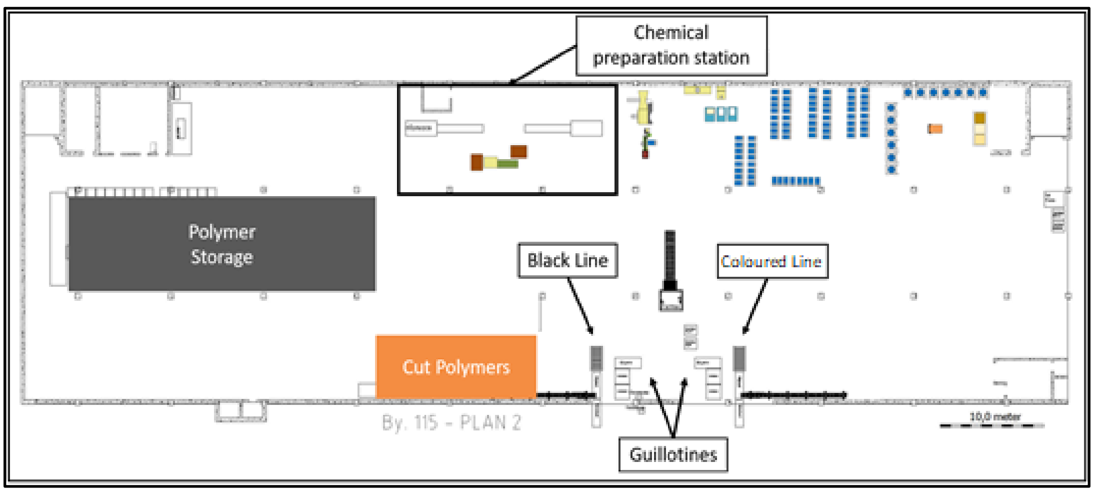

Figure 3: The current production layout of Mixing

The *Polymer Storage* consists of bins containing polymer slabs. The bins stand directly on the floor and can be transported using a forklift. An example of a bin can be seen in Figure 4 below. The Cut Polymer Storage consists of cut pieces of polymer which have been placed on pallet sized steel trays, see Figure 5 below.

Figure 4: The polymer bins in which polymer is delivered from the suppliers

Figure 5: Steel trays loaded with cut pieces of polymer

1.6.2 The Present Production flow

An order consists of multiple batches, between 1 and 99 batches. The polymer which is cut is the excess weight that is needed in addition to the weight of whole slabs. As an example, if a batch needs 30 kg of a certain polymer and a whole slab weighs 25 kg. A 5 kg piece of polymer will be cut up.

The first production step for an order is to cut up pieces of polymer. The polymers needed are transported by forklift from the polymer storage to the guillotines. At the guillotine station, operators weigh the whole slab and measure the length, as depicted in Figure 6 below. The operator then marks the point on the slab where a cut is needed to reach the desired weight. Using the laser line shown in Figure 6 below, the operator manually aligns the point on the slab with the laser line. Once aligned, the operator initiates the cutting sequence. Lastly, the operator control weighs the cut piece and makes any necessary adjustments. This production step is repeated until the whole order has been cut.

Figure 6: Measuring the length of a polymer slab, and a look inside the guillotine where a laser shows where the knife is going to cut

When the polymers have been cut, they are placed on pallet sized steel trays and transported to the *Cut Polymer Storage* area. This concludes the polymer preparation stage.

After the polymer preparation stage, the mixing stage is initiated. When initiating mixing of an order, cut polymer and whole slabs of polymer are collected from the *Cut Polymer Storage* and the *Polymer storage* respectively. The chemical components are also retrieved from the *chemical preparation station*.

At the mixing station the sequence for one batch is as follows. Whole slabs, cut pieces and chemicals are placed on the conveyor belt leading into the mixer. The operator then verifies the different components and initiates the mixing process. This is repeated for all batches in the order.

1.6.3 Auto-Guillotine

The Auto-Guillotine is a machine that has just been developed at Trelleborg AB. The machine is the first of its kind, with a main aim to automate the cutting process of polymers.

The Auto-Guillotine is loaded with whole polymer slabs which are weighed and cut to the correct weight automatically. When using the auto-guillotine, an operator chooses which order to cut polymer for. The operator then loads whole polymer slabs onto the *Loading Conveyor*, see Figure 7. The slabs then move to the *weighing conveyor* which determines where to cut the slab in order to reach the desired weight. The slab is then cut in the *guillotine*. The cycle time of the cutting sequence is measured to be 45s.

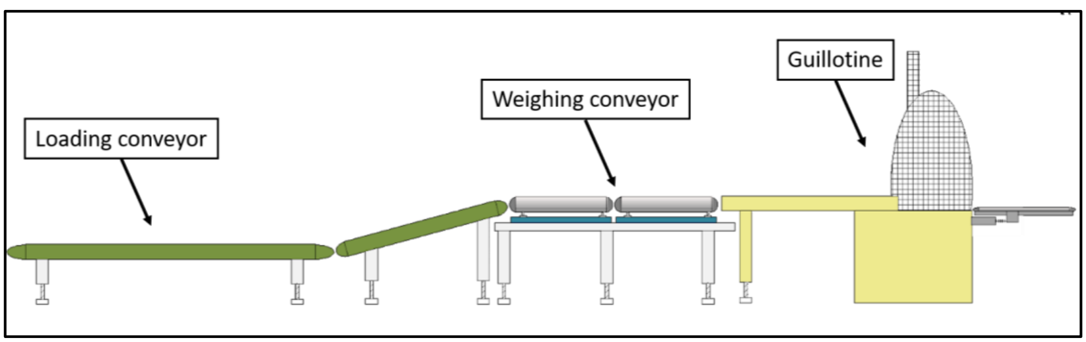

Figure 7: A sketch of the Auto-guillotine

The Auto-guillotine has already been built and is functional. However, it is not yet used in production. The Auto-Guillotine is available as a component in the production flows which are created and evaluated in this thesis.

2. Theoretical Framework

2.1 Lean Production

This chapter will discuss the theoretical and historical background of Lean and its principles. The tools related to these principles are presented in order to provide a basis for the Lean analysis.

2.1.1 The history of Lean

The concept of Lean production has its origins in the factories of Toyota Motor Corporation in Japan. Toyota developed a methodology called Toyota Production System (TPS), which had the aim to increase the factories' efficiency, see figure 8. The creation and development of TPS is attributed to the Chief of Production at Toyota at the time, Taiichi Ohno. The methodology's central point is to reduce waste and non-value-adding activities. In the book "The Machine That Changed the World", Lean as a concept was first introduced and after its release, Lean became a widespread methodology. The book is based on a research study on TPS which was carried out by Massachusetts Institute of Technology. [6] [7]

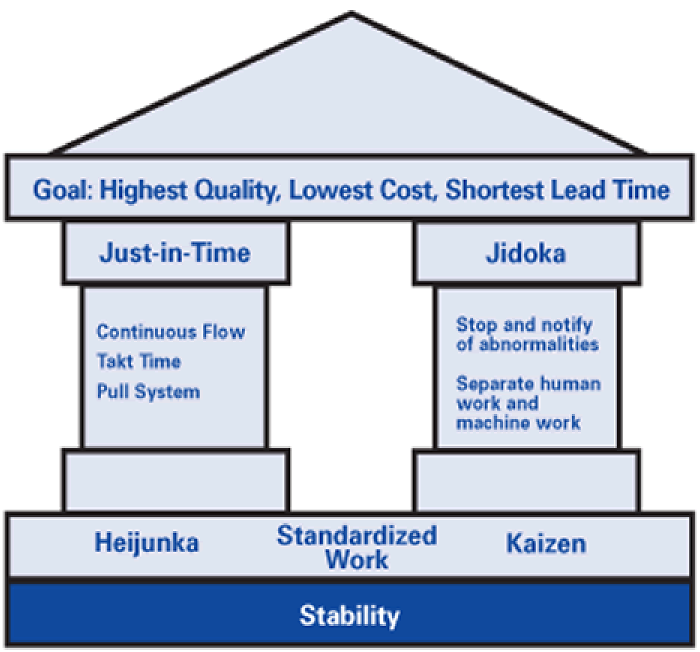

Figure 8: Toyota Production System [7]

2.1.2 The five Lean principles

The Lean methodology consists of five major principles, which can be found in figure 9. They were first introduced in Womack and Jones' book "The machine that changed the world". These principles create the foundation of all lean production and methods.

The first principle is to specify what *value* the process brings to the customer. It is important to clearly define what the customer is finding valuable and oppositely to find what is considered non-value adding. Historically, companies have had a tendency to focus their efforts on their own production metrics instead of focusing on what the customers value.

The second principle is to identify the *value stream*. The value stream is the series of processes in which the product goes through, from raw material to finished goods. The focus here lies in optimizing the whole supply chain as a whole, instead of suboptimizing each company in the chain. This follows the idea that the real competition lies between different supply chains and not within a supply chain between different companies.

The third Lean principle is to create *flow*. The main idea of this principle is to minimize queues and waiting time between value-adding activities. The value adding activities should never have to wait on the non-value adding activities to finish. Instead a flow of value adding activities should make up the production process.

The fourth principle of Lean is *pull* in the system. Pull refers to letting demand from the customer control the rate of production. It means to shorten reaction times and have minimal storage in the system. Furthermore, it aims to prevent overproduction and to keep the tied up capital of work in process goods to a minimum.

The fifth and final Lean principle is the pursuit of *perfection*. The perfection is divided into multiple aspects, such as product quality, delivery times, pricing and minimizing waste. This principle is most applicable when the production line is fully operational and it highlights the optimization work. There are several processes to follow in order to advance towards perfection. One of the most prominent concepts connected to this part of Lean is Continuous improvement, which strives to continuously optimize the production through incremental improvements [8].

Figure 9: The five principles of Lean

2.1.3 Differentiation to traditional improvement

There are a few fundamental differences between Lean improvement compared to traditional improvement. The key difference lies in the fact that traditional improvement is centered on improving the efficiency of individual parts of processes. Lean, on the other hand, focuses on improving the overall flow and removing wasteful activities. The traditional way runs a risk of suboptimizing and missing the 'big picture' of the overarching process. There is also a difference in the way that improvements are implemented. While the traditional way is to make large improvements sporadically, lean improvement is implemented frequently in small increments at a time. [8]

2.2 Tools

2.2.1 Value Stream mapping

Value stream mapping is a tool used to implement Lean concepts by identifying value and non-value adding activities. It has grown to become one of the most popular tools when investigating a more Lean way of production. VSM is used to map the flow of information and material within a production line or even through a product's entire life cycle. A Value stream map is a graphical representation of the different activities and their corresponding values, associated with producing a certain item. A map consists of standardised symbols and shows how value is added to a product through each step in production. A timeline also plays a crucial role in a VSM, in order to depict the value and non-value adding time spent [9].

Considering a VSM as a way of designing a future flow is important when using the tool. When mapping the as-is state, valuable information of the production process is gained. By scrutinizing the production process, all activities, even ones that are not commonly thought of, are mapped [10]. With this information, a future process can be mapped and discussed by also using a VSM.

When using a VSM in order to analyse the as-is state and future flows , an important step is to define the values. Finding the correct values can prove difficult, since companies often do not keep track of the exact value added in each step of the production process. Furthermore, value is not precisely defined, and can therefore be interpreted in different ways [9].

2.2.2 Spaghetti diagram

The spaghetti diagram is a commonly used tool within the Lean toolbox. Its idea is very simple, namely to follow an entity throughout its journey and document its movements. The next step is to create a visual representation of the journey, by sketching it on a factory layout map. The aim of this diagram is to expose unnecessary transportation and inefficient placement of working stations [8].

2.3 Traceability in Manufacturing

The concept of traceability in manufacturing has become ever more important as customers demand more insight into a product's composition and life cycle. The term can broadly be defined as identifying an entity and being able to see information such as its history and location, at any stage in its life cycle [11]. The extent to which information is traced in the production, depends on the level of detail needed for each product. By implementing or refining traceability in production, operations can receive insight into: what stages of production might be more problematic, better control of inventory levels, provide customers with more detailed product information etcetera [12].

Choosing the correct product identification method is crucial in order for a traceability system to work efficiently. There are two different ways of providing an entity with identification: direct or indirect marking. In the direct marking method an identifier is etched or printed onto the surface of an entity, common examples are laser marking and lithography. When using the direct marking method, a separate carrier is used for identification. Examples of indirect marking identifiers are barcodes or RFID tags [12].

2.4 Automation

Humans have utilized automation throughout history, with inventions ranging from windmills to the automatic loom. Though, modern automation has its roots in the 1950s at Ford Motor Company. The manufacturing principles developed at Ford, clearly described how the use of machines could replace human labor in many regards [13].

There is no universal definition of the term automation. However, according to Nof [13], automation implies "*operating or acting, or self-regulating, independently, without human intervention*". Hence, automation is a comprehensive category, concerning machines and systems which operate and complete tasks without the need of humans. Automation is often regarded as the combination of the following four disciplines: *Mechanization*, *Automatic control*, *Process continuity* and *Automation Rationalization* [13].

As mentioned above, mechanization is one of the subareas of automation. Mechanization refers to "the application of machines to perform work" [13]. There are several potential benefits with mechanization, such as higher efficiency and speed, and a safer system. It can also enable the system to complete tasks that before were impossible. Automatic control is another related sub category of automation. Automatic control is making use of both external input as well as feedback in order to update its output. In other words, with automatic control, the process can adjust itself without any intervention required. Process continuity refers to the creation of flow in the production process, in order to enable a higher efficiency. The assembly lines at Ford is one of the first implementations of process continuity. Automation Rationalization is the systematic planning and control of the process which is automated. It takes constraints, resources and implementation issues into consideration, and aims to optimize the final solution [13].

2.5 Prototyping

A prototype is a physical or virtual representation of an idea or concept, the definitions of a prototype do however differ between different disciplines. The different types of prototypes can be split into two main areas, the *Design prototype* and the *Functional prototype* [14].

A design prototype is commonly used in the beginning of a development project in order to represent an idea and define the scope of the issue at hand. Later on in the development phase, the design prototype can also come to incorporate functionality, however, focus shall be kept on the user and how this person interacts with the intended system or product. Since a design prototype most often is of low fidelity e.g. a virtual model, a sketch or a simple model, changes can be made at low cost. This enables the development to work iteratively and take multiple considerations into account [15].

When constructing a new product or system, it is essential to make sure that the functionality of the product is sufficient and possible to achieve. The role of a functional prototype is to prove whether the functionality of a product or system meets the criteria that have previously been set. A functional prototype is generally constructed during later stages of development, since the cost of altering rises significantly compared to a design prototype. Today, the goal of the functional prototype is to ensure that the results from previous steps of the development phase are possible to achieve and put into production. In the future however, the goal is to be able to combine the design and functional prototype at an early stage of development in order to avoid constructing a prototype that does not meet its intended functionality. Enabling this combination will be based on finding more cost effective ways of building functional prototypes [15].

3. Methodology

3.1 Methodology Structure

The Methodology follows the structure of a five step process, see figure 10, where data is gathered and analysed, it is then upon this data which new flows are designed. Firstly, data is collected, it is then analysed using various tools. With the results from these steps, requirements and limitations of future systems are determined. The design of new production flows is then built atop the insights gained from previous steps. Resulting production flows are then evaluated and compared in terms of feasibility and efficiency. Finally, critical components of the recommended production flow are prototyped as proof of concept.

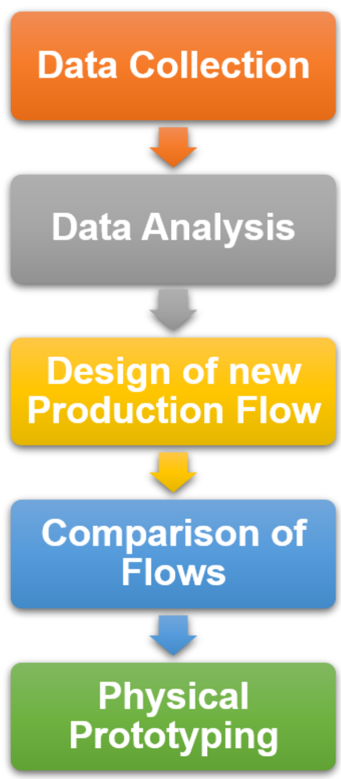

Figure 10: Methodology structure

3.1 Data collection

Before the improvement design phase could be conducted, extensive analysis of the current situation was performed. The analysis consisted of a mix between quantitative and qualitative data.

The first step of data collection was to determine what data was needed for the analysis. The tools of Lean has a number of parameters which need to be collected. Furthermore, the goals of the thesis were clear in terms of what metrics needed to be improved. On the basis of these parameters, discussions with the Company Supervisor were held. These discussions provided a basis of what data was possible to gather and the ways in which they could be collected.

3.1.1 Qualitative data gathering

The gathered qualitative data was obtained via interviews with multiple involved parties. Information regarding the workflow, workstations and the production, was given by the production line's operators. These interviews were semi-structured, where questions were prepared beforehand. The questions were then used as a starting point for the discussions. During the interviews, notes were taken on paper and then transferred to a computer document which summarised the findings of the interview notes. This document was also used to compare answers from the same question asked to multiple interviewees, with the intention of finding answers less dependent on any specific interviewee.

Additionally, the processes were mapped by spectating the workflow when the production line was operating. Data related to the organization and management of production, was gathered by interviewing the production planner. Advice and information regarding technical constraints, automation and mechanical components, were collected from interviews with the process engineer.

3.1.2 Quantitative data gathering

The quantitative data was gathered through physical measurements as well as extracts from Trelleborg's databases. The physical measurements consisted of timing current production in the factory, measuring the areas which were available for a new production flow, and measuring the distances traveled by the forklifts. Longer distances, such as the distance travelled by forklifts was measured manually using a measuring wheel. Smaller areas and distances were measured using tape measure or folding rule. These distances were then noted on paper and later transferred to a computer document. There is a possibility of measurement errors in the measurement of distance travelled by forklift. This is due to the fact that operators take slightly different routes when transporting polymer, which led to that the real route might not always correspond to the one which was travelled when manually measuring. Additionally, the distances measured were of substantial length which might have increased the impact of smaller errors. However, these differences should not have impacted the results in any significant way.

The extracts from Trelleborg’s databases consisted of data on past productions and components of products, which were analysed and cross-referenced using Excel.

3.2 Data analysis

When all relevant information had been gathered, the data was analysed with the assistance of multiple tools.

3.2.1 Production data analysis

When analysing the current production mix, two extracts were used. The first extract consisted of production data from 2020, and the second extract contained the components of each article. These extracts were then cross referenced and analysed using Excel as the main tool. The information was then consolidated and visualised. This visual depiction served as a basis for discussion during further interviews. The consolidated information served as a quantitative complement to the information gathered during the interviews, and created an understanding of the current production and product mix. Together with the interviews, they formed a solid information base on which a new production flow could be designed.

3.2.2 Value Stream Analysis

The value stream mapping and the Spaghetti Diagram were based on the production line’s main article. Through the performed data analysis, the most produced item was chosen. The article was also confirmed by the production staff as having a production process with close resemblance to how the rest of the articles are processed.

The gathered data regarding the production flow was then mapped by using the Lean tool Value Stream Map. During this process, both the value adding and the non-value adding activities were mapped.

In addition to the Value Stream Map, a Spaghetti diagram was created. The spaghetti diagram focused on the movement of the forklift, and enabled a visual representation of how much forklift transportation that one order required. The Spaghetti diagram also provided information regarding what parts of the production floor that was visited the most. These findings could then be used when designing the improved production flow.

3.3 Design of Improved Production flow

The principles of Lean production served as the basis upon which the new production flows were designed. In order to enable a better *flow*, the new layout would minimize waiting times, and make sure that the non-value adding activities would not hinder any value-adding. Furthermore, the changeover times would need to be kept to a minimum in order to allow for more *pull* in the system. A final consideration of a new production flow was to produce a flow which could be continuously improved once it is operational. Modularity of the new layout served as an important tool in order to simplify improvements of the system during operation.

In accordance with the lean principles, the design process included the different types of flow in production. Apart from the product flow, the operator and information flow was considered throughout the design process. By considering these secondary flows constraints regarding personnel and traceability could be included and analysed.

The new production flows were designed using Visio as the design tool, which enabled easy access to changing the layout to accommodate different aspects. The development of new production flows was done iteratively, with input from the process engineer and production staff during early stages. As the project progressed, a wider range of stakeholders, such as mechanics and upper management, provided input. This process ensured production flows deemed feasible by all relevant stakeholders.

3.4 Comparison between possible production flows

When the possible production flows had been finalized, they were individually evaluated on a number of criteria.

Based on these metrics together with the constraints and goals provided by Trelleborg, one of the possible solutions was selected as the recommended production flow. Components of the recommended flow were then physically prototyped.

3.5 Physical prototyping

In order to demonstrate the recommended production flow, as well as ensuring its feasibility, the production flow was physically prototyped. More specifically, the physical prototypes were focused on the most critical technical parts of the production flow. These will serve as proof-of-concept for the final implementation of the improved production line.

The material and tools needed for the physical prototypes were provided by the workshop of Trelleborg. The parts which could not be constructed at the Trelleborg site, were designed and then ordered from third-party mechanics shops.

4. Results

4.1 Current Situation Analysis

The Current Situation Analysis is comprised of the areas: *Production data analysis*, *Value Stream Map*, *Spaghetti Diagram* and *Information gathered from interviews*. The Production data analysis is primarily based on the extracts from the Trelleborg Production Database. Correspondingly, the remaining areas are predominantly based on qualitative data and physical measurements conducted at the production floor.

4.1.1 Production data analysis

The number of batches mixed each production day during 2020 was firstly analysed. The data was synthesized into a diagram which is shown below in Figure 11. Many orders require two mixing stages, however in those cases only the first mixing stage was registered. The reason behind this is that the second mixing requires no additional polymers and hence is not relevant in the context of the thesis. This explains why, in Figure 11, the highest peaks are followed by lower values, where instead the second mixing is performed.

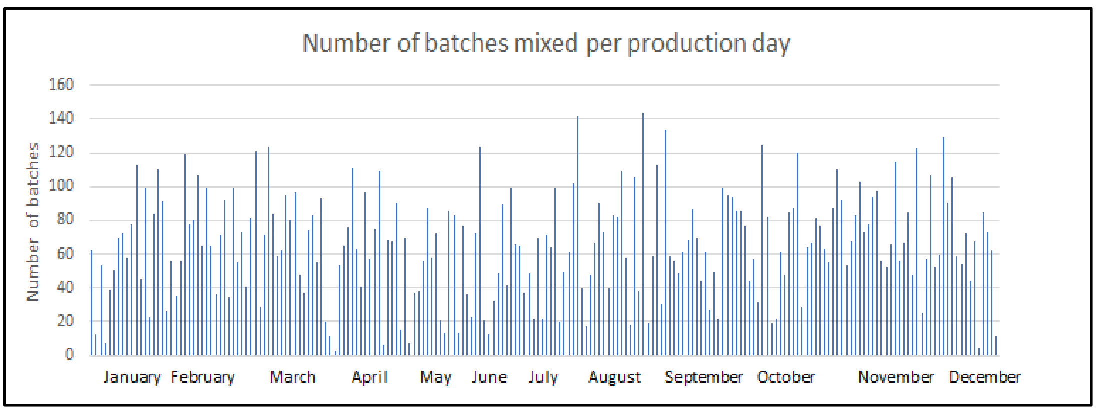

Figure 11: Number of batches mixed per production day, in 2020

From the diagram above, some key findings were made. Firstly, it is evident that the number of batches fluctuates greatly from day-to-day. Secondly, the mean, median and maximum values can be extracted. The values are presented in Table 1 below.

Table 1: Mean, Median and Maximum number of batches produced per day in 2020

Description	Value
Mean: number of batches/day	65
Median: number of batches/day	65
Max: number of batches/day	144

Table 1 shows that the maximum number of batches per day is substantially higher than the mean value. A conclusion which can be drawn from this finding is that a proposed solution would need to be flexible enough to effectively handle both a relatively small number of batches on normal days as well as having the capacity to manage a large number of batches at peak days.

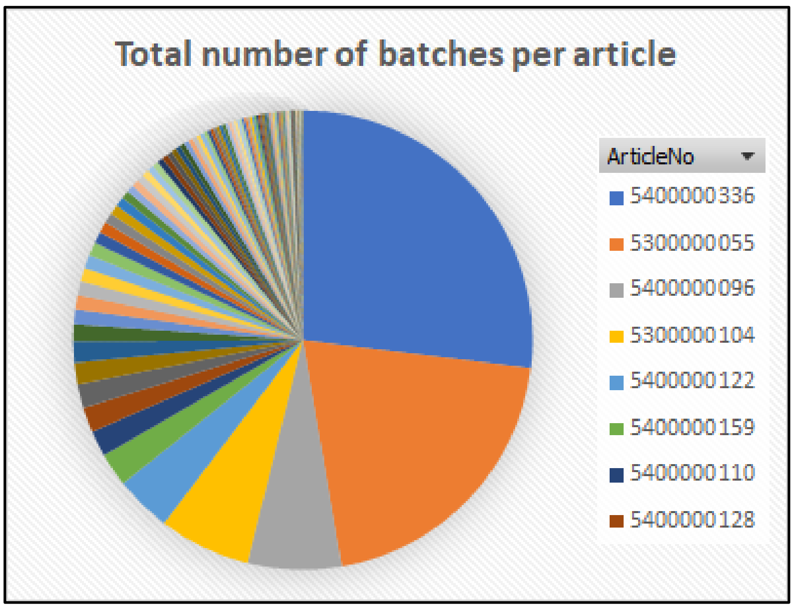

Figure 12: Total number of batches produced per article, in 2020

The product mix was also analysed, by comparing the total number of batches per article. The results were combined into the pie chart shown in Figure 12. As can be seen, there are two articles which account for nearly 50 % of the total batches produced. The other half of the chart is, however, composed of articles with small quantities. The key points from this chart are that the current product mix requires flexibility in terms of changeover times, especially when producing smaller orders. On the other hand, the system must be able to efficiently handle large quantities of articles *5400000336* and *5300000055*, since they amount to just under 50% of batches produced.

The polymers used in production were analysed and a pie chart was composed, shown in Figure 13. The three polymers *Polymer 1*, *Polymer 2* and *Polymer 3* , make up almost 60 % of the total polymer consumption. This information will need to be taken into account when designing the polymer storage.

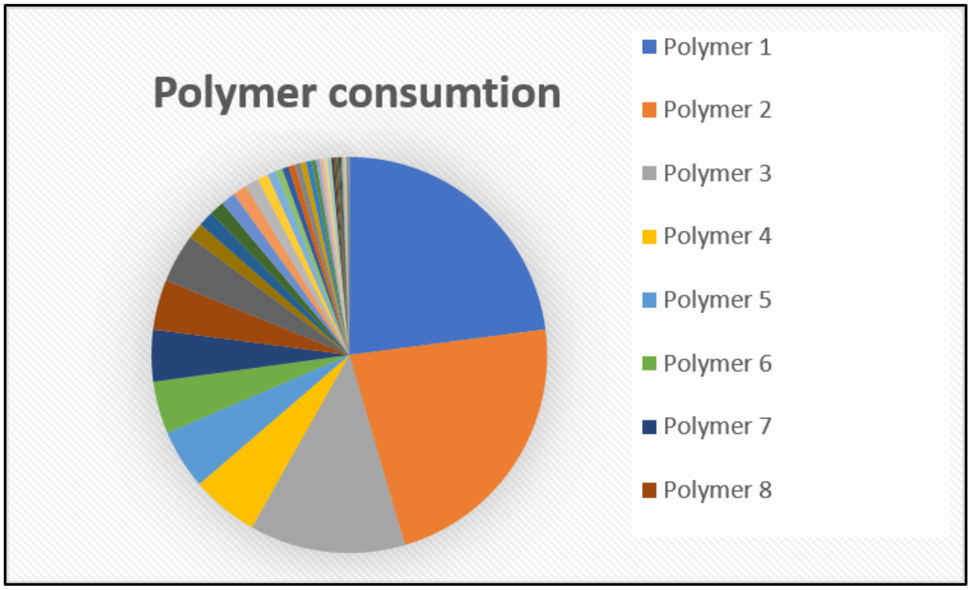

Figure 13: Polymer consumtion during 2020

In order to investigate the time it takes to mix the batches, the most common article, *5400000336*, was analyzed. From interviews with the production operators, information was given that this article's time per batch can serve as an approximation of the average time per batch across articles. A histogram was created and is shown in Figure 14. Underflow and Overflow bins were added, in order to handle anomalies and transitions across shifts. From the histogram, it can be concluded that most batches have a mixing time of X to Y minutes. More precisely, a median value was calculated which is shown in Table 2. The median value was used to represent the time per batch in further analysis, in order to minimize impact of the anomalies as discussed above. Because of the confidentiality of the batch mixing time, this information has been removed from the report.

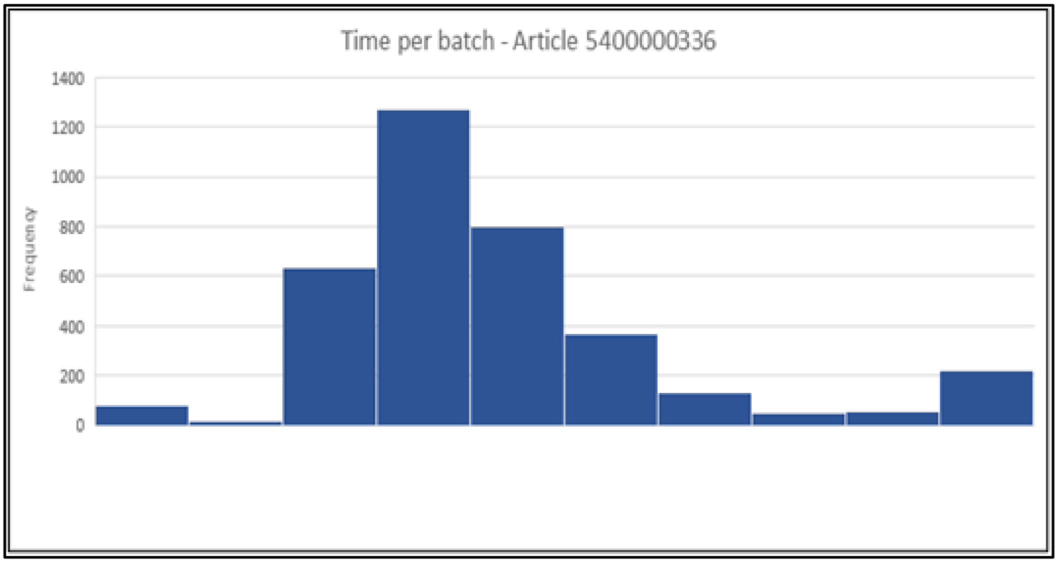

Figure 14: Histogram of mixing time per batch of 5400000336, in 2020

Table 2: Median mixing time per batch of 5400000336, in 2020

Description	Value
Median: Time per batch	00:XX:YY

The number of different polymers needed per batch was also studied. The mean and the maximum value were extracted from the data and can be found in Table 3. Each batch requires either 1, 2 or 3 different polymers. The different polymers require separate storage once cut, in order to enable individual control weighing of each polymer. The average number of batches per order, was also analyzed and the results can be found in Table 4 below.

Table 3: Mean and maximum number of polymers per batch, during 2020

Description	Value
Mean: Number of polymers/batch	1,65
Max: Number of polymers/batch	3

Table 4: Mean number of batches per order, during 2020

Description	Value
Mean: Number of batches / order	16,1

4.1.2 Value Stream Map analysis

A Value Stream Map was composed, in order to gather insights into the value adding activities performed during the production process. The resulting map can be found in Figure 15. The mapping activity revealed that the current production process only has two value adding activities, *Polymer Cutting* and *Mixing*. All other activities such as storage and transportation are non-value adding.

An additional conclusion which can be drawn from the VSM is that the value-adding activities of today are rather time consuming. Since the mixing stage is outside of this thesis's scope, the improvements which will be presented in this thesis will focus on reducing the operator time spent cutting, as well as minimising non-value adding activities.

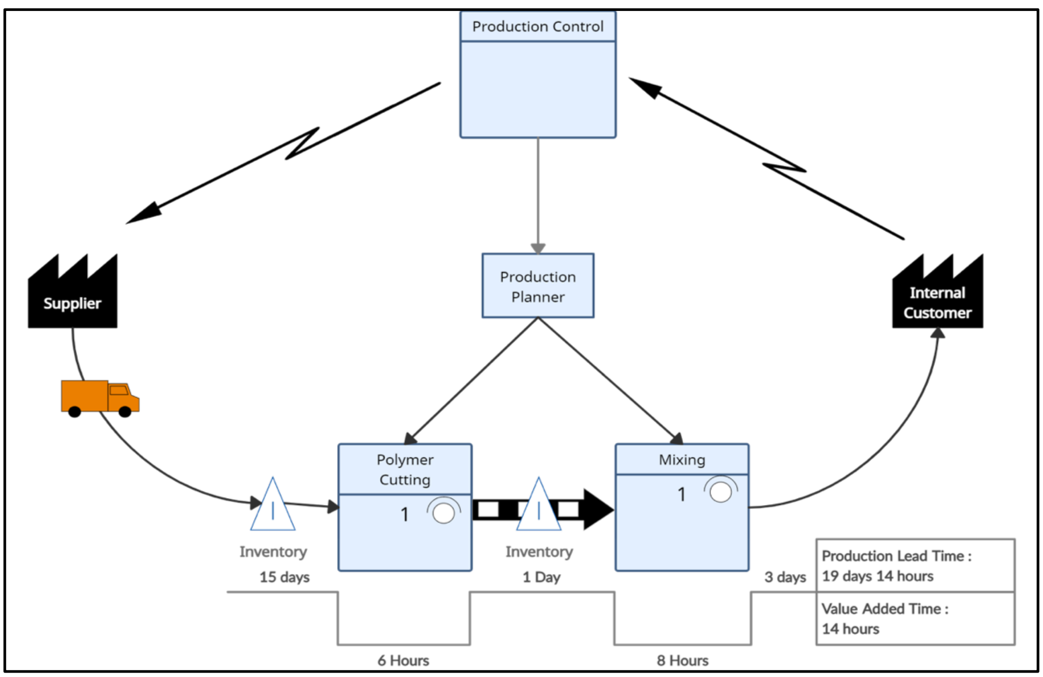

Figure 15: Value Stream Map of the Polymer mixing process

4.1.3 Spaghetti Diagram

A spaghetti diagram was made in order to map and visualise the movement which a forklift would have to perform when cutting and mixing an order. The article under examination was *5400000336*. This article was chosen since it, like most articles, contains two polymers. In addition, it is the most common article produced in the factory. The distance between different stations in the factory was measured as well as the movement of the truck between the aforementioned points during the cutting and mixing phase. The results from the spaghetti diagram can be seen in Appendix A and Figure 16. The main conclusion which can be drawn from the spaghetti diagram is that the forklift moves a total distance of 3538m when preparing and mixing polymer for an order. The diagram also highlights the inefficient flow between the polymer storage, the guillotine and the mixer.

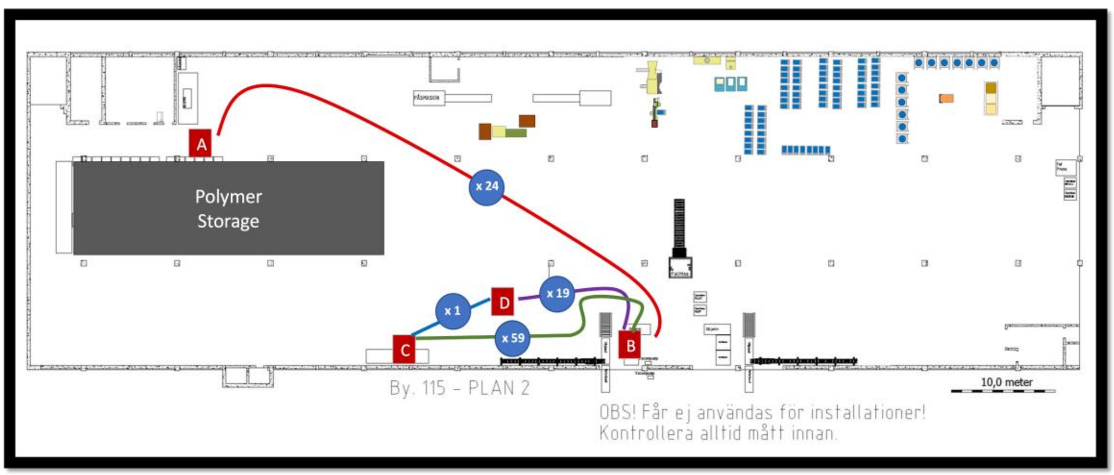

Figure 16: Spaghetti diagram of the current forklift transportation

4.1.4 Information gathered from interviews

The information presented in this chapter has been extracted from interviews with production staff and process engineers.

As of today, Trelleborg has a set time of 10 minutes between orders. During this time, operators clean scrap pieces of polymer compound from the mixer, as well as prepare components for the coming order.

Currently, cutting an order of article *5400000336* takes one operator approximately 6 hours to complete, which was further verified through rough time measurements. This time includes all steps in the cutting process, from order until all batches have been cut.

4.2 Requirements for a new production flow

This chapter will serve as a summation of the findings from the current situation analysis. In combination with the goals of the thesis, a requirements list was developed. Upon this requirements list, the future flows will be based.

4.2.1 Forklift Transportation

According to the thesis' initial objectives, forklift transportation should be decreased with at least 20%. From chapter 4.1.3, the current distance travelled by the forklift during an order of *5400000336* amounted to 3538 meters. Hence, a new polymer handling flow should result in a total transportation of: $80\% \times 3538\, meters \approx 2830\, meters.$

Through interviews with production management, all operator led transportation within the factory should be performed using forklifts. Thus, transportation vessels must be able to be lifted by a forklift. Additionally, the vessels have weight limitations. The maximum floor pressure per m^2 is 1000kg. This means that a vessel with the base of a euro-pallet cannot weigh more than: $0{,}9m \times 1{,}2m \times 1000kg/m = 960kg.$

4.2.2 Changeover times

The median mixing time was previously found to be XX min YYs, which will be used to represent the mixing time per batch. The changeover time between batches within the same order, cannot exceed the mixing time. Hence, the changeover time between batches cannot exceed XX min YYs.

As described in chapter 4.1.4, the set time between mixing orders is 10 minutes. If the changeover time between orders would be longer than that time, it would slow down the entire process. Hence, a new polymer handling flow should not have a changeover time between orders which exceeds 10 minutes.

4.2.3 Capacity

The analysis of production intensity presented in chapter 4.1.1 revealed that the average number of batches produced per day was 65 during 2020. However, during the most productive day, 144 batches were produced. Furthermore, one of the goals of this thesis is to produce a solution which can handle a 50% increase in production. Since a new solution must be able to handle peak days, this requires a daily capacity of : $150\% \times 144\ batches = 216\ batches$.

4.2.4 Polymer Cutting

As found in interviews, the total time spent cutting polymer pieces for an order of *5400000336* is 6 hours. As stated in the goal-section of the thesis, this time should be reduced by 50%. Hence, a new polymer handling flow shall enable workers to only spend $50\% \times 6\ hours = 3\ hours$on cutting.

4.2.5 Summary of Requirements

A summarizing visualization of the requirements found in the analysis, is shown in Figure 17. These requirements created the basis for the development of improved production flows.

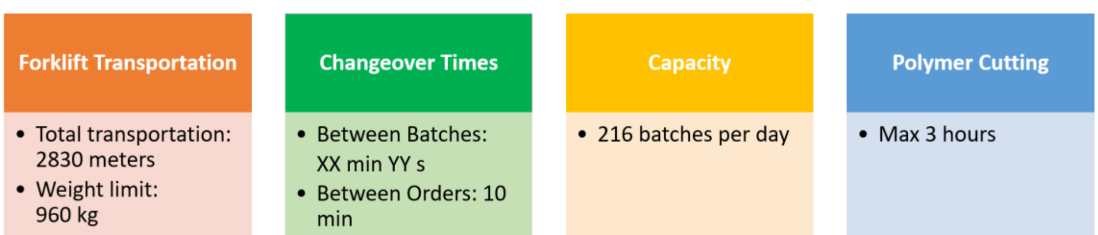

Figure 17: The requirements for a new polymer handling process

4.3 Production flow designs

4.3.1 Chapter Structure

In this chapter, new production flow designs will be presented and compared. The flows which are presented differ in a number of ways. However, there are some changes which are common for all of the solutions presented. These improvement suggestions are introduced in chapter 4.3.2 General Improvements. The two production flows are then presented individually. These production flows are the results of theoretical analysis combined with interviews focused on feasibility of implementation together with production managers. The structure of this chapter is illustrated in figure 18.

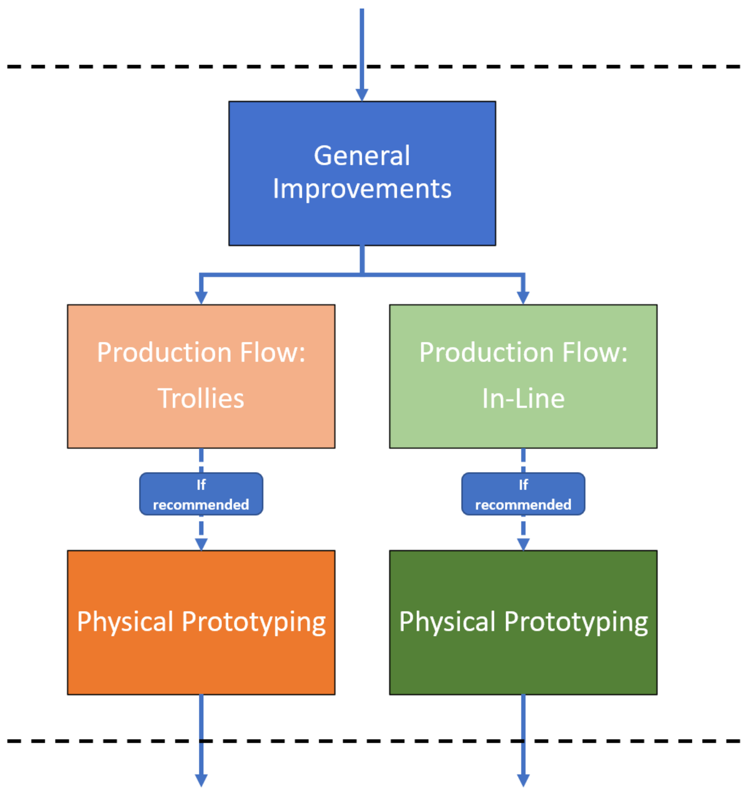

Figure 18: Structure of the chapter on new production flow designs

4.3.2 General improvements

4.3.2.1 Polymer Storage

As of today, the bins with whole slabs of polymers are picked up from point A in Figure 16. By changing sides where these bins are picked up, from the red to the green side in Figure 19, the distance travelled by forklift will be reduced.

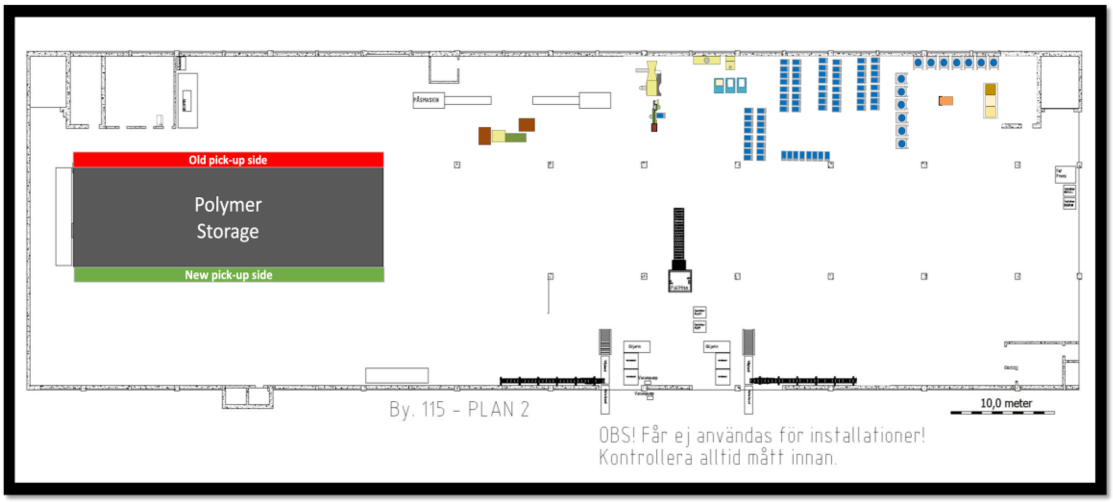

Figure 19: New pickup-side of the polymer bins

Additionally, the placement of different polymers were improved. From chapter 4.1.1, it was concluded that three polymers made up approximately 60% of the polymer used. These were *Polymer 1*, *Polymer 2* and *Polymer 3*. In order to minimize the forklift transportation, these polymers should be placed at the far right of the Polymer Storage seen in Figure 19.

4.3.2.2 Auto-Guillotine

Both production flows will make use of the auto-guillotine. The auto-guillotine measures and cuts each polymer slab exactly to the weight needed for each batch. In addition to the improved accuracy of cut polymer pieces, cutting an order will only result in one residual piece of polymer, since the auto-guillotine control weighs each piece and adjusts to the batch set weight. While the cutting sequence is not greatly affected by introducing the auto-guillotine, it enables the operator to do all in-between steps while the auto-guillotine is cutting. This is possible since the operator can load the auto-guillotine with multiple slabs, and then have a window where they can perform the supporting tasks, such as collecting the bins and storing the cut polymer. From the analysis, these supporting tasks have been shown to be the most time-consuming parts of the cutting process.

4.3.3 Production flow: Trolleys

The first proposed production flow will make use of trolleys in order to store the cut polymer pieces. The trolleys' vertical storage will enable a more space-efficient storage compared to the steel trays used today. It will also enable storage of individual batches, thus creating better opportunities for traceability. Furthermore, operators will not have to keep track of which pieces of cut polymer belong to what order, leading to less human created errors.

4.3.3.1 Trolley design

The trolley is the chosen container on which cut pieces of polymer will be stored and transported throughout the production flow. The trolleys will consist of a steel base of the same size as a euro-pallet, 1200x800mm. Each trolley will have nine stories and each story will consist of two trays. One trolley will thereby store a maximum of: $9\ storeys \times 2\ trays/storey = 18\ compartments$, or 9 batches given 2 polymer compartments per batch. To facilitate the 216 batches, which was determined in chapter 4.2.5, there is a need of: $216 \div 9 = 24\ trolleys$. Hence, the production flow presented, shall have a capacity of 24 trolleys. As can be found in Appendix B, each trolley will weigh approximately 397 kg. Given a set weight of 20kg per polymer in a fully loaded trolley, it will weigh a total of: $397kg + 30kg * 18 = 937kg$. This is below the maximum weight of 960kg. A 3D-model of the trolley is shown in figure 20.

Figure 20: 3D-sketch of the trolley

4.3.3.2 Loading onto trolley

The polymer is firstly cut by the auto-guillotine and then directly weighed using a weigher conveyor belt. The polymer is then transported onto a buffer band which can move vertically. The buffer band is then moved vertically until it reaches the height of the correct trolley story. Lastly, the polymer is pushed, using a piston, onto the trolley. A 3D model of how the loading station might look like can be seen in figure 21. The purple conveyor belt is the weighing belt, coming directly from the auto-guillotine. The piston will be powered by air-pressure and will be moving vertically by two chains which run along the red rack's right side. Similarly, the buffer conveyor will move vertically by two chains which run along the red and green racks' left side.

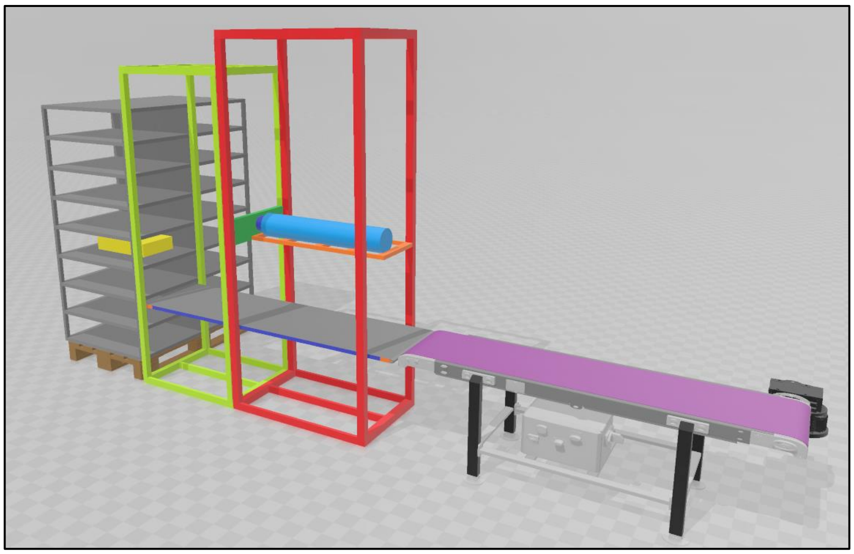

Figure 21: 3D-sketch of the onloading-station

4.3.3.3 Cut Polymer Storage

Once each trolley has been filled with cut pieces of polymer, they will need to be stored before mixing. This flow will make use of a floor storage, where the trolleys will be placed on marked areas within the production layout. The storage will consist of a 3x13 grid, where trolleys belonging to the same order can be placed in front of each other, while trolleys which do not, are placed in separate rows. A large display will also be mounted above the floor storage in order for operators to see which trolleys to collect for mixing.

4.3.3.4 Loading off trolley

When unloading the cut pieces from the trolleys, a set of pistons will be used. The pistons will be powered by air pressure. Once the pieces have been pushed off the trolley, they will be control weighed on a weighing conveyor. Thereafter, the pieces will move on a conveyor towards the mixer and will be fed onto the mixing conveyor when the operator begins preparing the next batch to be mixed.

4.3.2.5 Trolley transportation

The empty trolleys will automatically be transported on a chain conveyor back towards the guillotine. This chain conveyor also serves as storage for the empty trolleys. Implementing this conveyor solution will eliminate all transportation of empty trolleys.

4.3.3.6 Operator flow

The flow of operators have been mapped and can be found in Appendix C. The cutting phase and the mixing phase are both run individually by one operator each. The two flows can be executed independently, as long as there are cut orders which the mixing operator can mix.

4.3.3.7 Production layout

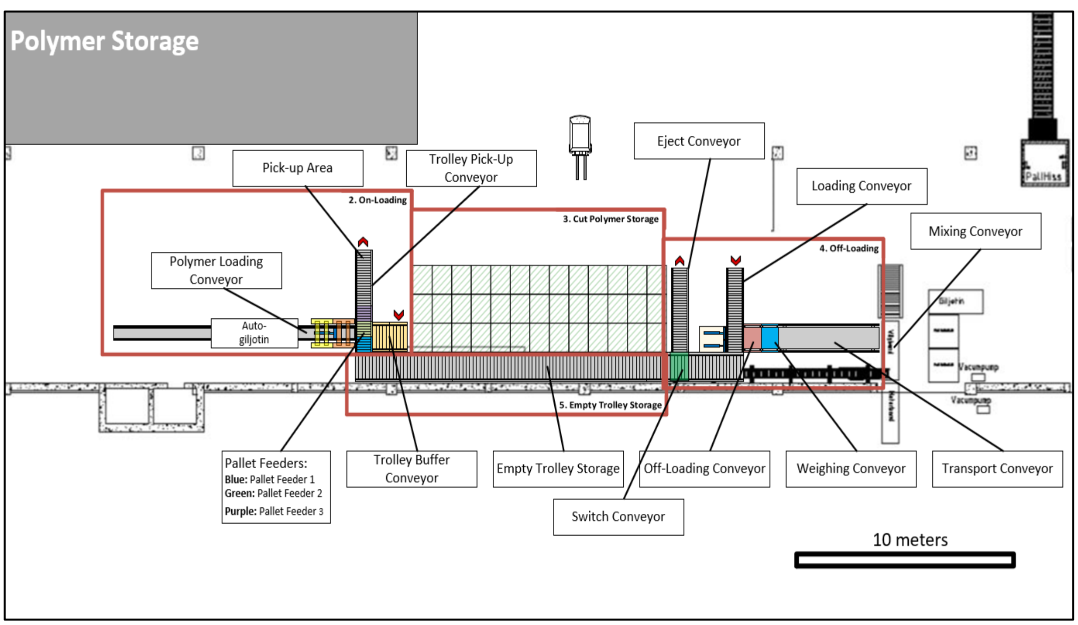

Figure 22: Layout with captions of how the proposed trolley flow

The new production flow is placed along the southern wall of the factory, and can be seen in figure 22 above. Whole polymer slabs are placed on a conveyor belt leading into the auto-guillotine. When a piece has been cut, it moves onto a weighing conveyor which then leads onto a buffer conveyor. The buffer conveyor can move vertically in order to align with the correct story on the trolley. The cut piece is then pushed onto the trolley with the help of a piston. This sequence is repeated until the order is finished, or the trolley is full. Up to three trolleys can be loaded without operator intervention. If the order requires multiple polymers, the three trolleys are loaded as follows:

1. Polymer 1 is loaded onto the leftmost conveyor belt and cut by the Auto-guillotine.
2. Trolley 1 is transported to the loading area.
3. Trolley 1 is loaded with the cut Polymer 1.
4. When trolley 1 is fully loaded, it is transported sideways to the yellow buffer conveyors.
5. Trolley 2 is then following the same procedure as Trolley 1 in steps 2 - 4.
6. Trolley 3 is then transported to the loading area.
7. When Trolley 3 has been fully loaded with Polymer 1, the operator starts to feed the leftmost conveyor with Polymer 2 instead.
8. The cut Polymer 2 is loaded onto Trolley 3.
9. When Trolley 3 is fully loaded, it is transported onto the pickup conveyor.
10. Trolley 2 is then transported from the yellow buffer conveyor, and onto the loading area.
11. Trolley 2 is then following the same procedure as Trolley 3 in steps 8 - 9.
12. Trolley 3 is then transported from the yellow buffer conveyor, and onto the loading area.
13. Trolley 3 is then following the same procedure as Trolley 3 in steps 8 - 9.
14. Now, all trolleys have been filled with both polymers. The operator transports the trolleys by forklift to the floor storage.

Filled trolleys are transported to the floor storage using a forklift. The floor storage is the green striped area in Figure 22. When initiating mixing of an order, a trolley is transported to the loading conveyor using a forklift.

If a trolley contains more than one order of cut polymers, and the remaining orders on the trolley shall be produced later, the trolley with the remaining polymer moves along to the eject-conveyor. This trolley is then transported back to the floor storage using a forklift, awaiting further production.

4.3.3.8 Traceability

Each trolley must be uniquely identified in order to enable traceability. The trolleys must thereby be equipped with a product identification method, such as RFID. Using an indirect identification method will ensure that the identifier is not worn out during usage, which is a risk when choosing to use a direct identification method such as an etched or laser printed identifier. Furthermore, the operator will scan the polymer bins before loading the polymer onto the auto-guillotine's loading conveyor. This will ensure that the cut polymers are traceable throughout the production flow.

4.3.4 Production flow: In-Line

The aim of the in-line production flow is to eliminate the buffer of cut polymer, as well as reducing the usage of forklift for transporting trays or other vessels carrying cut polymer. The production flow's main components are the multiple auto-guillotines, and a traverse robot fitted with a vision-system which can detect the exact position of individual polymer slabs. The in-line production flow will handle whole polymer slabs and cut them into the weight needed for a batch. Thus, operators will not need to lift any polymer slabs, or separate cut pieces.

4.3.4.1 Polymer bin placement

The most common articles produced contain two polymers, but some contain one or three different polymers. To facilitate the different articles in an in-line cutting setup, there needs to be three production lines, one for each polymer. The placement of polymer bins must thereby have three rows. These three rows each have their own conveyor belts and auto-guillotines.

The polymer bin placement area will consist of the three rows as described above.
Through interviews with production staff we found that during the requested changeover time between orders, which is 10 minutes, operators can replace six bins of polymer. Combining this with the fact that the most common articles contain two types of polymer, it is found that having three spots for each polymer is the most fitting solution.

4.3.4.2 Traverse robot

Instead of manual loading of polymer slabs onto the auto-guillotines' conveyors, a traverse robot loads the slabs onto the conveyors. The traverse robots will have a mounted vision system which identifies the individual polymer slabs. Hence, the traverse robot will identify a slab, pick it up and then load onto the conveyor belt. The traverse robot will pick up the polymer using an attachment placed on the robot. The attachment enables the robot to either screw into the polymer or to pull up the polymer using a vacuum powered lifting device.

4.3.4.3 Operator flow

Two operators will be needed at all times during production. The first operator will control the mixer and will also add all chemical and hand weighed components. The second operator will use the forklift to transport polymer bins to and from the polymer bin placement area. A more detailed operator flow can be found in Appendix D.

4.3.4.4 Production layout

The production layout will, just like the trolley flow, be placed along the southern wall of the factory. The polymer bins will be placed on the Polymer placement area. From these bins, the traverse robot will lift whole slabs of polymer onto the corresponding conveyor leading into the auto-guillotine. A batch might need more polymer than the weight of a single slab, in such a case the auto-guillotine will let a whole slab go through, and cut a piece which corresponds to the weight needed to reach the batch set weight. The polymer needed for a batch will be transported on a conveyor belt to the mixer. On the mixer-conveyor, the different types of polymer needed for the batch will land, the chemical components will be added, and the operator will initiate mixing of the batch.

Figure 23 below illustrates how the production layout might look like.

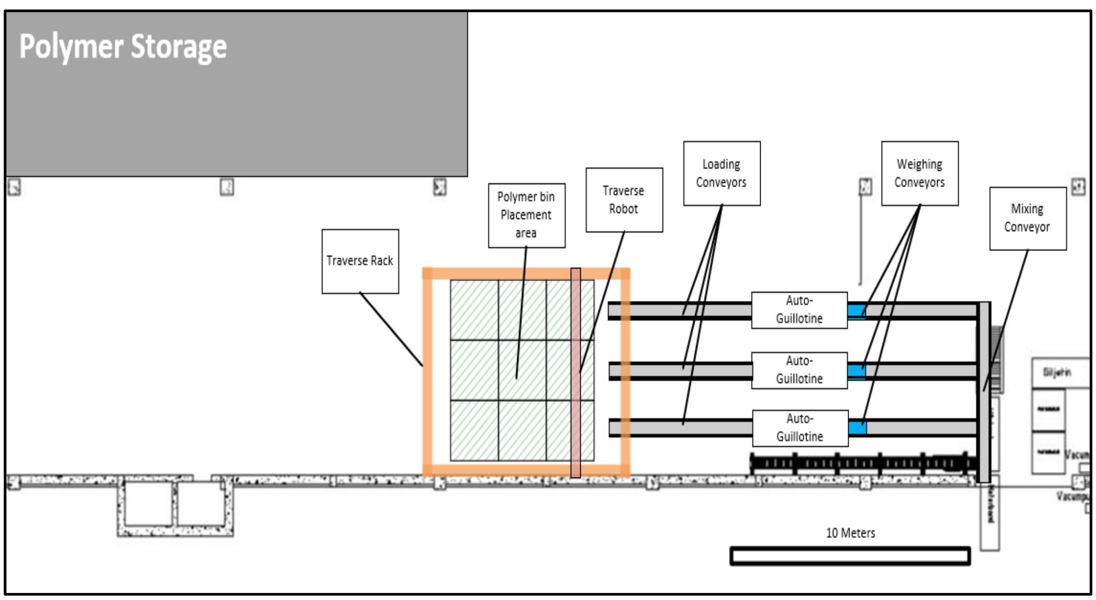

Figure 23: Layout with captions of the proposed in-line flow

4.3.4.5 Traceability

Since this is a closed production flow without a buffer storage, the production flow only needs an initial identification of the polymers. This is done by scanning the polymer bins before loading the polymer onto the auto-guillotines' loading conveyors. The polymers can then be traced throughout the production flow.

4.4 Production flow comparison

4.4.1 Comparison criteria

In order to compare the two production flows, they are evaluated on multiple criteria. The criteria are based on the requirements discussed in chapter 4.2. and are listed below:

- Polymer cutting time
- Forklift transportation
- Capacity
- Changeover times
- Number of Operators needed each shift
- Required floor area
- Risk level
- Ergonomics

4.4.2 Polymer cutting time

As was found in chapter 1.6.3 the auto-guillotine has a cutting sequence cycle time of 45 seconds. The in-line and trolley solution will make use of the same type of auto-guillotine, which means that both flows will have the same time spent on actually cutting the polymer. Since the in-line solution makes use of three separate auto-guillotines and will cut each type of polymer separately, it has the possibility of cutting faster. However, the speed of the in-line solution is dependent on the mixing time, which in chapter 4.1.1 was found to be XX min YY seconds. Followingly, the trolley solution's speed at which an order is cut will only depend on the cycle time of the guillotine.

Hence, the trolley solution has a cutting time of one order of 5400000336 which is: $96\ batches \times 2\ polymers/batch \times 45s/polymer\ cut = 8640s = 2h\ 24min.$

The in-line solution has a total cutting time of a similar order as described above which is determined to be 5 h 58 min. The calculation of the the in-line solution cutting time has been removed from the report because of confidnetiality reasons.

4.4.3 Forklift transportation

The total distance travelled by a forklift when operating the in-line and the trolley solution was calculated and can be found in Appendix E respectively Appendix F. The resulting distances were 400 meters for in-line, and 1092 meters for the trolley solution. In these calculations, an order of 5400000336 was used as the basis. The fact that only cut pieces are transported using trolleys, while the in-line solution takes care of both whole and cut pieces, was taken into account.

4.4.4 Capacity

The capacity for the trolley solution is dependent on the number of trolleys available in the production flow. As described in chapter 4.3.2, there will be 24 trolleys available, which makes for a capacity of: $\frac{24\ trolleys \times 18\ compartments\ /\ trolley}{2\ polymers\ /\ order} = 216\ batches$

The capacity for the in-line solution is determined by the mixer. To determine the mixer capacity, we first need to calculate the time per order. The calculation uses a changeover time of 10 minutes, the median time per batch (XX min YYs) and the average number of batches per order (16,1) which was found in chapter 4.1. Then the average number of batches which can be mixed in an 8-hour shift is calculated, and lastly, it is multiplied by 3 to show the capacity of a 3-shift day. The calculations are as follows:

$$Time/Order \approx 1{,}17h$$

$$Capacity\ per\ shift = \frac{8h}{1{,}17h/order} \times 16{,}1\ batches/order \approx 110\ batches$$

$$Capacity\ per\ day\ =\ 110\ batches/shift\ * 3\ shifts\ =\ 330\ batches$$

Hence, the capacity for the in-line solution is determined to be 330 batches/day.

4.4.5 Changeover times

The changeover times have been thoroughly discussed with the production operators. The changeover times between orders was determined to stay within the 10 minute interval for both solutions. The changeover times between batches was also determined to be within its interval of XX min YYs. However, the changeover time for the in-line solution is dependent on that there always are two operators present.

4.4.6 Number of operators per shift

The trolley solution is based on two distinctive steps, first the cutting step where polymer is cut and stored on trolleys. And the second step, the mixing stage, where the cut pieces of polymer are offloaded from the trolley and transferred to the mixing conveyor. Because of this two-step process, the two steps can be performed separately. As a result of this, mixing an order can be performed by one operator. Since this operator only needs to focus on placing chemicals and whole slabs on the mixing conveyor as well as transporting full trolleys to the loading conveyor. All of these steps can be performed whilst a previous batch is being mixed, which enables the possibility of having two operators at the first shift (one operator cutting polymer for the next three shifts and the second operator mixing) and only one operator by the mixer for the following two shifts.

The in-line production flow on the other hand needs two operators during all shifts for it to function. This is based on the fact that in order to meet the changeover time between batches, a second operator will need to change the empty bins while the other keeps mixing batches. Furthermore, since there is no buffer in this solution, it is of high importance that the solution is functional. To achieve this, a second operator will need to be available to monitor and solve issues which might lead to a stop which would bottleneck the entire production flow.

4.4.7 Required floor area

The floor area required for each solution was roughly estimated, using the layout plans which were mapped in chapter 4.3.2 respectively chapter 4.3.3. The area was abstracted down to the smallest rectangle possible which covers all parts of each flow, and was calculated as follows:

$$Floor\ area_{In-Line} = 20m \times 6m = 120m^2$$

$$Floor\ area_{Trolleys} = 31m \times 6m = 186m^2$$

The production management has provided a rough target to keep the production flow within an area of $175m^2$.

4.4.8 Risk level

In this criteria, the risk level of the two possible solutions are discussed and compared. Two potential risk areas have been identified in the trolley solution. Firstly, it requires a fairly advanced control system in order to enable traceability throughout the production flow. The system must have an interface to the control systems which are already in place and is currently handling the production orders. Secondly, the on- and offloading is considered to be a risk area. Since polymer as a material is difficult to handle, the on- and offloading of the trolleys may prove difficult. Hence, these parts of the production flow should be thoroughly tested before deployment.

The in-line production flow has fewer steps compared to the trolley solution, however, there are a number of key technical components which are critical. The two most critical components are the vision system and the traverse robot. The vision system poses a risk connected to the intended functionality of the system. The polymer slabs are tightly packed in the bins, thus it can prove difficult for the system to accurately detect singular slabs. Followingly, the traverse robot will, with the help of the vision system, lift slabs from the bins and onto the conveyor leading into the corresponding auto-guillotine. Here, the problem of tightly packed polymer slabs pose another risk. The polymer is, in many cases sticky and is therefore difficult to lift from the bins. From interviews, it was found that in some cases operators need to use hooks or even a forklift to get the slabs out of their bins. Therefore, the traverse robot and its vacuum powered lifting device might not be able to lift slabs out of their bins.

Having these risk areas in mind, the two solutions' overall risk levels were discussed with the Production Team Leader and Process engineer. The conclusion of the discussion was that the trolley solution is considered to be of moderate risk, while the in-line solution was determined to be of a high risk level.

4.4.9 Ergonomics

The ergonomics perspective of the proposed solution was examined using the checklist "Checklista för bedömning - utifrån föreskrifterna om belastningsergonomi, AFS 2012:2", which is provided by the *Swedish Work Environment Authority*. First, the checklist was used to examine the current situation. Thereafter both of the proposed solutions were evaluated, using the same checklist.

The results of the checklist evaluation was summarized into Table 5 and the three categories represent the severity of the aspect covered in that specific question. The three categories are green, yellow and red, where green represents satisfactory, yellow a minor concern, and red a greater concern.

All ergonomics evaluation was carried out in consultation with the factory's health and work environment manager. The full checklists can be found in Appendix G.

4.4.10 Summary of Comparison

Table 5: Comparison of the trolley and in-line flow in combination with the targets

Criteria	Target	Trolley Flow	In-Line Flow
Polymer cutting time	3h	2h 24min	5h 58min
Forklift transportation	2830 m	1092 m	400 m
Capacity per day	216 batches	216 batches	330 batches
Changeover time - between batches	XX min YY s	< XX min YY s	< XX min YY s
Changeover time - between orders	10 min	< 10 min	< 10 min
# of operators shift 1	2	2	2
# of operators shift 2	1	1	2
# of operators shift 3	1	1	2
Required floor area	175m^2	186m^2	120m^2
Risk level	As low as possible	Moderate	High
Ergonomics	12 / 9 / 31	2 / 9 / 41	5 / 2 / 45

4.4.11 Recommended production flow

The two production flows were compared using the criteria that have been summarized in Table 5 From this, it can be concluded that most criteria are met by both flows. However, it is evident that when it comes to the required number of operators, in-line needs two operators, one running the mixer and one supervising the traverse-robot. This need of always having two operators instead favor the trolley flow, where there is no need for a second operator during shift 2 and 3. The risk levels of the two solutions also differ, even though both flows have their downsides. The possible difficulties of the control system of the trolley flow is however outweighed by the risks associated with implementing the vision system and the lifting device needed for the in-line flow.

The trolley production flow will lead to the following improvements.

A reduction in polymer cutting times by: $\frac{6\ hours - 2\ hours\ 24\ minutes}{6\ hours} = 60\%$.

A reduction in forklift transportation by: $\frac{3538\ meters - 1092\ meters}{3538\ meters} \approx 69\%$

In conclusion, even though the in-line flow has a higher capacity, less transportation by forklift and requires less space, **the trolley solution is recommended**. This solution is recommended because it is a better fit with the specific targets that the company has set up. Additionally, the implementation of this production flow is connected to a lower risk level. The extra floor space required for this production flow has been discussed with production management, and even though it is greater than the target, it was still seen as acceptable.

5. Physical prototyping

Upon reaching the conclusion that the trolley solution is the recommended flow at this point in time, the next step was to prototype critical components. As mentioned in chapter 4.4.8 the on- and offloading of the trays are considered to be important aspects of the production flow, therefore the prototyping has been narrowed down to this part.

5.1 Initial prototype

The aim of the initial prototype was to examine whether a piston could be used to push pieces of polymer onto a metal tray, see figure 24. This prototype was of low fidelity, since the only goal was to see whether a piston could actually have enough power and accuracy to move the polymer in a straight path.

5.1.1 Prototype construction and testing

The prototype consisted of a piston and a constructed metal tray. The piston was mounted onto a pallet, and a plastic pusher was attached to the head of the piston. The metal tray was mounted onto a pallet and two runners were attached to the same pallet in order to guide the pusher.

Figure 24: Initial prototype, used for testing if a piston could push a piece of polymer

In the initial test runs, it was concluded that pushing the polymers directly onto the metal created a great amount of fiction. Hence, a belt was wrapped around the metal tray in order to decrease the friction and smoothen the pushing process.

Upon finding that a belt wrapped around the tray was needed in order to reduce friction, a design decision regarding the trolley was necessary. Since the belt might wear after a time of usage it would need to be replaced with a new one. Thus, the metal trays would need to be removable in order to change belts.

Further test runs were then completed with polymer slabs ranging from 1 kg up to 30 kg. The piston could successfully push all polymer slabs on the trays.

5.1.2 Summary of findings

The results from the initial prototype showed that the principle of using a piston to load polymer onto trays works effectively. Along with finding the principle successful, two new features of the functionality were found to be necessary. Firstly, a belt wrapped around the tray is needed to reduce friction. Because of this, the trays need to be removable to enable replacement of worn belts. The tray also needed to have rounded edges for the belt to easily run along without catching onto any sharp edges.

5.2 Final prototype

With the findings of the initial prototype in mind, more refined prototypes were created. These prototypes intended to test the onloading and offloading principles. Since it was concluded that it will be necessary to wrap belts around the trays, different belts were also tested in order to find what type of belt is most suitable.

5.2.1 Prototype requirements

When determining the design of the final prototype, a set of key testing aspects were considered. These are summarised in the list below:

- To prototype the onloading, the polymer would need to travel on a conveyor belt which led to the tray
- To prototype the offloading, the polymer would need to travel on the tray which then led to a conveyor belt.
- The conveyor belt and piston needed to be vertically adjustable.
- The force needed to push a piece of polymer would need to be measured.
- A set of different belts had to be able to be tested.

5.2.2 Design prototype

The design prototype was sketched as a 3D-model, using Microsoft 3D Builder. Emphasis was placed on creating a modular setup which enabled easy rearrangement in order to test different types of belts, as well as changing between on- and offloading testing.

The prototypes consisted of the following parts:

- Pushing piston - mounted on a small lifting table screwed to the floor.
- A conveyor belt mounted on a lifting table
- A tray with rounded edges fitted with a belt, mounted on a stack of pallets.

The first prototype designed was the onloading prototype. The conveyor belt was placed next to the piston and the tray was placed just in front of the conveyor belt. Two pressure sensors were also mounted onto the pusher, in order to be able to measure the pressure that the piston must generate.

The final design of the on-loading prototype can be seen in Figure 25 below.

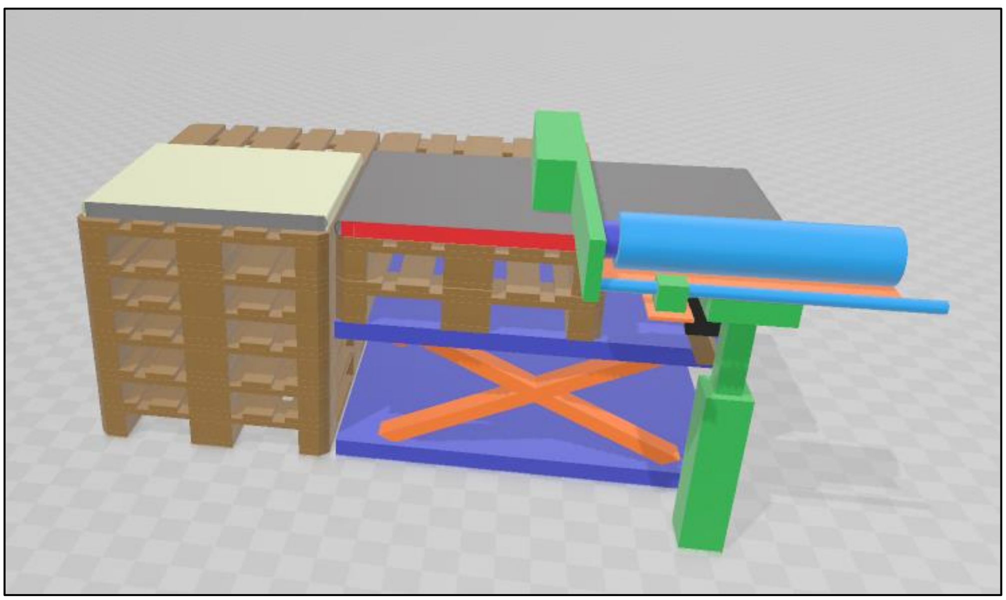

Figure 25: 3D-sketch of the onloading prototype.

The second prototype that was designed, was the off-loading prototype. In this prototype, the tray was placed next to the piston and the conveyor belt was placed just in front of the tray.

The final design of the off-loading prototype can be found in Figure 26 below.

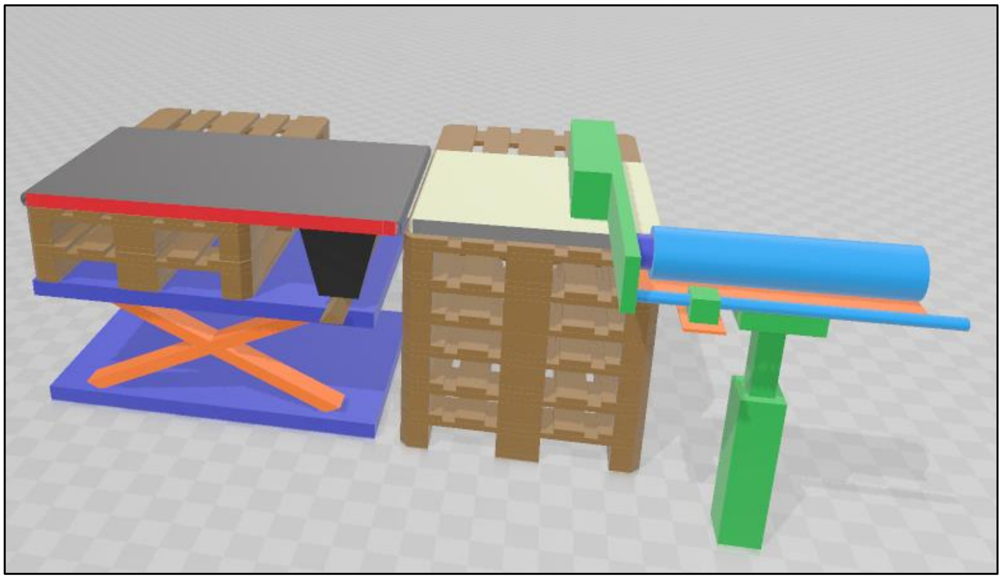

Figure 26: 3D-sketch of the offloading prototype

5.2.3 Functional prototype and testing results

Once the setup of the prototype had been decided, the actual prototype was constructed. An air-powered piston with an extension range of 0,8 meters was used. The piston was attached to a small electric powered lifting table. A guiding rod was attached to the side of the piston in order to increase stability, this part of the prototype is shown in figure 27.

Unlike the setup of the onloading presented in chapter 4.3.3.2, in the prototype the piston is placed on the side of the conveyor belt, instead of it being mounted on a lifting system placed above the conveyor belt. This difference occurred because there were no lift systems resembling the one presented in chapter 4.3.3.2 present at the Trelleborg site. Changing the setup to enable testing of the intended functionality was deemed more important than creating a prototype that exactly resembled the model. The pressure sensors used were, as previously stated, placed between the pusher and the rod attached to the piston, as to not gain faulty readings caused by leverage.

Figure 27: The piston mounted on a small lifting table, with a guiding rod for stability

In the picture below, the entire prototype used to test the onloading is presented. The piston can be seen on the right. The piece of polymer is placed on top of a conveyor belt which stands on two pallets placed on top of a hydraulic powered lifting table. The metal tray is fitted with aluminium profiles on the side in order to get some height between the actual tray and the pallet. When changing belts on the tray, it could easily be screwed off the aluminium profiles.

The onloading prototype can be seen in Figure 28 below.

Figure 28: The onloading protoype

Since the prototype only had three main parts i.e. the conveyor belt, the tray and the piston, these parts were easily rearranged in order to test the offloading. No parts were added or taken away, the only change was that the tray and conveyor belt swapped places.

The off-loading prototype can be seen Figure 29 below.

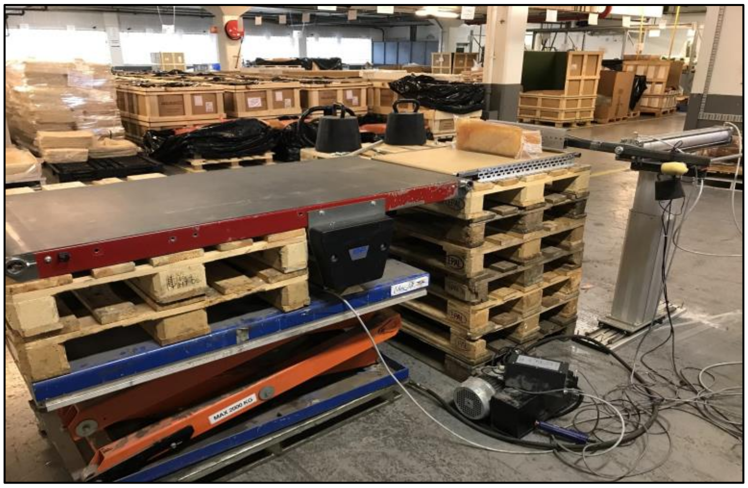

Figure 29: The offloading prototype

5.2.4 Belt testing

Five different belts were tested. These belts' materials were chosen since they were available in large quantities in the Trelleborg factory and would hence not lead to any extra costs. The belts' characteristics can be found in Table 6 below.

Table 6: Descriptions of the different belts tested.

	Description
Belt 1	Similar to an oil cloth in texture. Good traction on the outside, a bit sticky on the inside.
Belt 2	Thin fabric. Very low friction on both sides. Not stiff at all.
Belt 3	Silicone coating on the outside, fabric on the inside. Stiffness is very similar to Belt 1.
Belt 4	Thicker than belt 1. Silicone coating on outside, fabric on inside. Stiffer than both belt 1 & 3.
Belt 5	A coarse fabric with no coating. Stiffness similar to belt 1.

In order to test the belts, the pressure shown on the pusher's pressure sensors were recorded. The pressure when pushing both a 7-kg polymer and a 18 kg polymer slab was measured for all belts. The maximum pressure can be found in Table 7 below.

The controllability of the belts was another important aspect to evaluate. The belts' controllability were estimated by visually examining how much the belts moved sideways during testing. The controllability was ranked with the scale *Low*, *Medium* and *High*, where *Low* indicated substantial sideways movement, *Medium* indicated minor sideways movement, and *High* indicating that the belt did not show any sideways movement. The results of the controllability can be found in the rightmost column of Table 7 below.

Table 7: Pressure needed to push polymer onto the tray wrapped with different belts

	Pressure, 7 kg polymer (in kg)	**Pressure, 18 kg polymer (in kg)**	**Controllability**
Belt 1	3.277	8.227	Medium
Belt 2	2.202	5.094	Low
Belt 3	3.816	7.105	Medium
Belt 4	4.139	6.773	High
Belt 5	2.865	5.773	High

The results of the belt test runs showed that *Belt 2* proved to lead to the lowest pressure, both for the smaller and the larger polymer slab. However, it proved to have a low controllability, which may lead to that the belt might travel sideways and be adjusted frequently. Hence, *Belt 2* is not suitable for the trolley trays. *Belt 5* on the other hand were the second best belt regarding the pressure aspects, as well as having a high controllability. These two properties of *Belt 5* made it highly suitable for the trolley trays.

5.2.5 Summary of findings

The results of the test runs showed that both the onloading and the offloading principles functioned properly. Since these aspects were seen as the most uncertain elements of the trolley production flow, the prototypes proved that the production flow is physically implementable. Furthermore, test runs showed that *Belt 5* proved to be the best suited belt for the trolleys' trays. The belt has no coating and consists of relatively stiff material.

6. Discussion

6.1 Current situation analysis

A large amount of the quantitative data was retrieved from Trelleborg's databases. The data is automatically inserted into the databases from the production's control systems. This might lead to some discrepancies in the data such as operator breaks and test batches affecting the final results. To account for this, only mean and median values were used in the analysis, in order to minimize the discrepancies' effects on the results. Some of the data gathered had faulty labels, e.g. oil components were labeled as polymers. This was discussed with our supervisor who already had insights into this problem. The data which contained these inconsistencies were cleaned to a large extent, however some of these might have affected the data being analysed.

The qualitative data was retrieved from interviews with relevant Trelleborg personnel. These interviews had various levels of structure, where some interviews were structured and some were solely based on a few key main questions. The information gathered from interviews were verified with multiple Trelleborg employees when possible, and validated through taking rough measurements and performing estimations.

6.2 Production flows

Throughout the project, the main goal was to present a new polymer handling flow. In order to present a new flow as detailed as possible, it was necessary to focus on a few possible solutions, one with a buffer and one in-line, rather than multiple different ones. By choosing to aim on comparing two flows which were different on a number of key aspects, the pros and cons of two contrasting solutions could be discussed whilst at the same time maintaining as great a focus on detail as possible. Discussing more possible solutions, such as a hybrid solution, and comparing these to the ones presented in this thesis would further strengthen the analysis.

6.3 Prototyping

In order to keep the costs of the project as low as possible, the prototypes consisted of parts which were already available at the Trelleborg site. During the prototyping phase, the designs of the prototypes were redone multiple times, as a result of the fact that the required parts often were not available.

Apart from keeping the costs of the project as low as possible, acquiring parts from outside suppliers also proved to be very time consuming. Because of the limited time frame of this thesis project, it was hence decided to only order the tray from an outside supplier. All electrical components which needed to be implemented or adjusted, were done by Trelleborg's electrical engineers, because of the safety aspect.

The prototyping was limited to the on- and offloading, since those were determined to be the most critical parts of the production flow. However, other parts of the production could be prototyped as well. For example a complete trolley and a trolley conveyor belt could be prototyped as well, to further prove the feasibility of the proposed production flow. However the limited time of this project ultimately led to the project solely focusing on the on- and offloading.

7. Conclusion

By analysing the production flow from a lean perspective, an improved production flow has been designed. The critical part of the design has also been prototyped in order to prove its feasibility.

The recommended production flow is an improvement in multiple regards. The time spent cutting the polymers is reduced by 60% and the forklift transportation is reduced by 69%. This fulfills the goals of both forklift transportation and polymer cutting times where these goals were set to a reduction of 50% and 20% respectively. The new solution opens up for the possibility of introducing three shifts instead of the two which Trelleborg has today. This is done by providing a solution where all polymer used during three shifts can be cut during one shift. By storing the cut pieces on the trolleys, the floor space needed is not increased in the same way as it is today. Furthermore, the ergonomics for the production operators is greatly improved.

The implementation of the recommended production flow should be made gradually. This should be done by firstly thoroughly unit testing the individual parts, such as the auto-guillotine and the on- /offloading stations. By implementing it gradually, it enables the process engineers to adjust for any unforeseen flaws of the design.

7.1 Future possibilities

In this thesis the focus has been on optimising the flow of polymer, and especially the cut pieces, there are, however, more components which are added to the mix. Incorporating a more automated handling of chemical bags and whole slabs of polymer is something which would greatly improve efficiency and should be investigated. Space for such an extension of the production flow has been left between the mixer and the offloading station in order to facilitate further improvements to the solution presented.

If the solution which we have provided is successful, replicating this setup to the other mixing line would be straightforward. There is also a potential of copying the setup to other Trelleborg factories, since the mixing process is very similar across factories.

Based on the research performed in this thesis, the trolley solution is the one that best fits the needs of Trelleborg and its product mix at this point in time. However, in future conditions where technological advances enable better lifting devices and vision systems which increase the reliability of the system, the in-line flow might be favorable. It is therefore recommended that Trelleborg further investigates the in-line possibility in the future, especially if the product mix was to shift to larger quantities of fewer products.

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Appendix A

Forklift Transportation - Current Situation

Points	Description
A	Polymer Storage
B	Mixer
C	Cut Polymers
D	Empty Trays

Points	Distance (m)
A - B	51
B - C	31
B - D	25
A - D	38
C - D	10

Cutting phase:

Description	Points	Distance	Multiplicity	Total distance (m)
Forklift to Empty Tray Storage	B - D	25	4	100
Empty Pallet Storage to Guillotine	D - B	25	4	100
Guillotine to Polymer 1	B - A	51	3	153
Polymer 1 to Guillotine	A - B	51	3	153
Cutting of Polymer 1				0
Returning excess Polymer 1	B - A	51	1	51
Retrieve Polymer 1	A - B	51	1	51
Store cut Polymer 1	B - C	31	12	372
Retrieve new Polymer 1	C - B	31	11	341
Retrieve empty tray for Polymer 2	C - D	10	1	10
Drop off empty tray to the Guillotine	D - B	25	1	25
Guillotine to Polymer 2	B - A	51	2	102
Polymer 2 to Guillotine	A - B	51	2	102
Cutting of Polymer 2				0
Returning excess Polymer 2	B - A	51	1	51

Retrieve cut Polymer 2	A - B	51	1	51
Store cut Polymer 2	B - C	31	3	93
Return to the guillotine	C - B	31	3	93
TOTAL				**1848**

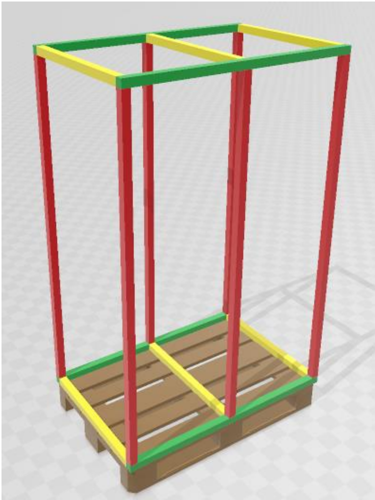
Mixing phase:

Description	Points	Distance	Multiplicity	Total distance (m)
Retrieve bins of Polymer 2	B - A	51	5	255
Drop off bins of Polymer 2 at mixer	A - B	51	5	255
Retrieve cut polymer 1 and 2	B - C	31	15	465
Drop off cut polymers at mixer	C - B	31	15	465
Return empty trays	B - D	25	5	125
Retrieve empty trays	D - B	25	5	125
TOTAL				**1690**

Appendix B

Weight Specification of Trolley

Trolley Skeleton:



For the trolley-skeleton three different lengths of hollow square rod, which can be seen in the figure above. All the rods will be 40x40 mm.

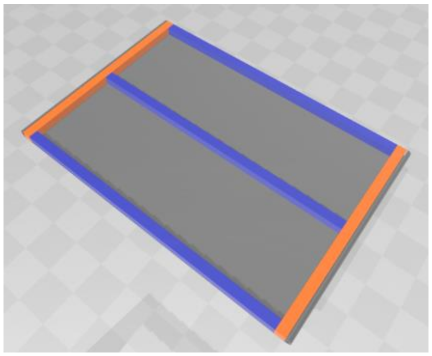
The total length of hollow square rod is calculated below.

Pieces	Multiplicity	Length (mm)	Total Length (mm)
Green Pieces	4	1200	4800
Yellow Pieces	6	720	4320
Red Pieces	6	1775	10 650
Total Length			19 770

Assuming the square rod is 1mm thick, and the density of steel sheet is 7,9kg/dm^3 then the total weight of the skeleton will be 16mm x 19,77m x 7,9kg/ dm^3 = **250kg.**

Trays:

Each tray will consist of a bent steel sheet. In order to support each tray, five pieces of square rod will be needed. The three blue rods following the longer side and the two orange rods following the short side.



The supporting rods marked in orange and blue shall be 24x24mm square rod.

- The orange pieces shall be 515mm
- The blue pieces shall be 725mm

Pieces	Multiplicity	Length (mm)	Total Length (mm)
Orange Pieces	2 x 18 = 36	515	18 540
Blue Pieces	3 x 18 = 54	725	39 150
Total Length			57 690

Assuming the sheet used for the square rod is 1mm thick, then the supporting rods will weigh:

$$576{,}9dm \times 0{,}01dm \ \times 0{,}96dm \times 7{,}9kg/\ dm3 \approx 44kg$$

From weighing we know that the bent pieces of sheet metal weigh: **3,5kg.** The sheet metal will hence weigh:

$$3{,}5kg \times 18trays = 63kg$$

The total weight of all trays including supporting rods will thereby be: $44kg\ +\ 63kg = 107kg$.

Total weight of both trolley skeleton, all trays and pallet base:

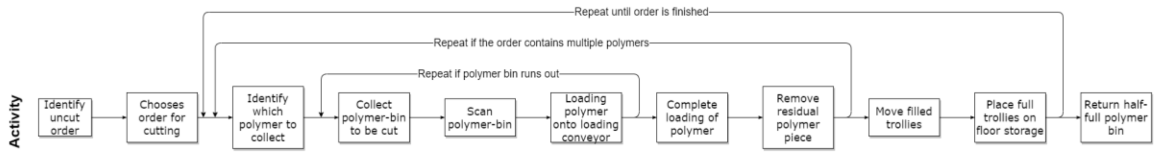
- Trolley Skeleton: 250 kg
- All trays: 107 kg
- Pallet Base: 40 kg

TOTAL WEIGHT: **397 kg**

Appendix C

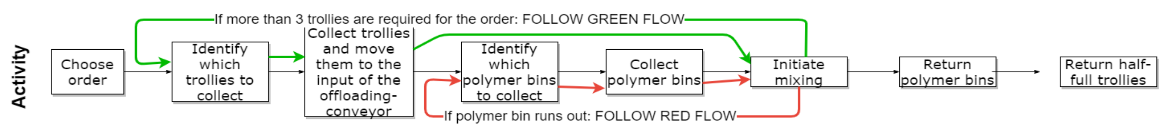
Operator flow - Trolley

When cutting



Activity	Description	Location
Identify uncut order	Operator identifies an uncut order and therefore initiates cutting.	Display by loading station
Chooses order for cutting	Operator chooses which order to cut	Display by loading station
Identify which polymer to collect	The display shows the polymer/polymers needed	Display by loading station
Collect polymer-bin to be cut	Operator collects the polymer shown on the display	Between loading station and polymer storage
Scan polymer-bin	Operator scans the barcode on the collected bin	Display by loading station
Loading polymer onto loading conveyor	Operator lifts whole polymer slabs onto the loading conveyor	By loading station
Complete loading of polymer	The display indicates when enough polymer has been loaded	By loading station
Remove residual polymer piece	When the display indicates that cutting is completed, collect residual polymer piece and place back into polymer bin	Display by loading station and next to the guillotine
Move filled trollies	The display by the loading station indicates when filled trollies need to be moved	Display by loading station and trolley output by guillotine
Place full trollies on floor storage	The display indicates whether the trolly should be placed on a single row, or can be placed in front of trolley X	Display by trolley output from guillotine and floor storage
Return half-full polymer bin	When the display indicates that the order is finished, return half-full polymer bins to polymer storage	Display by loading station

When mixing

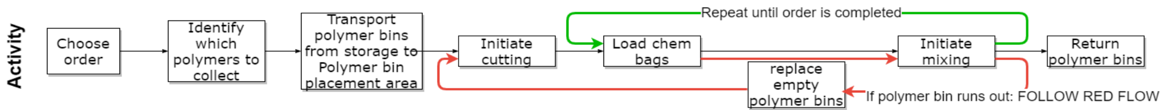


Activity	Description	Location
Choose order	Which order to run is chosen in BASE by the operator, in the same way as today.	The computer by the mixer
Identify which trollies to collect	On the two displays, which trollies/trolley to collect is shown.	Display by the mixer as well as a display above the floor storage
Collect trollies and move them to the input of the offloading-conveyor	Collect the trollies which have been identified and lift these onto the input of the offloading-conveyor	Floor storage as well as input for the offloading-conveyor
Identify which polymer bins to collect	Identify the polymer bins with whole polymer slabs, which are needed for the order	Display by the mixer
Collect polymer bins	Collect the polymer bins needed for the order	By the mixer and polymer storage
Initiate mixing	Initiate mixing, place whole polymer slabs and chem-bags on mixer-conveyor. Cut pieces are loaded automatically	By the mixer
Return polymer bins	Return half-full bins of polymer slabs	From mixer to polymer storage
Return half-full trollies	Return half-full trollies to floor storage	From trolley-eject conveyor to floor storage

Appendix D

Operator flow - In-Line

In-line



Description	Which order to run is chosen in BASE by the operator, in the same way as today.	The cutting operator identifies which polymers need to be collected	Collect the polymer bins needed for the article which is going to be produced	Initiate cutting of polymer	Load chem bags onto the mixing conveyor	Remove empty bins and replace them with full bins.	Initiate mixing of a batch	return half-full polymer bins when order is completed
Location	The computer by the mixer	Display by the polymer bin placement area	Polymer storage and polymer bin placement area	Display by the polymer bin placement area	By the mixer	Polymer storage and polymer bin placement area	by the mixer	Polymer bin placement area and polymer storage
Operator	Mixer operator	cutting operator	cutting operator	cutting operator	mixer operator	cutting operator	mixer operator	cutting operator

Appendix E

Forklift distance calculations for trolley solution

Points	Description
A	Polymer Storage
B	Polymer Bin Placement Area

Description	Points	Distance	Multiplicity	Total Distance (m)
Polymer is transported from storage to Traverse Robot	A-B	20	10	200
Forklift transports empty bins to storage and picks up new bins	B-A	20	10	200
			Total	**400**

Appendix F

Forklift distance calculations for trolley solution

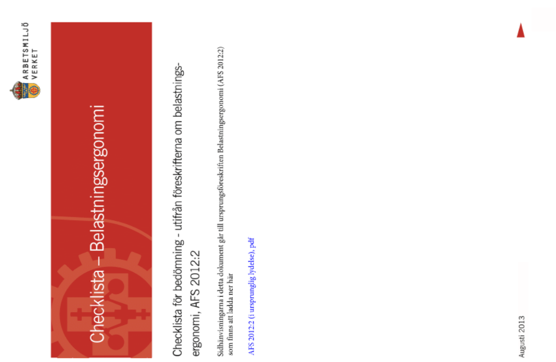
Article 5400000336 contains two polymers, Polymer 2 and Polymer 3. One batch of this product contains 64 kg Polymer 2 and 27 kg Polymer 3. One slab of Polymer 2 weighs 25 kg and one slab of Polymer 3 weighs 30kg. This means that in the trolley solution all of the Polymer 3 which is in a batch is cut in the guillotine. While only 14 kg of Polymer 2 is cut in the guillotine. Since one full bin of both Polymer 3 and Polymer 2 weighs 1000kgs, only two bins of Polymer 2 will be transported to the guillotine, while all 3 bins of Polymer 3 will be transported to the guillotine.

Points	Description
A	Polymer Storage
B	Guillotine Loading
C	Trolley Pick-up Area
D	Cut Polymer Storage
E	Loading Conveyor
F	Mixing Conveyor

Description	Points	Distance	Multiplicity	Total Distance(m)
Polymer is transported from storage to Guillotine Loading	A-B	10	5	50
Forklift transports empty bins to storage and picks up new bins	B-A	10	5	50
Forklift transports full trolleys to floor storage	C-D	14	11	154
Forklift goes back to Trolley pick-up area to get more trolleys	D-C	14	11	154
Forklift transports trolleys from floor storage to Loading Conveyor	D-E	12	11	132
Forklift goes back to get more trolleys from floor storage	E-D	12	11	132
Forklift transports full bins of polymer from polymer storage to Mixing Conveyor	A-F	42	5	210
Forklift goes back to floor storage to pick up more full bins	F-A	42	5	210
			Total	**1092**

Appendix G

Ergonomics, Current situation



ARBETSMILJÖVERKET

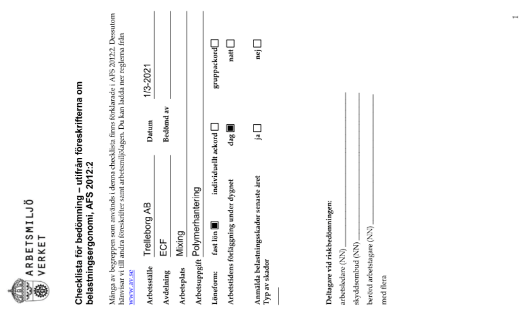
Checklista – Belastningsergonomi

Checklista för bedömning - utifrån föreskrifterna om belastnings-ergonomi, AFS 2012:2

Sidhänvisningarna i detta dokument går till ursprungsföreskriften Belastningsergonomi (AFS 2012:2) som finns att ladda ner här

AFS 2012:2 (i ursprunglig lydelse), pdf

Augusti 2013



ARBETSMILJÖVERKET

Checklista för bedömning – utifrån föreskrifterna om belastningsergonomi, AFS 2012:2

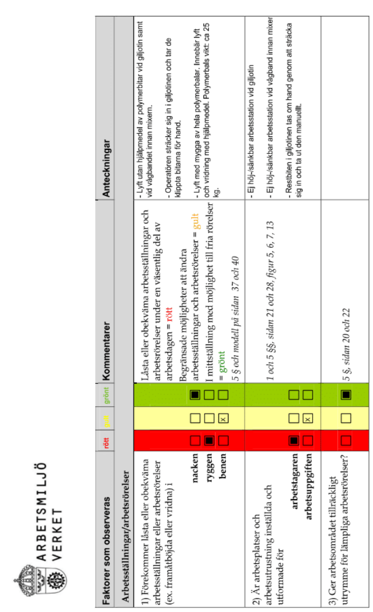
Många av begreppen som används i denna checklista finns förklarade i AFS 2012:2. Dessutom hänvisar vi till andra föreskrifter samt arbetsmiljölagen. Du kan ladda ner reglerna från www.av.se

Arbetsställe Trelleborg AB **Datum** 1/3-2021
Avdelning ECF **Bedömd av**
Arbetsplats Mixing
Arbetsuppgift Polymerhantering
Löneform: fast lön ■ individuellt ackord ☐ gruppackord ☐
Arbetstidens förläggning under dygnet dag ■ natt ☐

Anmälda belastningsskador senaste året ja ☐ nej ☐
Typ av skador

Deltagare vid riskbedömningen:
arbetsledare (NN)
skyddsombud (NN)
berörd arbetstagare (NN)
med flera

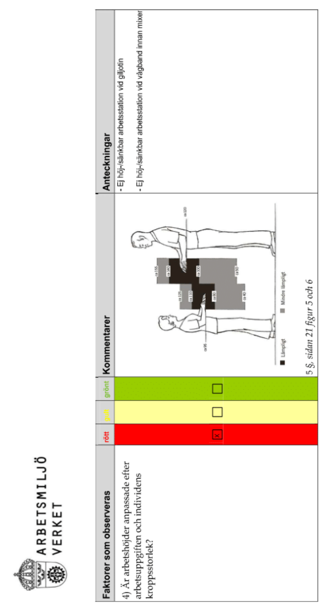
1



ARBETSMILJÖVERKET

Faktorer som observeras	rött	gult	grönt	Kommentarer	Anteckningar
Arbetsställningar/arbetsrörelser					
1) Förekommer låsta eller obekväma arbetsställningar eller arbetsrörelser (ex. framåtböjda eller vridna) i **nacken**	☐	☐	■	Låsta eller obekväma arbetsställningar och arbetsrörelser under en väsentlig del av arbetsdagen = rött Begränsade möjligheter att ändra arbetsställningar och arbetsrörelser = gult I mittställning med möjlighet till fria rörelser = grönt *5 § och modell på sidan 37 och 40*	- Lyft utan hjälpmedel av polymerbitar vid giljotin samt vid vågbandet innan mixern. - Operatören sträcker sig in i giljotinen och tar de klippta bitarna för hand. - Lyft med mygga av hela polymerbalar. Innebär lyft och vridning med hjälpmedel. Polymerbals vikt: ca 25 kg.
ryggen	■	☐	☐		
benen	☐	☒	☐		
2) Är arbetsplatser och arbetsutrustning inställda och utformade för **arbetstagaren**	■	☐	☐	*1 och 5 §§, sidan 21 och 28, figur 5, 6, 7, 13*	- Ej höj-/sänkbar arbetsstation vid giljotin - Ej höj-/sänkbar arbetsstation vid vågband innan mixer - Restbiten i giljotinen tas om hand genom att sträcka sig in och ta ut den manuellt.
arbetsuppgiften	☐	☒	☐		
3) Ger arbetsområdet tillräckligt utrymme för lämpliga arbetsrörelser?	☐	☐	■	*5 §, sidan 20 och 22*	

2



ARBETSMILJÖVERKET

Faktorer som observeras	rött	gult	grönt	Kommentarer	Anteckningar
4) Är arbetshöjder anpassade efter arbetsuppgiften och individens kroppsstorlek?	☒	☐	☐	*5 §, sidan 21 figur 5 och 6*	- Ej höj-/sänkbar arbetsstation vid giljotin - Ej höj-/sänkbar arbetsstation vid vågband innan mixer

3

ARBETSMILJÖ VERKET

Faktorer som observeras	rött	gult	grönt	Kommentarer	Anteckningar
5) Kan arbetstagaren se arbetsobjekten utan ansträngning? Om inte ange i vilket avseende synbarheten är begränsad.					- Begränsad sikt vid klippande av polymer i giljotinen.
placering i höjdled	[ ]	[ ]	[x]	*5 §, sidan 25*	
fri sikt	[ ]	[x]	[ ]		
belysningsstyrka	[ ]	[ ]	[x]		
kontrast mot bakgrunden	[ ]	[ ]	[x]		
bländning	[ ]	[ ]	[x]		
reflexer	[ ]	[ ]	[x]	Teckenskärpa och teckenstorlek. Se *AFS 1998:5, 2 § (Arbete vid bildskärm)*	
skärpa för bildskärm och display	[ ]	[ ]	[■]		
6) Förekommer arbetsrörelser				Ta med i bedömningen; hur ofta, hur mycket och hur länge.	Under knähöjd: - Vid pålastning av uppklippta polymerbitar på brickor, även avlastning. - Vid pålastning av hela polymerbalar vid mixern
över axelhöjd	[ ]	[ ]	[■]		
under knähöjd	[■]	[ ]	[ ]	*5 och 7 §§, modell sidan 37 och 40*	
7) Förekommer arbetsställningar				Ta med i bedömningen om rörelserna är ofta återkommande eller långvariga.	
i knästående	[ ]	[ ]	[■]		
i huksittande	[ ]	[ ]	[x]		
i liggande	[ ]	[ ]	[■]	*5 och 7 §§, modell sidan 37 och 40*	

ARBETSMILJÖ VERKET

Faktorer som observeras	rött	gult	grönt	Kommentarer	Anteckningar
8) Finns det möjlighet att växla till sittande, då arbetet innebär långvarigt stående eller gående?	[x]	[ ]	[ ]	Nej = rött Sällan = gult Ja, i direkt anslutning till arbetsplatsen = grönt *5 och 7 §§, sidan 37 samt AFS 2009:2, 38 §*	
9) Förekommer arbetsrörelser				Ta med i bedömningen; hur ofta, hur mycket och hur länge.	
under stark tidspress	[ ]	[ ]	[■]		
hotfulla och obehagliga situationer	[ ]	[ ]	[■]	*4 §, sidan 17*	
10) Förekommer röstkrävande arbete	[ ]	[ ]	[■]	Ta med i bedömningen; hur ofta, hur mycket och hur länge.	-inget röstkrävande arbete förekommer
Om ja, ta hänsyn till					
arbetsställning	[ ]	[ ]	[ ]	*4 §, sidan 16*	
störande buller	[ ]	[ ]	[ ]		

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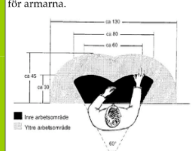
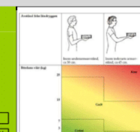
ARBETSMILJÖ VERKET

Faktorer som observeras	rött	gult	grönt	Kommentarer	Anteckningar
11) Är arbetsutrustning och arbetsobjekt placerade i lämplig höjd och på lämpligt sträckavstånd, dvs. i det inre arbetsområdet?	[x]	[ ]	[ ]	Frekventa rörelser utanför yttre arbetsområdet ska undvikas. Ta med i bedömningen möjlighet till stöd för armarna.  *5 §, sidan 21 och 22, figur 5, 6 och 7*	- Operatören behöver sträcka sig för att nå vid klippning vid giljotinen. - Lyft av polymer från polymerbingarna kräver att operatören sträcker sig för att nå de nedersta lagerna.
12) Är arbetsstolen anpassad för individen och arbetsuppgifterna?	[ ]	[ ]	[ ]	Ta hänsyn till om stolen är lätt att ställa in *5 §, sidan 23, figur 9* Behöver stolen vibrationsdämpas?	-ej tillämpbart

ARBETSMILJÖ VERKET

Faktorer som observeras	rött	gult	grönt	Kommentarer	Anteckningar
Manuell hantering och annan kraftutövning					
13) Förekommer manuella lyft av tunga bördor eller laster? Om ja: Ta hänsyn till dessa faktorer vid bedömning:					- Lyft av uppklippta polymerbitar sker ca 50 ggr /dag - Bitarna väger 1-25kg. - Lyfts ca 10s per lyft, kort sträcka.
frekvens (hur ofta)	[■]	[ ]	[ ]		
duration (hur länge)	[ ]	[ ]	[x]		
greppbarhet	[ ]	[x]	[ ]	*6 §, OBS! Tänk på påverkande faktorer i Bilaga A sidan 9*	
utrymme	[ ]	[x]	[ ]	Här kan du även prova KIM 1 ADI 627 www.av.se/checklistor	
14) Används hjälpmedel?	[ ]	[x]	[ ]	Nej, men behöver användas = rött Ibland = gult Ja, alltid när det finns behov = grönt *6 och 7 §§, sidan 15 och 26*	- Hela polymerbalar lyfts med mygga. - Uppklippta polymerbitar lyfts manuellt.
15) Finns det tillgång till hjälpmedel för rullande hantering (vagn, kärra) i stället för att bära bördor?	[ ]	[ ]	[x]	Nej, men behov finns = rött Inte optimal tillgång till hjälpmedel = gult Ja (eller behov finns inte) = grönt 6§	

ARBETSMILJÖ VERKET

Faktorer som observeras	rött	gult	grönt	Kommentarer	Anteckningar
16) Bedöm arbetsmoment där man skjuter eller drar. Ha med dessa faktorer vid bedömningen:				Kraft (N) / Rött / Gult / Grönt; Igångsättning: >300 / 300-150 / <150; Kontinuerligt: >200 / 200-150 / <100	- Vid klippning med giljotin, drar operatören ut restbiten manuellt. Detta sker vid varje klipp.
lastens tyngd	☐	☐	■	*6 §, sidan 39. OBS! beakta påverkande faktorer i Bilaga A sidan 9*	
frekvens (hur ofta)	■	☐	☐		
duration (hur länge)	☐	☐	☒	Här kan du även prova KIM 2 ADI 668 www.av.se/checklistor	
avstånd	☐	☐	☒		
placering av handtag	■	☐	☐		
friktion mot underlaget	☐	☐	☒		
underlaget ostabilt eller lutande	☐	☐	☒		
17) Finns det hjälpmedel för att avlasta vid arbete med handhållna maskiner/verktyg (skruvdragare)?	☐	☐	☒	Nej, men behövs = rött Inte tillräckligt = gult Ja, tillräckligt = grönt *6 §*	

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ARBETSMILJÖ VERKET

Faktorer som observeras	rött	gult	grönt	Kommentarer	Anteckningar
18) Förekommer:					-manuella lyft av klippta polymerbitar kräver stor kraftansträning och obekvämt handgrepp. Bitarna är asymmetriska och kan väga upp till 25kg.
grepp med stor kraftansträngning	■	☐	☐		
obekväma handgrepp	■	☐	☐		
dålig greppbarhet	☐	☒	☐	*1, 6 och 7 §§, sidan 17 och 18, figur 13 och 14*	
stora precisionskrav	☐	☐	☒		
negativ klimatpåverkan t.ex. kyla	☐	☐	☒		
finmotoriskt krävande nypgrepp	☐	☐	☒		
vibrationer	☐	☐	☒		
19) Utförs arbetet med upprepade böj- eller vridrörelser för hand och underarm?				> halva arbetsdagen = rött < halva arbetsdagen = gult sällan = grönt *5 och 7§§, sidan 23*	-handen behöver vridas för att plockas upp från giljotinen samt för att lägga bitarna rätt på brickan.
rörelsehastighet	☐	☐	☒		
frekvens	■	☐	☐	Här kan du även prova HARM www.av.se/checklistor	

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ARBETSMILJÖ VERKET

Faktorer som observeras	rött	gult	grönt	Kommentarer	Anteckningar
Repetitivt, starkt styrt eller bundet arbete					
20) Förekommer repetitivt arbete det vill säga: "att upprepa liknande arbetsrörelser om och om igen. Tiden för varje arbetsmoment är kort och rörelserna sker i sådan omfattning att det finns risk för besvär"	☐	☒	☐	Arbetscykeln upprepas flera ggr/min. under minst halva arbetsskiftet = rött Arbetscykeln upprepas flera ggr/min. under minst en timme eller många ggr/timme under minst halva arbetsskiftet = gult Arbetscykeln upprepas några gånger i timmen = grönt Arbetsskift = normalt 7-8 timmar *7 § sidan 40 modell för att identifiera och bedöma repetitivt arbete*	-klippning vid giljotin upprepas flera gånger per timme. Under minst halva arbetsskiftet.

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ARBETSMILJÖ VERKET

Faktorer som ska observeras	rött	gult	grönt	Kommentarer	Anteckningar
Handlingsutrymme					
21) Möjligheter att påverka arbetstakt, arbetsuppgifters inbördes ordning, inflöde av arbetsuppgifter, tidpunkt när arbetet ska vara slutfört, hur arbetet ska utföras och tider för pauser och återhämtning?	☐	☐	■	Arbetet är helt styrt av andra/annat = rött arbetet är delvis styrt av annat/andra = gult Goda möjligheter att anpassa arbetet efter egen förmåga. Inflytande över planering och upplägget av arbetet = grönt *8 §, sidan 31 och modell på sidan 40*	
22) Kan arbetstagaren lämna sin arbetsplats åtminstone för korta stunder utan att service eller produktion störs?	☐	☒	☐	Nej, bundet arbete = rött Ibland = gult Ja = grönt *8 §, sidan 31*	-operatören vid mixern kan endast lämna mycket små stunder utan att produktionen avstannar.
23) Finns det handlingsutrymme, som medger tillräcklig rörelsevariation och återhämtning?	☐	☐	☒	Nej = rött delvis = gult ja = grönt *8 §, sidan 16, modell sidan 40*	

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ARBETSMILJÖ VERKET

Faktorer som ska observeras	rött	gult	grönt	Kommentarer	Anteckningar
Kunskap och kompetens					
24a) Har arbetsledare/chefer, instruktörer/faddrar tillräcklig kunskap om gällande regler samt belastningsergonomiska risker.	☐	☐	☐	*9 § sidan 32 samt AFS 2001:1, 7 §*	-ej tillämpbart
24b) Finns regelbunden utbildning för					
arbetsledare/chefer	☐	☐	☐		
skyddsombud	☐	☐	☐		
instruktörer/faddrar	☐	☐	☐		
25) Innehåller företagets introduktionsprogram belastnings-ergonomi, för att de anställda ska arbeta rätt från början?	☐	☐	☐	*9 § sidan 32*	-ej tillämpbart

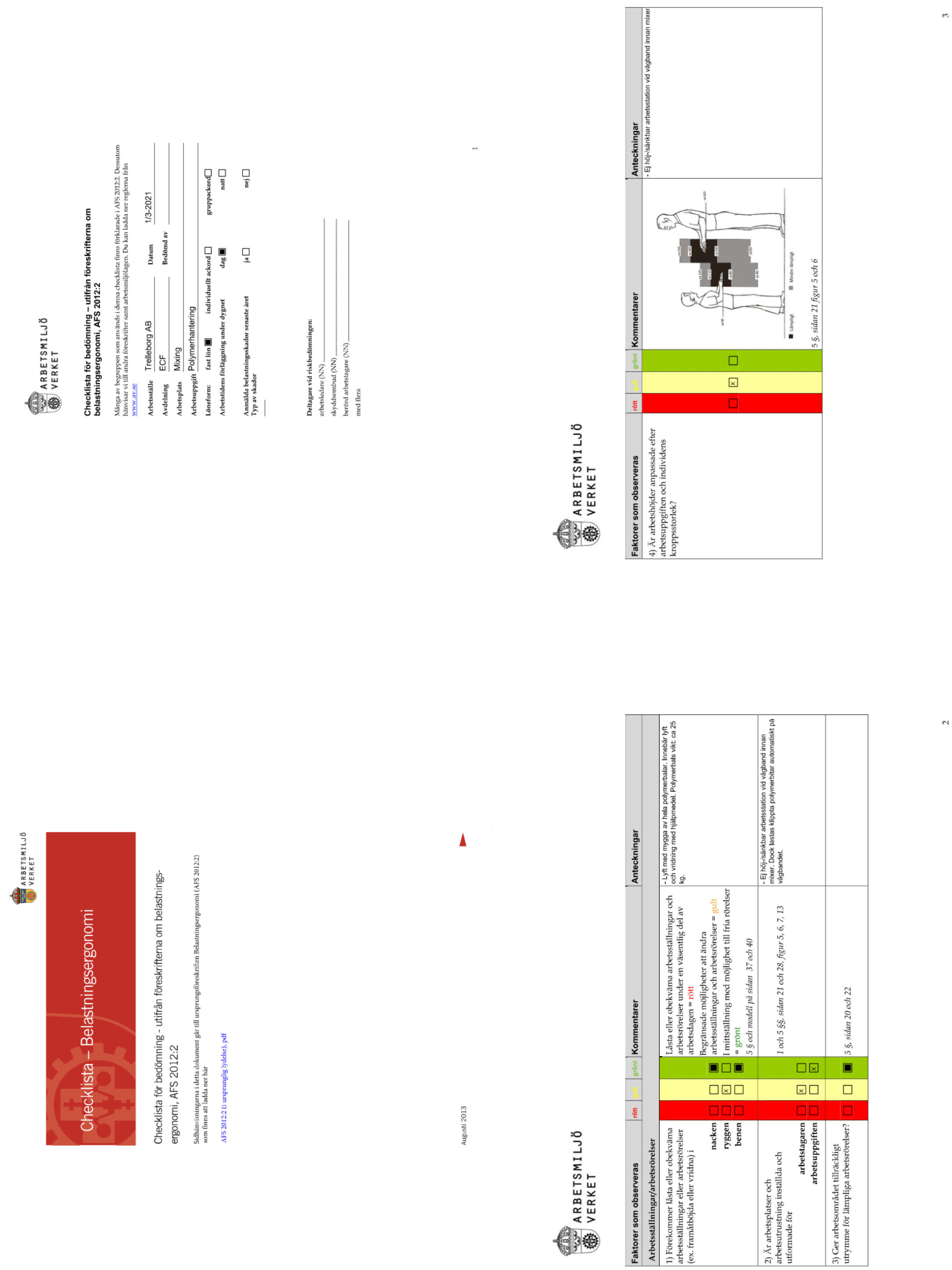
ARBETSMILJÖ VERKET

Faktorer som ska observeras	rött	gult	grönt	Kommentarer	Anteckningar
26) Har arbetstagaren tillräckliga kunskaper för att kunna utföra arbetsuppgifter ergonomiskt riktigt?				*9 § sidan 32*	-ej tillämpbart
Lämpliga arbetsställningar/rörelser	☐	☐	☐		
Teknisk utrustning/hjälpmedel	☐	☐	☐		
Risker vid olämplig arbetsteknik	☐	☐	☐		
Tecken på överbelastning	☐	☐	☐		
Har fått skriftliga instruktioner vid allvarliga risker	☐	☐	☐		
27) Får arbetstagarna möjlighet att praktiskt träna in lämplig arbetsteknik?	☐	☐	☐	*9 § sidan 32*	-ej tillämpbart
28) Sker uppföljning av att anställda följer instruktioner och arbetar på ett ergonomiskt lämpligt sätt?	☐	☐	☐	*9 § kommentar sidan 33*	-ej tillämpbart
Påverkande faktorer vid identifiering och bedömning av ergonomiska risker					
29) Finns tillräckligt med tid för att utföra arbetsuppgifterna?	☐	☐	☒		

ARBETSMILJÖ VERKET

Faktorer som ska observeras	rött	gult	grönt	Kommentarer	Anteckningar
30) Finns påverkande psykosociala faktorer?					
tydlig rollfördelning	☐	☐	☐		
inflytande	☐	☐	☐		
utvecklingsmöjligheter	☐	☐	☐		
krav och kontroll	☐	☐	☐		
socialt stöd från: **arbetskamrater**	☐	☐	☐		
chefer	☐	☐	☐	*sidan 17 och 18*	
andra	☐	☐	☐	*AML 2 kap. 1 §*	
Riskbedömningar					
31) Är bedömningar av ergonomiska risker gjorda på övriga delar i företaget?	☐	☐	☐	Nej = rött Delvis = gult Ja = grönt *AFS 2001:1, 8 och 10 §§*	
32) Gör ni bedömningar av ergonomiska risker vid förändringar i verksamheten? (produktions- eller organisationsförändringar.)	☐	☐	☐	Nej aldrig = rött Ibland = gult Alltid = grönt *AFS 2001: 1 och 8 §*	-ej tillämpbart

Ergonomics, Trolley production flow



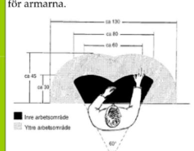
ARBETSMILJÖ VERKET

Faktorer som observeras	rött	gult	grönt	Kommentarer	Anteckningar
5) Kan arbetstagaren se arbetsobjekten utan ansträngning? Om inte ange i vilket avseende synbarheten är begränsad.					- Vid truckkörning blockerar vagnpallen delvis synfältet. -Vid pålasting på vagnpall är sikten begränsad dels i höjdled, men också av vagnpallens konstruktion och placering.
placering i höjdled	☐	☒	☐	*5 §, sidan 25*	
fri sikt	■	☐	☐		
belysningsstyrka	☐	☐	☒		
kontrast mot bakgrunden	☐	☐	☒		
bländning	☐	☐	☒		
reflexer	☐	☐	☒		
skärpa för bildskärm och display	☐	☐	■	Teckenskärpa och teckenstorlek. Se *AFS 1998:5, 2 § (Arbete vid bildskärm)*	
6) Förekommer arbetsrörelser				Ta med i bedömningen; hur ofta, hur mycket och hur länge.	- Vid pålastning av hela polymerbalar vid mixern
över axelhöjd	☐	☐	■		
under knähöjd	☐	☒	☐	*5 och 7 §§, modell sidan 37 och 40*	
7) Förekommer arbetsställningar				Ta med i bedömningen om rörelserna är ofta återkommande eller långvariga.	
i knästående	☐	☐	■		
i huksittande	☐	☐	☒		
i liggande	☐	☐	■	*5 och 7 §§, modell sidan 37 och 40*	

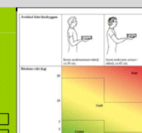
ARBETSMILJÖ VERKET

Faktorer som observeras	rött	gult	grönt	Kommentarer	Anteckningar
8) Finns det möjlighet att växla till sittande, då arbetet innebär långvarigt stående eller gående?	☒	☐	☐	Nej = rött Sällan = gult Ja, i direkt anslutning till arbetsplatsen = grönt *5 och 7 §§, sidan 37 samt AFS 2009:2, 38 §*	
9) Förekommer arbetsrörelser				Ta med i bedömningen; hur ofta, hur mycket och hur länge.	
under stark tidspress	☐	☐	■		
hotfulla och obehagliga situationer	☐	☐	■	*4 §, sidan 17*	
10) Förekommer röstkrävande arbete	☐	☐	■	Ta med i bedömningen; hur ofta, hur mycket och hur länge.	
Om ja, ta hänsyn till					
arbetsställning	☐	☐	☐	*4 §, sidan 16*	
störande buller	☐	☐	☐		

ARBETSMILJÖ VERKET

Faktorer som observeras	rött	gult	grönt	Kommentarer	Anteckningar
11) Är arbetsutrustning och arbetsobjekt placerade i lämplig höjd och på lämpligt sträckavstånd, dvs. i det inre arbetsområdet?	☐	☒	☐	Frekventa rörelser utanför yttre arbetsområdet ska undvikas. Ta med i bedömningen möjlighet till stöd för armarna.  *5 §, sidan 21 och 22, figur 5, 6 och 7*	- Lyft av polymer från polymerbingarna kräver att operatören sträcker sig för att nå de nedersta lagerna.
12) Är arbetsstolen anpassad för individen och arbetsuppgifterna?	☐	☐	☐	Ta hänsyn till om stolen är lätt att ställa in *5 §, sidan 23, figur 9* Behöver stolen vibrationsdämpas?	- ej tillämpbart

ARBETSMILJÖ VERKET

Faktorer som observeras	rött	gult	grönt	Kommentarer	Anteckningar
Manuell hantering och annan kraftutövning					
13) Förekommer manuella lyft av tunga bördor eller laster? Om ja: Ta hänsyn till dessa faktorer vid bedömning:					-lyft av hela polymerbalar sker med mygga. Både vid uppklippning, och vid mixing.
frekvens (hur ofta)	☐	☒	☐		
duration (hur länge)	☐	☒	☐		
greppbarhet	☐	☐	■	*6 §, OBS! Tänk på påverkande faktorer i Bilaga A sidan 9*	
utrymme	☐	☐	☒	Här kan du även prova KIM 1 ADI 627 www.av.se/checklistor	
14) Används hjälpmedel?	☐	☐	☒	Nej, men behöver användas = rött Ibland = gult Ja, alltid när det finns behov = grönt *6 och 7 §§, sidan 15 och 26*	
15) Finns det tillgång till hjälpmedel för rullande hantering (vagn, kärra) i stället för att bära bördor?	☐	☐	☒	Nej, men behov finns = rött Inte optimal tillgång till hjälpmedel = gult Ja (eller behov finns inte) = grönt 6§	

ARBETSMILJÖ VERKET

Faktorer som observeras	rött	gult	grönt	Kommentarer	Anteckningar
16) Bedöm arbetsmoment där man skjuter eller drar. Ha med dessa faktorer vid bedömningen:					
lastens tyngd	☐	☐	■	6 §, *sidan 39. OBS! beakta påverkande faktorer i Bilaga A sidan 9*	
frekvens (hur ofta)	☐	☐	☒		
duration (hur länge)	☐	☐	☒	Här kan du även prova KIM 2 ADI 668 www.av.se/checklistor	
avstånd	☐	☐	☒		
placering av handtag	☐	☐	☒		
friktion mot underlaget	☐	☐	☒		
underlaget ostabilt eller lutande	☐	☐	☒		
17) Finns det hjälpmedel för att avlasta vid arbete med handhållna maskiner/verktyg (skruvdragare)?	☐	☐	☒	Nej, men behövs = rött Inte tillräckligt = gult Ja, tillräckligt = grönt 6 §	

Kraft (N)	Rött	Gult	Grönt
Igångsättning	>300	300-150	<150
Kontinuerligt	>200	200-150	<100

ARBETSMILJÖ VERKET

Faktorer som observeras	rött	gult	grönt	Kommentarer	Anteckningar
18) Förekommer:					
grepp med stor kraftansträngning	☐	☐	☒		
obekväma handgrepp	☐	☐	☒		
dålig greppbarhet	☐	☐	■	*1, 6 och 7 §§, sidan 17 och 18, figur 13 och 14*	
stora precisionskrav	☐	☐	☒		
negativ klimatpåverkan t.ex. kyla	☐	☐	☒		
finmotoriskt krävande nypgrepp	☐	☐	☒		
vibrationer	☐	☐	☒		
19) Utförs arbetet med upprepade böj- eller vridrörelser för hand och underarm?				> halva arbetsdagen = rött < halva arbetsdagen = gult sällan = grönt *5 och 7§§, sidan 23* 	
rörelsehastighet	☐	☐	☒		
frekvens	☐	☐	■	Här kan du även prova HARM www.av.se/checklistor	

ARBETSMILJÖ VERKET

Faktorer som observeras	rött	gult	grönt	Kommentarer	Anteckningar
Repetitivt, starkt styrt eller bundet arbete					
20) Förekommer repetitivt arbete det vill säga: "att upprepa liknande arbetsrörelser om och om igen. Tiden för varje arbetsmoment är kort och rörelserna sker i sådan omfattning att det finns risk för besvär"	☐	☐	■	Arbetscykeln upprepas flera ggr/min. under minst halva arbetsskiftet = rött Arbetscykeln upprepas flera ggr/min. under minst en timme eller många ggr/timme under minst halva arbetsskiftet = gult Arbetscykeln upprepas några gånger i timmen = grönt Arbetsskift = normalt 7-8 timmar *7 § sidan 40 modell för att identifiera och bedöma repetitivt arbete*	-hela polymerbalar lastas upp med mygga för uppklippning. Här sker ett relativt repetitivt moment. Men det sker endast enstaka timmar per pass.

ARBETSMILJÖ VERKET

Faktorer som ska observeras	rött	gult	grönt	Kommentarer	Anteckningar
Handlingsutrymme					
21) Möjligheter att påverka arbetstakt, arbetsuppgifters inbördes ordning, inflöde av arbetsuppgifter, tidpunkt när arbetet ska vara slutfört, hur arbetet ska utföras och tider för pauser och återhämtning?	☐	☐	■	Arbetet är helt styrt av andra/annat = rött arbetet är delvis styrt av annat/andra = gult Goda möjligheter att anpassa arbetet efter egen förmåga. Inflytande över planering och upplägget av arbetet = grönt *8 §, sidan 31 och modell på sidan 40*	
22) Kan arbetstagaren lämna sin arbetsplats åtminstone för korta stunder utan att service eller produktion störs?	☐	☒	☐	Nej, bundet arbete = rött Ibland = gult Ja = grönt *8 §, sidan 31*	-operatören vid mixern kan endast lämna mycket små stunder utan att produktionen avstannar.
23) Finns det handlingsutrymme, som medger tillräcklig rörelsevariation och återhämtning?	☐	☐	☒	Nej = rött delvis = gult ja = grönt *8 §, sidan 16, modell sidan 40*	

ARBETSMILJÖ VERKET

Faktorer som ska observeras	rött	gult	grönt	Kommentarer	Anteckningar
Kunskap och kompetens					
24a) Har arbetsledare/chefer, instruktörer/faddrar tillräcklig kunskap om gällande regler samt belastningsergonomiska risker.	☐	☐	☐	*9 § sidan 32 samt AFS 2001:1, 7 §*	
24b) Finns regelbunden utbildning för					
arbetsledare/chefer	☐	☐	☐		
skyddsombud	☐	☐	☐		
instruktörer/faddrar	☐	☐	☐		
25) Innehåller företagets introduktionsprogram belastnings-ergonomi, för att de anställda ska arbeta rätt från början?	☐	☐	☐	*9 § sidan 32*	

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ARBETSMILJÖ VERKET

Faktorer som ska observeras	rött	gult	grönt	Kommentarer	Anteckningar
26) Har arbetstagaren tillräckliga kunskaper för att kunna utföra arbetsuppgifter ergonomiskt riktigt?				*9 § sidan 32*	
Lämpliga arbetsställningar/rörelser	☐	☐	☐		
Teknisk utrustning/hjälpmedel	☐	☐	☐		
Risker vid olämplig arbetsteknik	☐	☐	☐		
Tecken på överbelastning	☐	☐	☐		
Har fått skriftliga instruktioner vid allvarliga risker	☐	☐	☐		
27) Får arbetstagarna möjlighet att praktiskt träna in lämplig arbetsteknik?	☐	☐	☐	*9 § sidan 32*	
28) Sker uppföljning av att anställda följer instruktioner och arbetar på ett ergonomiskt lämpligt sätt?	☐	☐	☐	*9 § kommentar sidan 33*	
Påverkande faktorer vid identifiering och bedömning av ergonomiska risker					
29) Finns tillräckligt med tid för att utföra arbetsuppgifterna?	☐	☐	☒		

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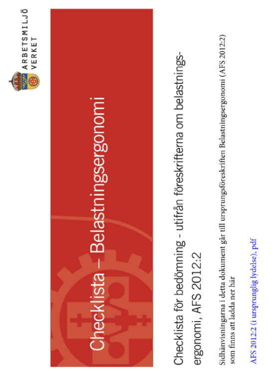
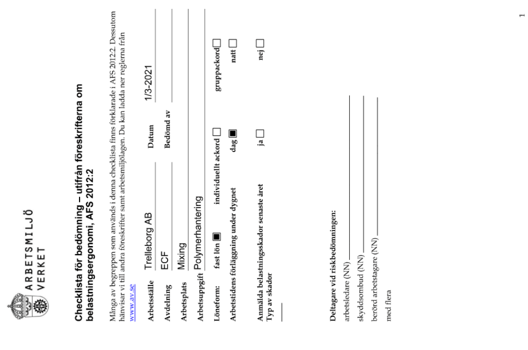
ARBETSMILJÖ VERKET

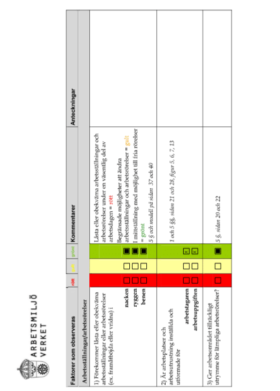
Faktorer som ska observeras	rött	gult	grönt	Kommentarer	Anteckningar
30) Finns påverkande psykosociala faktorer?					
tydlig rollfördelning	☐	☐	☐		
inflytande	☐	☐	☐		
utvecklingsmöjligheter	☐	☐	☐		
krav och kontroll	☐	☐	☐		
socialt stöd från: **arbetskamrater**	☐	☐	☐		
chefer	☐	☐	☐	*sidan 17 och 18*	
andra	☐	☐	☐	*AML 2 kap. 1 §*	
Riskbedömningar					
31) Är bedömningar av ergonomiska risker gjorda på övriga delar i företaget?	☐	☐	☐	Nej = rött Delvis = gult Ja = grönt *AFS 2001:1, 8 och 10 §§*	
32) Gör ni bedömningar av ergonomiska risker vid förändringar i verksamheten? (produktions- eller organisationsförändringar.)	☐	☐	☐	Nej aldrig = rött Ibland = gult Alltid = grönt *AFS 2001: 1 och 8 §*	- ej tillämpbart

16

In-line Production flow







ARBETSMILJÖ VERKET

Faktorer som observeras	rött	gult	grönt	Kommentarer	Anteckningar
5) Kan arbetstagaren se arbetsobjekten utan ansträngning? Om inte ange i vilket avseende synbarheten är begränsad.					-inhägnad arbetsyta för hela polymerbingar blockerar insyn. -Traversrobot rör sig i vertikal led, kan ge begränsad synbarhet.
placering i höjdled	☐	☒	☐	*5 §, sidan 25*	
fri sikt	■	☐	☐		
belysningsstyrka	☐	☐	☒		
kontrast mot bakgrunden	☐	☐	☒		
bländning	☐	☐	☒		
reflexer	☐	☐	☒		
skärpa för bildskärm och display	☐	☐	■	Teckenskärpa och teckenstorlek. Se *AFS 1998:5, 2 § (Arbete vid bildskärm)*	
6) Förekommer arbetsrörelser				Ta med i bedömningen; hur ofta, hur mycket och hur länge.	
över axelhöjd	☐	☐	■		
under knähöjd	☐	☐	■	*5 och 7 §§, modell sidan 37 och 40*	
7) Förekommer arbetsställningar				Ta med i bedömningen om rörelserna är ofta återkommande eller långvariga.	
i knästående	☐	☐	■		
i huksittande	☐	☐	☒		
i liggande	☐	☐	■	*5 och 7 §§, modell sidan 37 och 40*	

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ARBETSMILJÖ VERKET

Faktorer som observeras	rött	gult	grönt	Kommentarer	Anteckningar
8) Finns det möjlighet att växla till sittande, då arbetet innebär långvarigt stående eller gående?	☒	☐	☐	Nej = rött Sällan = gult Ja, i direkt anslutning till arbetsplatsen = grönt *5 och 7 §§, sidan 37 samt AFS 2009:2, 38 §*	
9) Förekommer arbetsrörelser				Ta med i bedömningen; hur ofta, hur mycket och hur länge.	för att inte produktionen ska avstanna krävs kontinuerlig uppklippning av polymer. För att detta ska vara genomförbart behöver operatör snabbt kunna byta ut tomma polymerbingar.
under stark tidspress	■	☐	☐		
hotfulla och obehagliga situationer	☐	☐	■	*4 §, sidan 17*	
10) Förekommer röstkrävande arbete	☐	☐	■	Ta med i bedömningen; hur ofta, hur mycket och hur länge.	
Om ja, ta hänsyn till					
arbetsställning	☐	☐	☐	*4 §, sidan 16*	
störande buller	☐	☐	☐		

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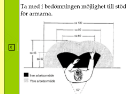
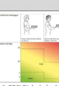
ARBETSMILJÖ VERKET

Faktorer som observeras	rött	gult	grönt	Kommentarer	Anteckningar
11) Är arbetsutrustning och arbetsobjekt placerade i lämplig höjd och på lämpligt sträckavstånd, dvs. i det inre arbetsområdet?	☐	☐	☒	Frekventa rörelser utanför yttre arbetsområdet ska undvikas. Ta med i bedömningen möjlighet till stöd för armarna.  *5 §, sidan 21 och 22, figur 5, 6 och 7*	- Lyft av polymer från polymerbingarna kräver att operatören sträcker sig för att nå de nedersta lagerna.
12) Är arbetsstolen anpassad för individen och arbetsuppgifterna?	☐	☐	☐	Ta hänsyn till om stolen är lätt att ställa in *5 §, sidan 23, figur 9* Behöver stolen vibrationsdämpas?	- ej tillämpbart

6

ARBETSMILJÖ VERKET

Faktorer som observeras	rött	gult	grönt	Kommentarer	Anteckningar
Manuell hantering och annan kraftutövning					
13) Förekommer manuella lyft av tunga bördor eller laster? Om ja: Ta hänsyn till dessa faktorer vid bedömning:					
frekvens (hur ofta)	☐	☐	☒		
duration (hur länge)	☐	☐	☒		
greppbarhet	☐	☐	■	*6 §, OBS! Tänk på påverkande faktorer i Bilaga A sidan 9*	
utrymme	☐	☐	☒	Här kan du även prova KIM 1 ADI 627 www.av.se/checklistor	
14) Används hjälpmedel?	☐	☐	☒	Nej, men behöver användas = rött Ibland = gult Ja, alltid när det finns behov = grönt *6 och 7 §§, sidan 15 och 26*	
15) Finns det tillgång till hjälpmedel för rullande hantering (vagn, kärra) i stället för att bära bördor?	☐	☐	☒	Nej, men behov finns = rött Inte optimal tillgång till hjälpmedel = gult Ja (eller behov finns inte) = grönt 6§	

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ARBETSMILJÖ VERKET

Faktorer som observeras	rött	gult	grönt	Kommentarer	Anteckningar
16) Bedöm arbetsmoment där man skjuter eller drar. Ha med dessa faktorer vid bedömningen:				<table><tr><td>Kraft (N)</td><td>Rött</td><td>Gult</td><td>Grönt</td></tr><tr><td>Igångsättning</td><td>>300</td><td>300-150</td><td><150</td></tr><tr><td>Kontinuerligt</td><td>>200</td><td>200-150</td><td><100</td></tr></table>	
lastens tyngd	☐	☐	■	*6 §, sidan 39. OBS! beakta påverkande faktorer i Bilaga A sidan 9*	
frekvens (hur ofta)	☐	☐	☒		
duration (hur länge)	☐	☐	☒	Här kan du även prova KIM 2 ADI 668 www.av.se/checklistor	
avstånd	☐	☐	☒		
placering av handtag	☐	☐	☒		
friktion mot underlaget	☐	☐	☒		
underlaget ostabilt eller lutande	☐	☐	☒		
17) Finns det hjälpmedel för att avlasta vid arbete med handhållna maskiner/verktyg (skruvdragare)?	☐	☐	☒	Nej, men behövs = rött Inte tillräckligt = gult Ja, tillräckligt = grönt *6 §*	

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ARBETSMILJÖ VERKET

Faktorer som observeras	rött	gult	grönt	Kommentarer	Anteckningar
18) Förekommer:					
grepp med stor kraftansträngning	☐	☐	☒		
obekväma handgrepp	☐	☐	☒		
dålig greppbarhet	☐	☐	■	*1, 6 och 7 §§, sidan 17 och 18, figur 13 och 14*	
stora precisionskrav	☐	☐	☒		
negativ klimatpåverkan t.ex. kyla	☐	☐	☒		
finmotoriskt krävande nypgrepp	☐	☐	☒		
vibrationer	☐	☐	☒		
19) Utförs arbetet med upprepade böj- eller vridrörelser för hand och underarm?				> halva arbetsdagen = rött < halva arbetsdagen = gult sällan = grönt *5 och 7§§, sidan 23* 	
rörelsehastighet	☐	☐	☒		
frekvens	☐	☐	■	Här kan du även prova HARM www.av.se/checklistor	

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ARBETSMILJÖ VERKET

Faktorer som observeras	rött	gult	grönt	Kommentarer	Anteckningar
Repetitivt, starkt styrt eller bundet arbete					
20) Förekommer repetitivt arbete det vill säga: "att upprepa liknande arbetsrörelser om och om igen. Tiden för varje arbetsmoment är kort och rörelserna sker i sådan omfattning att det finns risk för besvär"	☐	☐	■	Arbetscykeln upprepas flera ggr/min. under minst halva arbetsskiftet = rött Arbetscykeln upprepas flera ggr/min. under minst en timme eller många ggr/timme under minst halva arbetsskiftet = gult Arbetscykeln upprepas några gånger i timmen = grönt Arbetsskift = normalt 7-8 timmar *7 § sidan 40 modell för att identifiera och bedöma repetitivt arbete*	

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ARBETSMILJÖ VERKET

Faktorer som ska observeras	rött	gult	grönt	Kommentarer	Anteckningar
Handlingsutrymme					
21) Möjligheter att påverka arbetstakt, arbetsuppgifters inbördes ordning, inflöde av arbetsuppgifter, tidpunkt när arbetet ska vara slutfört, hur arbetet ska utföras och tider för pauser och återhämtning?	■	☐	☐	Arbetet är helt styrt av andra/annat = rött arbetet är delvis styrt av annat/andra = gult Goda möjligheter att anpassa arbetet efter egen förmåga. Inflytande över planering och upplägget av arbetet = grönt *8 §, sidan 31 och modell på sidan 40*	-Då klippningen måste ske i takt med mixern, så kan operatör inte påverka eller lämna arbetsstationen.
22) Kan arbetstagaren lämna sin arbetsplats åtminstone för korta stunder utan att service eller produktion störs?	☒	☐	☐	Nej, bundet arbete = rött Ibland = gult Ja = grönt *8 §, sidan 31*	-operatören vid mixern kan endast lämna mycket små stunder utan att produktionen avstannar. Operatör kan inte lämna arbetsstationen i korta stunder då klippningen av polymer ska ske i takt med mixern.
23) Finns det handlingsutrymme, som medger tillräcklig rörelsevariation och återhämtning?	☐	☐	☒	Nej = rött delvis = gult ja = grönt *8 §, sidan 16, modell sidan 40*	

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ARBETSMILJÖ VERKET

Faktorer som ska observeras	rött	gult	grönt	Kommentarer	Anteckningar
Kunskap och kompetens					
24a) Har arbetsledare/chefer, instruktörer/faddrar tillräcklig kunskap om gällande regler samt belastningsergonomiska risker.	☐	☐	☐	*9 § sidan 32 samt AFS 2001:1, 7 §*	- ej tillämpbart
24b) Finns regelbunden utbildning för					
arbetsledare/chefer	☐	☐	☐		
skyddsombud	☐	☐	☐		
instruktörer/faddrar	☐	☐	☐		
25) Innehåller företagets introduktionsprogram belastnings-ergonomi, för att de anställda ska arbeta rätt från början?	☐	☐	☐	*9 § sidan 32*	- ej tillämpbart

14

ARBETSMILJÖ VERKET

Faktorer som ska observeras	rött	gult	grönt	Kommentarer	Anteckningar
26) Har arbetstagaren tillräckliga kunskaper för att kunna utföra arbetsuppgifter ergonomiskt riktigt?				*9 § sidan 32*	- ej tillämpbart
Lämpliga arbetsställningar/rörelser	☐	☐	☐		
Teknisk utrustning/hjälpmedel	☐	☐	☐		
Risker vid olämplig arbetsteknik	☐	☐	☐		
Tecken på överbelastning	☐	☐	☐		
Har fått skriftliga instruktioner vid allvarliga risker	☐	☐	☐		
27) Får arbetstagarna möjlighet att praktiskt träna in lämplig arbetsteknik?	☐	☐	☐	*9 § sidan 32*	- ej tillämpbart
28) Sker uppföljning av att anställda följer instruktioner och arbetar på ett ergonomiskt lämpligt sätt?	☐	☐	☐	*9 § kommentar sidan 33*	- ej tillämpbart
Påverkande faktorer vid identifiering och bedömning av ergonomiska risker					
29) Finns tillräckligt med tid för att utföra arbetsuppgifterna?	☐	☒	☐		

15

ARBETSMILJÖ VERKET

Faktorer som ska observeras	rött	gult	grönt	Kommentarer	Anteckningar
30) Finns påverkande psykosociala faktorer?					- ej tillämpbart
tydlig rollfördelning	☐	☐	☐		
inflytande	☐	☐	☐		
utvecklingsmöjligheter	☐	☐	☐		
krav och kontroll	☐	☐	☐		
socialt stöd från: **arbetskamrater**	☐	☐	☐		
chefer	☐	☐	☐	*sidan 17 och 18*	
andra	☐	☐	☐	*AML 2 kap. 1 §*	
Riskbedömningar					
31) Är bedömningar av ergonomiska risker gjorda på övriga delar i företaget?	☐	☐	☐	Nej = rött Delvis = gult Ja = grönt *AFS 2001:1, 8 och 10 §§*	- ej tillämpbart
32) Gör ni bedömningar av ergonomiska risker vid förändringar i verksamheten? (produktions- eller organisationsförändringar.)	☐	☐	☐	Nej aldrig = rött Ibland = gult Alltid = grönt *AFS 2001: 1 och 8 §*	

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