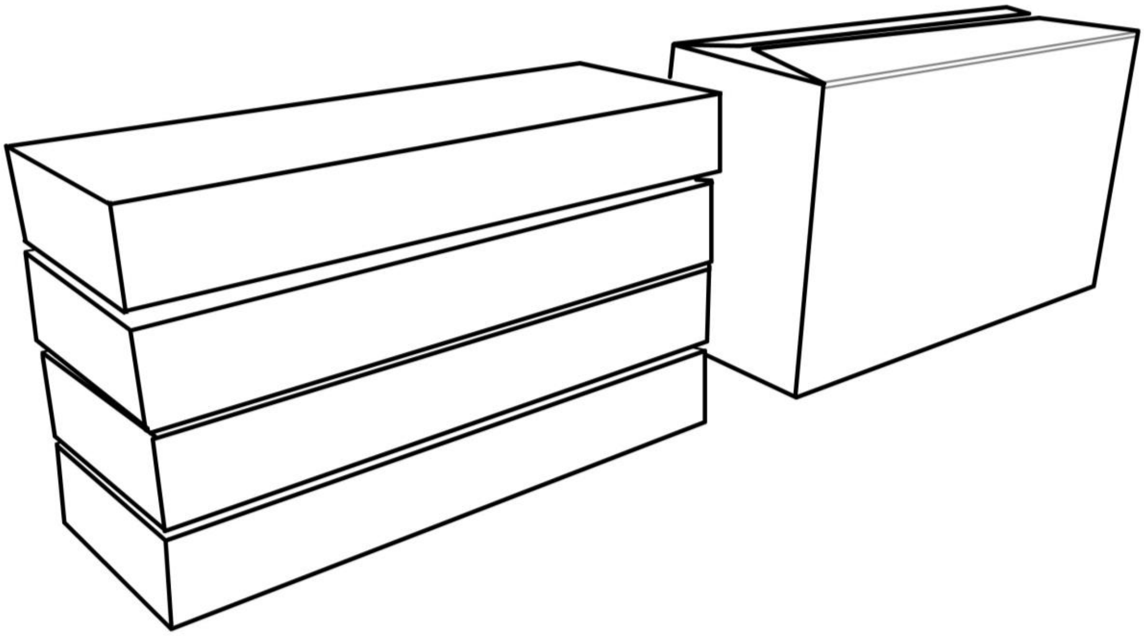
CHALMERS
UNIVERSITY OF TECHNOLOGY



# Resetting Performance Evaluation of an Automated Line with Short Setup Time

Master's thesis in Production Engineering


MATS JOSEFSSON
EMIL ÖDEBRINK

Department of Materials and Manufacturing Technology
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2014

# Resetting performance Evaluation on an Automated Line with Short Setup Time

by

MATS JOSEFSSON
EMIL ÖDEBRINK

**Diploma work No. 127/2014**
at Department of Materials and Manufacturing Technology
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden

Diploma work in the Master programme Production Engineering

**Performed at:** **Wellspect Healthcare Distribution Centre**
SE - 412 96 Gothenburg

**Supervisor(s):** Associate Professor Peter Almström
Chalmers University of Technology
SE – 412 96 Gothenburg

**Examiner:** Peter Almström
Department of Materials and Manufacturing Technology
Chalmers University of Technology, SE - 412 96 Gothenburg

**Resetting Performance Evaluation on an Automated Line with short Setup Timet**
MATS JOSEFSSON
EMIL ÖDEBRINK



Diploma work no 127/2014
Department of Materials and Manufacturing Technology
Chalmers University of Technology
SE-412 96 Gothenburg
Sweden
Telephone + 46 (0)31-772 1000

Cover:
[Schematic picture of product packages and transport boxes,
The input and output of the line studied.]

[Reproservice]
Gothenburg, Sweden 2014

Resetting Performance Evaluation on an Automated Line with Short Setup Time
MATS JOSEFSSON
EMIL ÖDEBRINK
Department of Materials and Manufacturing Technology
Chalmers University of Technology

SUMMARY
At the Wellspect distribution centre products are packaged for delivery all over the world. This requires a production system that quickly can change from producing packages for one country to produce for another. The fastest growing product segments are packaged in an automated line operated by four employees. To meet future demand an increase in capacity is needed.

The purpose of the project has been to look at the possible savings in setup times to reach higher productivity and thus higher capacity. The savings suggested should also decrease the variation of the setups to get a stable setup time.

The combined effect of implementing organisational, method, and technical improvements is that capacity increase of 15,7% has been achieved, with time savings of 32% for the most common setup variant. The investment cost is quickly repaid when calculating against the alternative cost of adding an extra shift.

The results where reached by videotaping the setup and analysing it in the Avix software. All methods and activities performed during the setup were then questioned to find improvements or possibility of doing the activity externally. Standardised work sheet and work combination tables have been developed to help support a standardised work and also act as a communication tool.

Keywords: setup, improvement, SMED, resetting, performance, capacity.

## Acknowledgment

We would like to give gratitude towards our examiner Peter who helped keeping the diploma work focused when we strayed towards to many variables.

A big thanks goes out to our supervisor Kjell at Welspect who always allowed us to interrupt to clarify questions and made sure we felt very welcome at the Distribution Centre. We would also like to give thanks to Markus at Wellspect who showed us the realistic expectations and whom we always could come to with the most specific questions.

Our warmest regards goes to all the staff out at the Distribution Centre for making us feel very welcome and always being ready to answer questions, willingly participating in our studies and for being as interested as us in the results.

## Terminology

| | |
|---|---|
| **Wet products** | Brand of products that include water for activation of the product. |
| **Overall equipment efficiency** | A measure of the total production efficiency of an equipment, including loss of quality, losses due to performance and availability. |
| **Setup** | The activities needed to change a machine or line from producing one subject to be able to produce another. Also called resetting. |
| **Format change** | Specific to this thesis a change of product requiring physical resetting as well as change of machine data. |
| **Order change** | Specific to this thesis a change of order but with keeping the same product and thus no physical resetting is needed. |
| **Pusher** | A machine that pushes boxes between two belt driven lines and thus enabling a box to change its forward direction. |
| **Depalletizer** | A machine that can unload a pallet. In this thesis the machine does this layer by layer using suction. |
| **Patient information leaflet** | A leaflet containing specific information about the product and its characteristics. |

# Table of Contents

# 1 INTRODUCTION

## 1.1 BACKGROUND

Catheters are used by people of all ages and gender around the world that for some reason are unable to naturally empty their bladder. This wide range of customers leads to a high variation of products when seeking to improve the quality of life for the users. Wellspect Healthcare is one of the world's largest producers of catheters, producing disposable products for customers around the world. With sales offices in 14 countries the production reaches several million catheters a year. At the Distribution Centre for Wellpect Healthcare in Gothenburg all catheters produced are packaged for end customer. The catheters arrive at the distribution centre in packages containing 20 to 30 catheters depending on model. . These product packages are then packaged at the distribution centre into transport boxes. A principal drawing of the packages and a transport can be seen in figure 1. There are either two or four packages per box depending on variant.

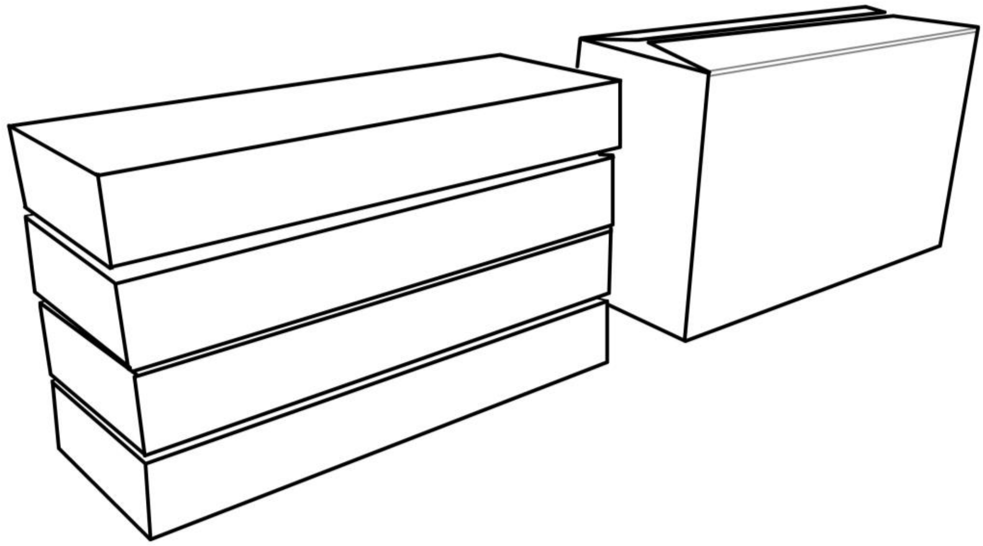


**Figure 1: A schematic picture of 4 packages and a box.**

Since all catheters produced are packaged into transport boxes at the distribution centre this means several different models, dimensions and many different customers and countries. It is also at the distribution centre that the individual packages become dedicated to a specific country, by applying country specific labels to the packages. This requires large flexibility in the production system. An automated line has been installed for a brand of products called the wet-products. This is a product segment with increased number of sales, in the form of more but smaller orders and new requirements on different packaging. This has led to an increase in the number of setups, leading to lower efficiency of the packaging line when higher utilisation is required to meet the rising number of different orders.

Very basic measures of the time spent on setups are used today to calculate the overall equipment efficiency (OEE). It has been seen that format changes and order changes takes up a considerable percentage of the available production capacity, and a reduction of setup time would increase the output and hence lower the cost of the catheters.
The incoming goods from the production are produced in large batches in factories where high utilisation and low cost together with quality has been focus. This focus has driven the production towards few setups and large stock. To increase flexibility, setup time reduction projects are planned and the thesis will help to serve as a basis for suitable methods.

The automated line for the wet-products consists of several automated machines connected by a conveyor system that transports the products out of the production facility into the warehouse. Due to the medical use of the products high traceability is required leading to rigours control of quality in the packaging process. An order change is separated from a format change, the principle difference between an order change and a format change is that in an order change the physical settings remains. The incoming material is the same as previous orders, thus the physical settings remains. In an order change there are mainly software changes. To clarify it's of importance to state that both an order change and a format change is a setup, but there are large differences in time allocation and possible savings.

## 1.2 Purpose

The purpose of the study is to analyse the current situation regarding controlled stoppage of the line and identify the reasons that affects the times of these stoppages. When a starting point has been established the thesis will look at both technical and organizational improvements of the format changes and order changes. Alternatives for improvements will be established in cooperation with the workforce through existing channels of communication to gain a standardised way of working. The master thesis will give recommendations and evaluate the solutions chosen, specified by time and cost to implement, potential earnings, and capacity increase.

The method used in the thesis will be described in such a way so that it can be used during future development at different production areas within Wellspect Healthcare.

Two important research questions have been established for the study:

1. What is the capacity increase possible by looking at reduction of setup time?
2. What is the cost of the capacity increase?

## 1.3 Delimitations

To ensure that all tasks undertaken during the project can be finished during the timeframe delimitations must be set to frame the study on the most crucial parts of the line, the following activities will therefore not be done:

- The study will not directly transfer any new methods to other lines
- The study wil not seek to actively improve production disturbances.
- The planned maintenance on the line each week is set and will not be questioned in this study.

To ensure that the study does as little impact on the daily production as possible and to ensure that follow-up questions are always possible one specific worker have been chosen be the main contact amongst the workers.

# 2 THEORY

There are different approaches to achieve higher capacity in a production system. Capacity can be bought by investing in new machines. This is often a very expensive way to reach higher capacity, especially if all the new capacity is not utilized. Another way to reach higher capacity is to keep the machine running by introducing more shifts. This means adding high staffing cost. A third way to reach higher capacity is by increasing the productivity in the current production system. Productivity can be calculated as:

$$Productivity = M \ x \ P \ x \ U$$

Where $M$ is the method used during production, the inverse of the ideal cycle time. $P$ is the performance factor which is how well the work is being carried out in relation to the ideal cycle time, for a machine operating at its ideal cycle time this is 100%. The utilisation, $U$, is also ideally at 100 %, but this is very seldom the case in automated machinery due to setup times and machine breakdowns (Almström, 2012). To improve the productivity of an automated line improving the utilisation factor often give large improvements. When improving utilisation resetting of the production is one of the important areas to improve (Johansson & Kaiser, 2002) (McIntosh et Al, 2007). The area of setup improvement has been dominated by references to the SMED model as proposed by Shingo (1985). By simply addressing the fact that setup activity that is done when the machine is still producing does not contribute to the setup time, the road to achieve best practice had a new focus, doing setup activities while the machine is running. From this several models and guides have been developed putting the main contribution of Shingo into the context of a improvement process (Kaiser, 2002)(McIntosh et Al, 2007)(Zandin, 2001). The area of how to properly reap the benefits of shorter setup by planning of order sizes costs and is also a mature research area (Olhager, 1993) (Allahverdi & Soroush, 2008). There has also been a development of analytical tools to use within the area that has gained increasing interest, for example the use of discrete event simulation (DES) on a setup procedure (Johansson & Kaiser, 2002).

## 2.1 Resetting Performance

A setup is defined as the time allocated on a machine to change from producing one product to another. This includes the ramping down from the previous production until the new product can be produced at full pace (Zandin, 2001.). A schematic illustration can be seen in figure 2 showing the setup time in relation to the production. It is when the capacity is down at 0% that the machine is stopped.

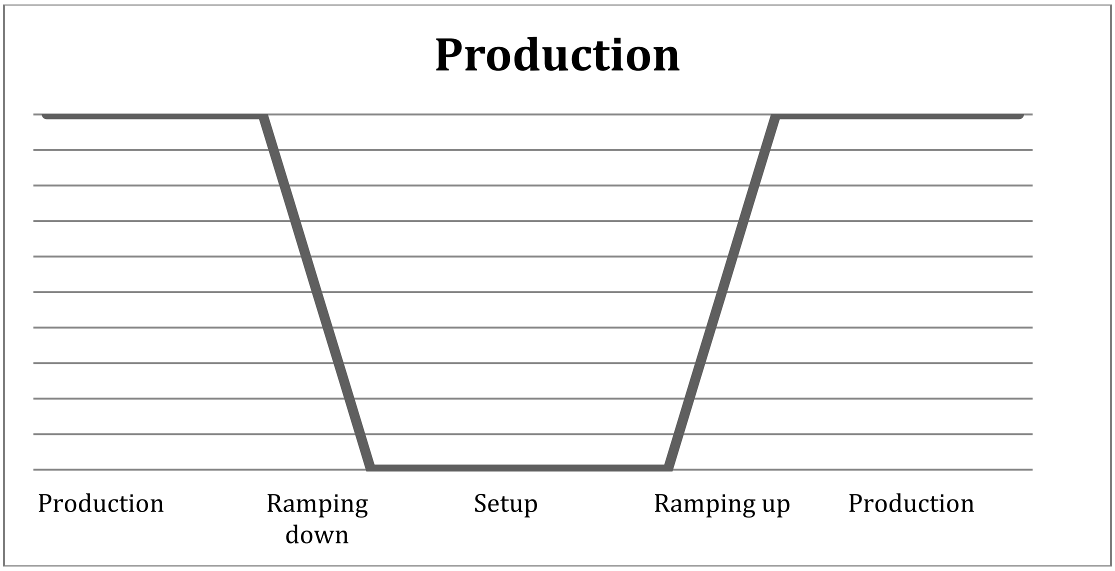



**Figure 2: Principle illustration of production in comparison to setup.**

When a new process is implemented into a production facility the resetting time is often designed with the goal to be below 10 minutes. When the final design is completed the setup time possible often ends up well above the desired time, as illustrated by figure 3. The real setup becomes even higher due to deviation in organisation, method and to a small amount the technical system. The organisational deviation is often the highest followed by method and the technical systems variation is often negligible (Kaiser, 2002). This leads to the conclusion that organisational improvements are the easiest way to achieve the most improvement with the least effort.

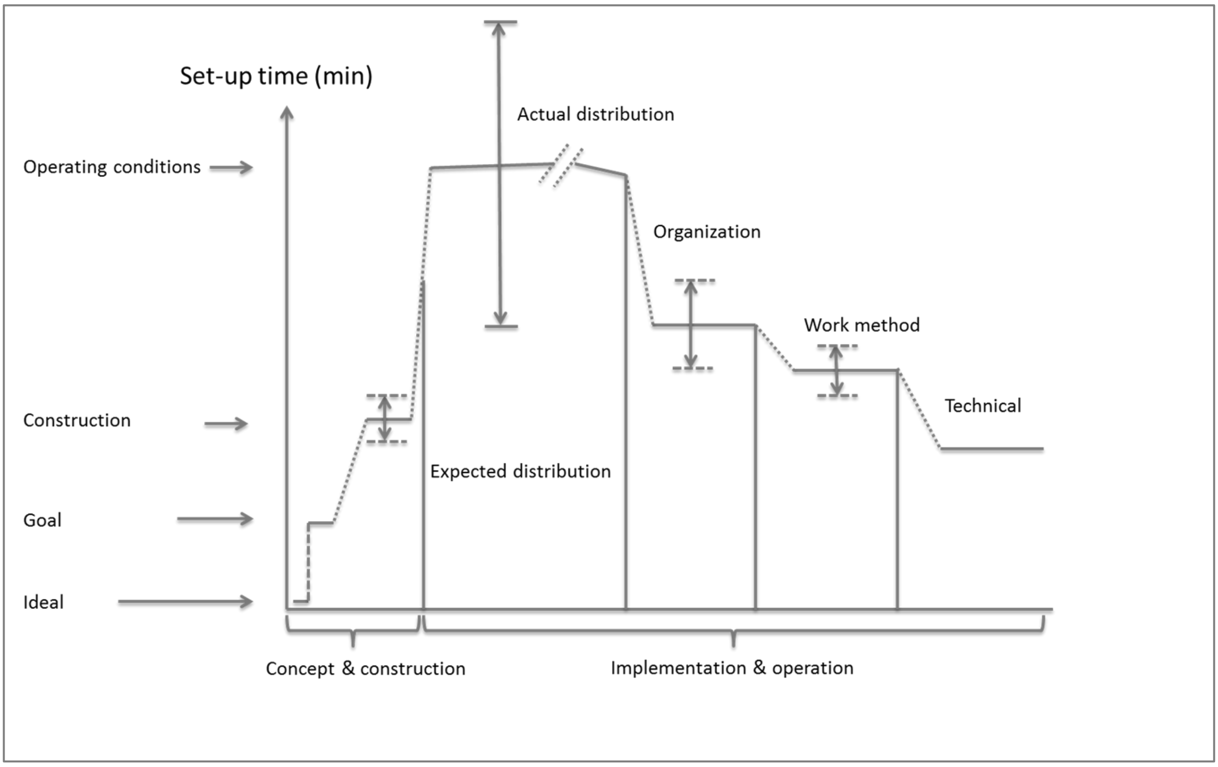



**Figure 3: Illustration of potential savings in resetting based on Kaiser (2002).**

When evaluating a setup operation it is recommended to use an evaluation approach to focus on effectiveness and efficiency. This way the redesigned setup can be benchmarked against the previous state as well as what is theoretically possible (Kaiser, 2002). To sustain a change of the resetting procedure McIntosh et Al (1996) state that redesigning the entire system will prevent backsliding but Kaiser (2002) advocates a combination of design and organisational improvements.

## 2.2 Resetting performance evaluation

The resetting performance evaluation (RPE) framework is a structure for achieving a sustainable improvement of a setup. The framework is divided into four levels; profitability, organisation, method and technical. Kaiser (2002) also suggests a structured way to improve the resetting operation again using the same three levels. Due to the nature of deviation within a setup operation it is most efficient to go about the improvement work in the order of profitability, organisational, method and technical. This is a general recommendation, if an specific area is deemed to have large potential work can be started there and then continue elsewhere as the area with most potential shifts

### *2.2.1 Profitability evaluation*

On the most aggregated level, profitability, the improved setup will give results such as lowered cost of inventory and improved lead time. To help improve the profitability an analysis of the profitability data should be collected in co-operation with both the supply and accounting departments to gain valid data of how the costs of the operations are at present. This data will then be used to calculate the monetary savings as the total time for a resetting operation goes down. Having a quick and easy way to do this early on will help calculating return on assets for the investments suggested and set targets for the reduction(Kaiser, 2002).

### 2.2.2 ORGANISATION EVALUATION

On an organisational level the most important measure is the cell, or line, resetting time and how it is improved. The ingoing factors of the organisational level are to plan in what sequence operations are performed and by whom. An important factor to remember is to optimize walking paths.

To improve the organisation an understanding of the often complicated activity of a resetting organisation analysing the current situation and compiling a chart with the sequences performed during the reset is recommended. The enabling and preventive relations should also be noted, technical as well as rational. This will help in compiling a new more efficient organisation with lower amount of deviation (Kaiser, 2002).

**Single Minute Exchange of Die**

The term SMED was coined by Shingo in 1969 whilst working on a die change improvement at Toyota, single minute exchange of die or SMED has had a large influence on resetting performance since (McIntosh et al, 2007). With large experience from industry Shingo (1985) developed a method based on four conceptual stages where the first two stages directly deals with organisational improvements.

First stage is the preliminary one. It deals with studying the production and setup in detail to get an understanding of what operations take place to make a setup possible. This can be done through work sampling study or videotaping the resetting operation. If this is not possible one can come a long way by observing and talking to the operators.

Stage one is separating internal and external setup, see figure 4. Here internal setup is operations that have to be conducted whilst for example the line is stopped, i.e. the machine is fully stopped. The external setup is actions that can be done during production. It is important to try to treat as much as possible of the setup as external and question why some operations have to be done as part of internal setup. One should also look at possibilities to separate operations within an internal setup process to achieve external setup operations. All operations that are classified as external setup can now be done during regular production.

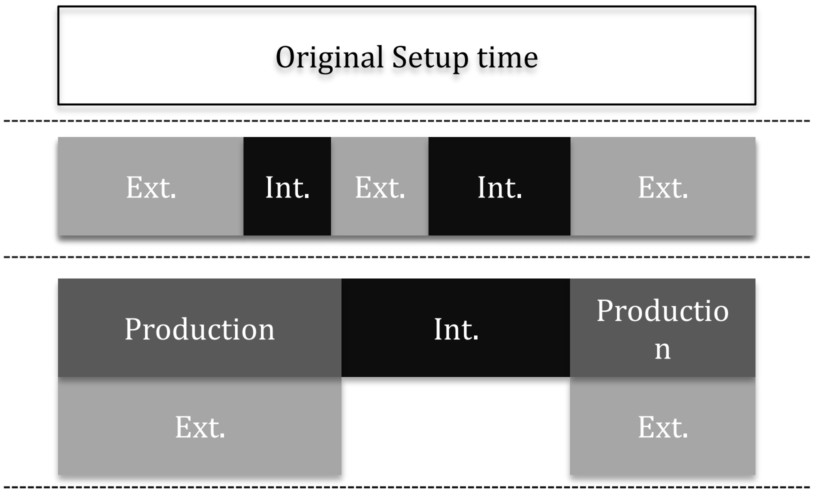



**Figure 4: Separating internal and external setup.**

### 2.2.3 *METHOD EVALUATION*

On the method evaluation level the setup of individual machines and other standalone operations are reviewed. An important factor to look at is the value adding work to the total work performed on individual machines.

Engineers working on improvements of the reset time are often very quick to jump to improvements without making a thorough analysis of the method. This means that a lot of potential is missed for the easy to see solutions. When a method is thoroughly analysed the engineer has to really understand each task and can also question every operation separately. When the method is broken down improvements can be discussed with the worker and with the entire workforce to gain agreement on the new work method, opening up for the ability to get accepted work standards.

**Single Minute Exchange of Die**

Stage two in the SMED methodology is to convert internal setup into external, see figure 5. To do this Shingo (1985) recommends looking at the internal operations again to see if any actions can be wrongly judged as internal. Shingo also stresses that these actions should be converted into external. Many times questioning the function behind the steps can help convert them to external by finding other means to fulfil that function. Many times this stage requires techniques that help preparing operating conditions, techniques such as intermediate jigs and function standardisation.

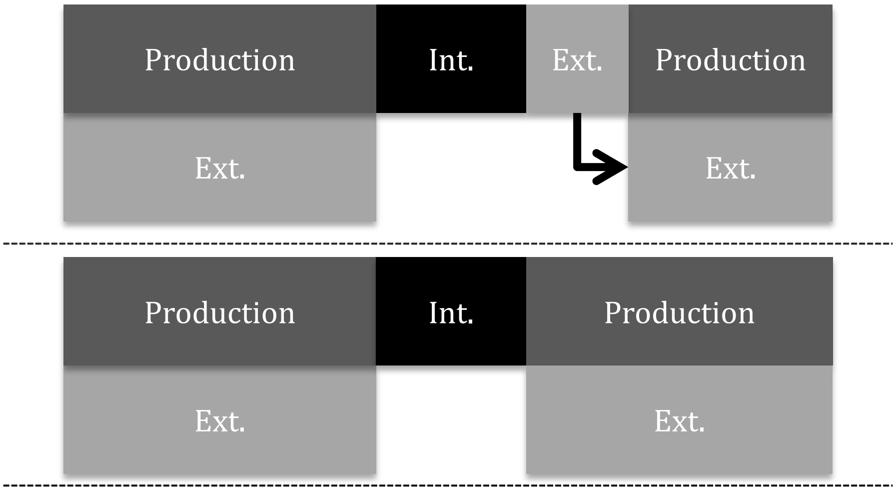



**Figure 5: Converting internal setup to external.**

Stage three in Shingos SMED methodology considers streamlining all aspects, internal as well as external, illustrated in figure 6. This means going into depth on how different steps are performed and to what cause, finding more effective ways of performing each part of the method. This is where Shingo (1985) comes into parallel operations as a means to reduce time spent on a machine considerably. Also using functional clamps, rethink the storage of tools and parts used in the setup process, elimination of adjustment is recommended.

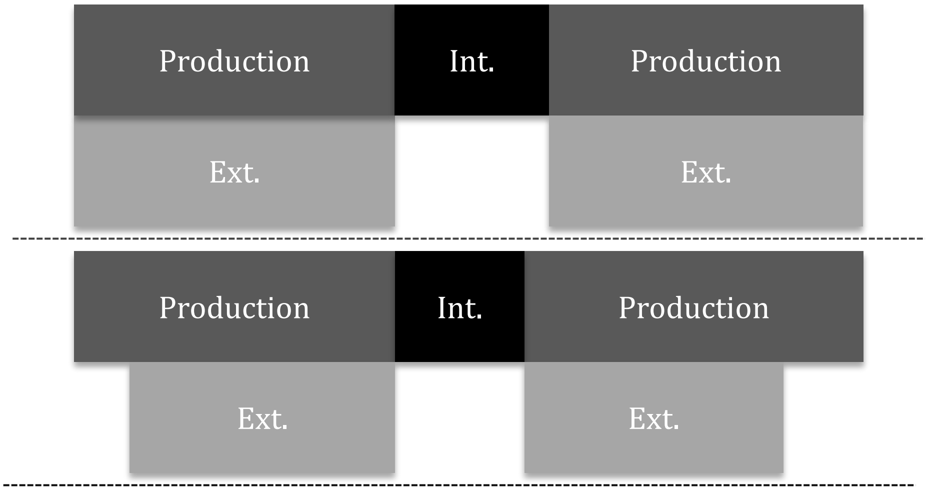



**Figure 6: Streamlining the setup.**

**Predetermined time system**

To be able to set a standard time for a setup all processes within must be defined and have a standard. The machine time in a process is often easy to calculate and has low variation. The manual tasks however are not as easy to decide upon. To do this time standards is used. Time standards is the time it takes for a person to perform a specific task, taking into account that the person performing the task should be averagely skilled, work in a normal tempo and allowing time for fatigue and allowances (Zandin, 2001).

In 1948 Maynard et al published *Methods time measurement*, by analysing the time it takes to do specific movements they built a predetermined time system that could analyse any manual task by breaking it down into basic motions which had a standard time. This system is what today is called MTM-1 (Zandin, 2001). MTM-1 consists of several basic motions, such as grasp, turn and reach. It is very detailed and therefore an analysis gives high precision but takes a very long time to perform. As a consequence of the time consuming process of analysing a sequence with MTM-1 several different versions have been developed with the aim to be more specific to a certain industry or simply provide quicker analysis but with lower amount of precision.

One of these predetermined time systems is SAM (Sequential Activity – and Methods Analysis). SAM is based on analysing sequential activities in the sequence of taking something and moving it to another position. The activities are grouped into basic activities, supplementary activities and repetitive activities. The different activities in turn have variables to compensate variance in the movements for example length of movement or weight of object. Each motion has a designated standard time which is given in factors. 20 000 factors is one hour, which makes one factor 0,18 seconds. Even though there is variants to all motions the system has an inbuilt variance to it, to achieve a time which has a precision of 95% one must analyse 1720 factors of manual work, corresponding to around 5 min and 9 seconds (MTM-Föreningen i Norden, 2004).

### 2.2.4 *Technical evaluation*

Analysing the technical system in the setup process with regards to design for assembly and design for manufacturing will help improve the technical system (Kaiser, 2002).

## 2.3 Standardised Work

Standardised work can be used for different purposes. It can for example be used to help operators achieve better cognitive ergonomics. Furthermore it can be used to control the speed and pace at which the workers are performing their work. It can also be used to guarantee that quality checks are performed and the product meets the quality standards. By having a standard that is followed, variation can be identified and measures can be taken to improve. The current standard is the base from which you can make improvements (Liker & Meier, 2006). There will always be flaws in the standard that needs to be improved. There is a need for a relatively stable process to be able to standardise the work. Otherwise the amount of deviation from the standard will be far too large and thus making the standard times impossible to achieve. Once the standard is implemented this will give not only the standard way for workers to perform tasks but also the time, giving a fair description of what is expected from them (Zandin, 2001). There are several documents that can be used in a business working with standardised work. It is important to keep in mind that these documents are an analysis tools and not a documentation plan (Marksberry et Al, 2011). As a result of the widespread use of ISO certificates many companies have turned standardised work into a very specific and rigid documentation plan. The purpose of the documents is to analyse work and follow up on standards (Marksberry et Al, 2011). Liker & Meier (2006) recommends three types of work documents to be used in establishing standardised work; standardised work chart, standardised work combination table and production capacity sheet. In a review of Toyotas work with standardised work Marksberry et Al (2011) states six documents used in analysing standardised word:

- Time measurement sheet
- Production capacity sheet
- Line balance chart
- Combination table
- Work chart
- Work method chart

The standardised work chart is a description of the work performed by an operator, including a picture of where the activities are performed and what time each activity consumes as well as the walking time. This allows for easy auditing of the work and identification when time standards are not met. The standardised work combination table is used to see the relations between man and machine or two operators working together (Liker & Meier, 2006). When automatic work is performed by a machine this can create a wait time for the operator, with the work combination table that time is visualised.

The standardized work documents are not put in place mainly for the operator's ability to see what to do. Of course the documents can be used by untrained operators or for tasks where the length and complexity of the tasks are high. Mainly they are there so that anyone walking by can easily see that the work is being performed in accordance to the standard. These audits should be done when there is a defect from the standard and at regular intervals (Liker & Meier, 2006). An identified error must be corrected, to ensure that solutions are implemented a visual board where defects and corrective actions are noted is used in many of Toyotas facilities (Liker & Meier, 2006). This gives the managers a possibility to follow up on deviation. By having standards implemented new improvements can be weighed against this standard time. Measuring if the standard time is achieved will also help evaluation and identification of improvement (Zandin, 2001). This is illustrated by figure 7.

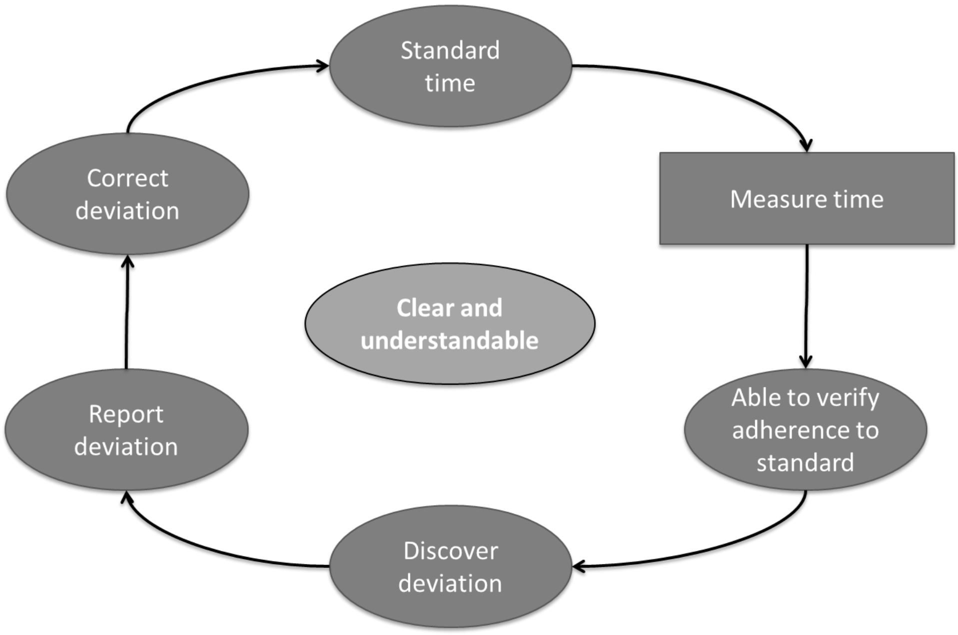



**Figure 7: Advantages of standardised times.**

It should be kept in mind that standardised work requires highly skilled operators that are familiar with the work. It is natural that the transgression into new method of working will result in errors during a run-up phase. This must be allowed so that the new method is not scrapped before it is properly implemented (Liker & Meier, 2006). According to Liker & Meier (2006) the most often neglected part of standardised work is visual control. Too use visual control without applying standardised work can often go to extremes where the visual control serves little or no purpose. When used together with standardised work visual control enables both cognitive ergonomics in seeing remembering what to do as well as clear signals of deviation, figure 8 gives a graphic explanation of how the visual control helps the adherence to standards.

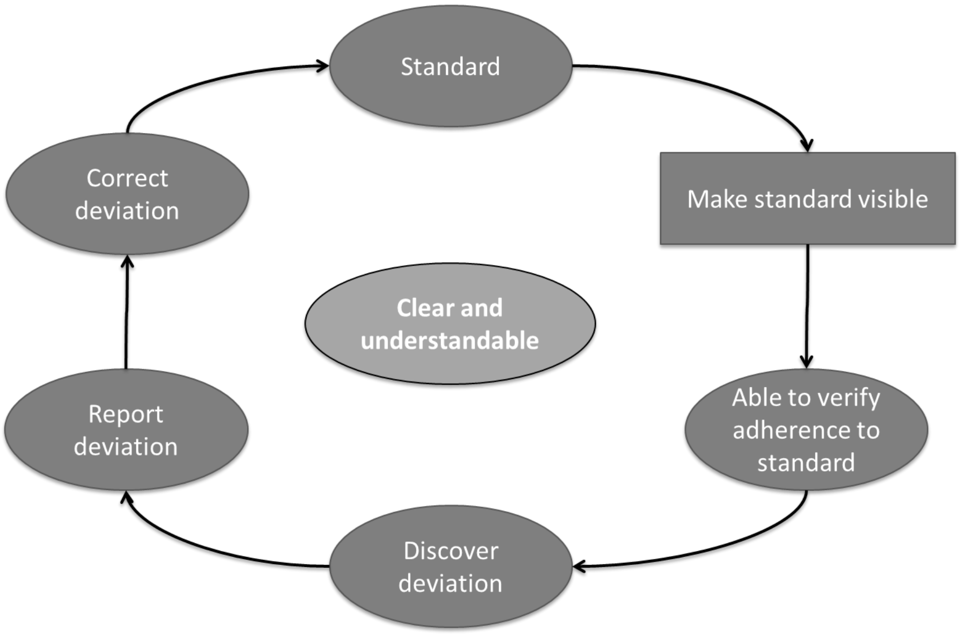



**Figure 8: Advantages of visual control in standardised work.**

# 3 METHOD

The method followed during the study is dominated by the resetting performance evaluation (Kaiser, 2002) where the classical SMED methodology (Shingo, 1985) has been adapted as tools to use within the different steps. The four steps in each of the processes correlate well to each other giving a comprehensive evaluation and improvement of a setup process. It is also beneficial for the project that the solutions gained early in the project are estimated to be the largest and requiring little or no investments. This gives the project early momentum, helping to keep the personnel involved. A schematic illustration of the method used during the study can be seen in figure 9. The illustration also clearly shows the iterative approach that is needed to gain a fully improved solution. To achieve a fully developed solution the iterative process is necessary, after improvements to the method or technology further improvements to the organization may be necessary.

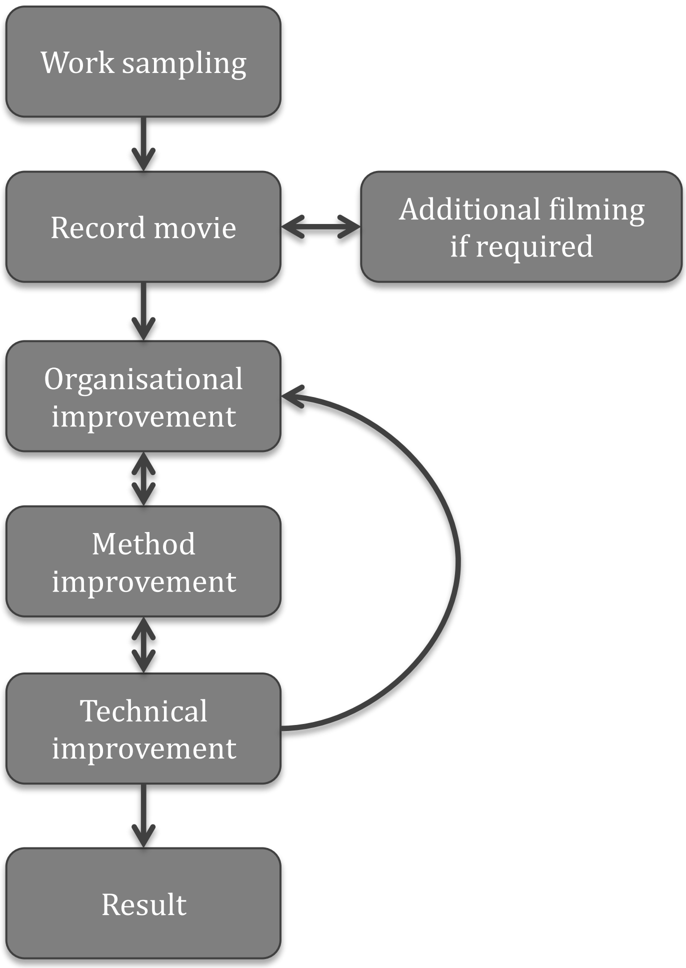



**Figure 9: Method for improvement**

## 3.1 PROFITABILITY EVALUATION

**Economic calculation model**

To evaluate the improvement proposals against economical terms the effect of not implementing was considered. If the market grows and Wellspect Healthcare needs to improve the capacity an extra shift is a reasonable solution. Therefor the improvement proposal was compared to the cost for an extra shift. The cost an extra shift would add is personnel cost, this is what the company consider takes in consideration and was asking for.

**Production data**

When trying to improve a resetting procedure it is important to be able to compare present state with the improvement suggestions. To be able to compare not only one time for a single setup but rather what that improvement means for the company in terms of increased production capacity or flexibility data was needed of historical production. The company could provide historical data of the number of setups, stoppage time, number of produced packages and preventive maintenance. These data where given on a weekly basis. Data for the amount of rework for each order could also be extracted. It should be noted that stoppage time and preventive maintenance are times filled in by the operators creating a large uncertainty to the validity of the times noted.

## 3.2 ORGANISATION EVALUATION

In the beginning of the project an understanding of how the production was organised and how and when a setup was performed needed to be established. To get a full understanding a wide range of methods where used. Special consideration was taken to videotaping the setup process to comply with the methods of Kaiser (2002) and Shingo (1985). To get a good understanding of the different actions performed during a setup the operators where followed during four setup procedures and the activities where documented. This enabled a better understanding of how the different activities were sorted between the operators and was the basis for planning the videotaping. To get an understanding of the possible machine changeovers all machines or fixtures that could be changed was documented. A meeting was held with an operator who thoroughly explained all possible variants in machine settings and between which product variants these had to be changed. This enabled the creation of a theoretical instruction on each possible variant. The activities performed during a setup were listed and during a meeting with an operator the relations between activities were questioned. This led to a document of how the current technical system delimited activities from being performed in certain sequence.

### *3.2.1 WORK SAMPLING*

A work sampling study was performed to get an overview of how the planned time at the line was allocated by the operators. It determines what actions during a day that is using the time and the utilization, with a large number of samples a mean is determined. The focus of the work sampling was to determine the amount of time spent on setup, but also to early on get an understanding of how the available time was allocated and how production and setup was organised.

The activities that are performed by the four operators were divided in 10 categories determined by preconceived opinions as well as the operator's opinion. A full description of the categories can be found in appendix 1, the categories measured where:

- Order change
- Format change
- Inspection
- Material handling
- Idle time
- Scheduled maintenance
- Machine adjustment
- Extra work
- Not at the machine
- Administrative work

### 3.2.2 *VIDEOTAPING THE SETUP*

To get measured times of all operations within a setup and to be able to review how the activities are performed the setup procedure was filmed. The advantage of filmed operations is the ability to revisit an operation again and again, not having to wait for the required operation to be performed. The filming was planned so that each of the four operator roles would be filmed once. Certain variants of setups that would guarantee that all activities within a role where performed was chosen. The operators where informed of the purpose of the videotaping and that it was voluntarily to be part of the study. Before filming, the operators were instructed to do the setup as they normally would, talking during the setup was up to the individual operator, and any mistakes they made would be taken out of the analysis. Although well planned, the filming needed to be complemented.

### 3.2.3 *AVIX*

Avix is a computer software program designed to handle filmed operations that are the subject of improvement. The purpose of Avix is to get standardised times for the operations that have been filmed. When optimising the organisation, during the project the Avix software has been used to great extent in combination with spaghetti diagrams. This enables both to identify walking patterns that would be beneficial for the tasks performed as well as giving a clear picture of the effects from parallelisation. By combining the first identified external setup operations and the organisational improvement of the setup process, potential time savings could be generated.

The filmed sequences were divided into separate activities in the Avix software. After this was done for the setups including all activities the activities were arranged in Avix to represent all variants of setup. During the division of the movie into activities the times from the film where used to give a representation of how the work was performed today. The activities in Avix can also be created using standard times. There are several different versions of the software to be had when creating standard times, from SAM to UAS, but all are based on MTM times. Analysing operations on this level helps determine the real time usage thus eliminating waste. This is time consuming work and therefore it was decided that creating MTM-based times would only be done for activities that where improved. By using knowledge on how activities were interrelated the activities that were external could be taken outside the internal setup in the SMED module. The Avix software has several modules to simplify the work and versatility of the software. One of these is the SMED module that allows the user to separate internal work from external and thus achieving a good visual representation of how making internal setup into external will affect the setup. The software also gives the time needed for internal setup to be performed.

Avix was also used to print work instructions where notes and pictures can be added to help guide the operators in how to perform the work. Furthermore data from different analyses can be extracted to show upon performance potential and strengthen the argument for improvement. The simplicity in creating new analyses together with the ability to rapidly create work instructions enables a lot of testing of new organisations, using the time saved to iterate new and improved states. This is shown in figure 10 where the process of improving the setups by using several iterations is illustrated. Using the pre-existing spaghetti diagram and by creating a precedence graph to determine the ability to parallelise a new improved organisation was established.

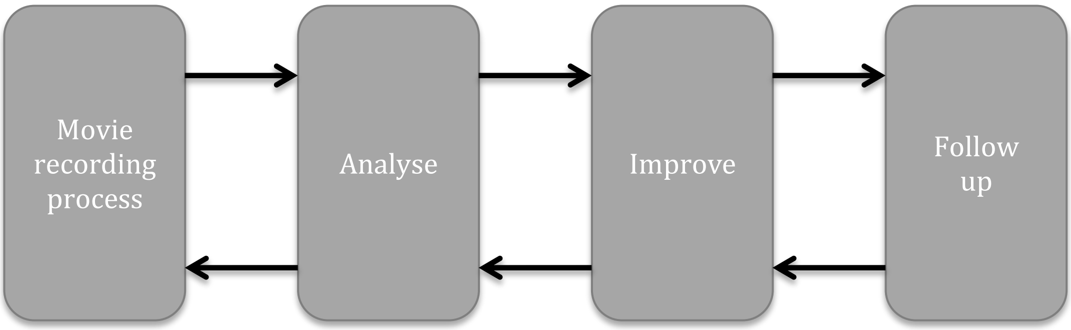



**Figure 10: Description of workflow in Avix.**

Once the organisation of the setup was evaluated and improved all organisationally improved setups where created as well. To be able to establish an average setup time for planning purposes the historical data on product variants was used. The percentage of how often variants occurred together was multiplied with the analysis of the setup between those specific variants and then all variants where summed up.

### *3.2.4 SPAGHETTI DIAGRAM*

To visualize the walking paths of the operators during a setup spaghetti diagram is an efficiant way to illustrate that. It's easy to understand and show upon the improvement with a before and after illustration. The spaghetti diagram is also intuitive and easy to comprehend therefor the effect of the improvements that have been made is possible to grasp. All tasks and walking paths during a setup have been recorded with a camera. Extracting these walking paths from the recorded movie and plotting them on to a principle map of the workshop gives the spaghetti diagram for the present state.
The spaghetti diagram for the evolved setup procedure is based on the improvements made. Extracting the tasks and the new order of the tasks from Avix and then choosing the shortest walking path gives the spaghetti diagram for the improved setup. The spaghettis diagram was also used to generate solutions, to start with a reasonable walking path and then adding the tasks that come along that walking way. The comparison between before and after improvements gives a picture of savings in terms of walking distance that is easy to comprehend and translate to saving in time. It is effectfive to show the before and after to make the operators realize the savings, it makes it easier to get them to try the new procedures.

### 3.2.5 *LINE LEAD TIMES*

The lead times within the line was measured to be able to represent in an Avix analysis. The time for a box to travel from the first pusher to the final one before the warehouse was measured. Since the line is moving at a constant speed only a few samples was needed to determine this time. The time of a line clearance was defined as the time from the last product leaving the final pusher until the operator could start a new production order. This time had a larger variation, but no historical data was available so a mean was taken to represent the time. Loading of the labels into the printers also has a large variation. When discussing these times with operators and staff at the company it was discovered that these as well had a large historical variation and had also significantly increased in time since installation A mean was taken here as well but efforts will be taken to calculate how the variation affects the standard times.

### 3.2.6 *STANDARDISED WORK*

A system for standardised work, focusing on the setup procedure, was established. It was determined that for the purposes of the project in this thesis only the standardised work sheet and standardised work combination table will be developed to serve as a basis for establishing standardised work during setup.

## 3.3 METHOD EVALUATION

The prioritisation of the methods improved was to first ignore those activities deemed as external. Secondly the priority was to start with the activities which gave most time savings in the setup operations. The operators was also consulted to recommend what they believed was improved ways of working and contributed with many ideas as well as, although very open-minded, reasons why some of the studies solutions would not work.

To be able to acquire a standard time for the new methods of work SAM analyses have been performed on the new work sequences. The standard times given by these analyses are an estimation on how the new method would be performed. Once the new method is implemented the standard should be reviewed to see that no part of the sequence has been neglected in the analysis. The total SAM analysis time of 5 min to get high precision in the analysis will not be met but it is still deemed that using SAM has higher precision than a SWAG[1].

## 3.4 TECHNICAL EVALUATION

The development of the technical system has had a lot of focus in researching the possibilities in reprogramming the line clearance to avoid the lead time this gives the resetting operation. To verify the possibilities of doing this a programmer who had previous experience of the line was consulted. The loading times of labels as well as other areas with critical result for the total lead time were investigated for improvements. Externalising has mainly been a question of reprogramming the line to allow for a activities to be less restrained by the technical system.

[1] Scientific wild ass guess

# 4 PRESENT STATE ANALYSIS

This chapter describes the results from the analysis of the data gathered. In order to understand the production system at the distribution centre today and what the base line for improvement is a description of the line and how setup and normal production is performed today is presented.

## 4.1 THE WET LINE

The wet line is an automated packaging line, packaging packages into transport boxes which are placed onto a pallet and wrapped for transport. There are three different products that are packed today and a total of eight variants including the number of packages in a transport box as well as the size of the packages. A schematic figure of the line is presented in figure 11 and figure 12 and a more comprehensive one can be had in Appendix 2.

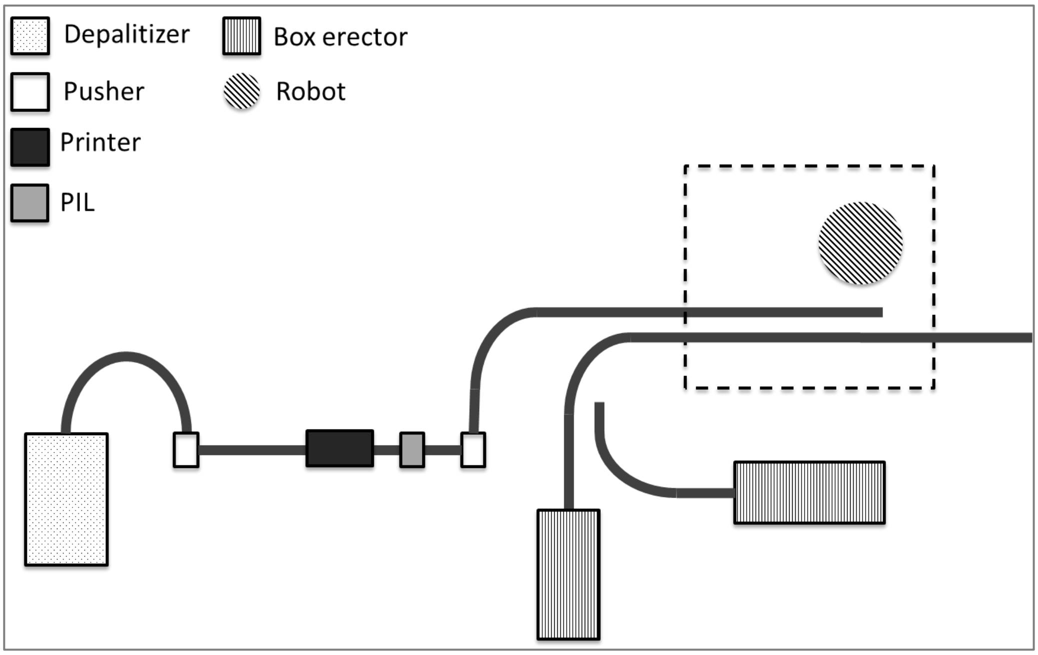



**Figure 11: Principle drawing of workshop floor, the main hall.**

The line starts with a depalletizer, cartons are removed from a pallet that is loaded in the depalletizer. The depalletizer is connected to an automated pick-and-placing robot that takes the packages from the transport line, rotates the cartons to the right direction and places them onto the line. The packages then travel along to a pusher.

When the line is running the pusher feeds the line with cartons. This part of the line has four adjustable guide rails that ensure that the packages are centred when passing the label printers along the line, these are called guide rail 1-4. Cartons that have passed the pusher are scanned by the datamatrix, a scanner reading barcodes, to determine that it's the right model. Then the packages go by the department printers and top printers where the packages are labelled. The first label added is called department label and the second added is called top label. They also get a patient information leaflet (PIL) glued when passing the PIL feeder. The first two printers apply department labels, the next two top labels. Both types of printers and the PIL feeders have duplicates to ensure that one can take over if material runs out in the other. As the packages have passed the printers and PIL-feeders they are scanned to ascertain that the labels and PIL have been correctly placed. If there is an error the packages are rejected, otherwise they are pushed forward to go into the robot cell. On their path into the robot cell the packages are centred by a guide rail that is adjustable for different widths, this rail is called guide rail 5.

The robot cell takes the packages and lifts them into transport boxes on a lower line coming into the cell. Both the upper and the lower guide rail in the robot cell can be adjusted to fit the width of the incoming material. The transport boxes are fed to the lower line from two box erectors. Filled boxes go out of the line, for some variants they get a transport PIL, and into a box sealer. Coming out of the box sealer the boxes are centred by a guide rail, guide rail 6. The sealed boxes get labelled with transport labels, whilst kept centred by guide rail 7, and finally the transport label is automatically scanned in a final pusher. If the label isn't correct the box is sorted out while approved boxes continue out into the warehouse.

After the second pusher the line continues into the warehouse where another robot will take the boxes and place them onto a pallet. Before the robot picks them up there is a height sensor measuring that the boxes have the correct height. The boxes are picked two and two from a picking station. To arrange the boxes for the robot a pusher is used, it is important that the boxes are centred when they reach the picking table. Therefore the last part of the guide rail before the picking station is positioned so that the different variants just pass through. Once all boxes are stacked the pallet is wrapped and ready for the warehouse, here the personnel belonging to the warehouse takes over.

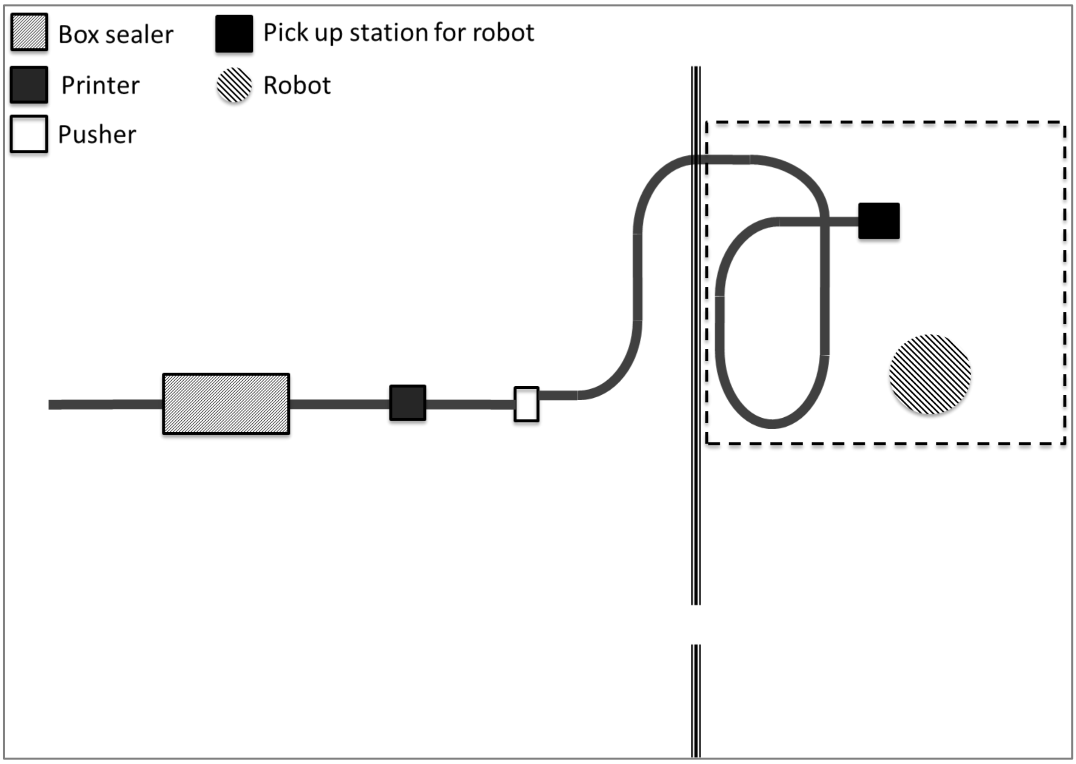


**Figure 12: Principle drawing of the workshop floor, warehouse.**

There are a few software loadings required by the line as a setup is done. The depalletizer needs a new recipe as a different product is loaded into the machine. The label printers needs to first load a blank label to ensure that no graphic from the previous label is put onto the new products. The printers also need to load the new labels. To ensure that there is no mix-up of products on the pallets going out a line clearance procedure is activated at the end of an order, requiring a completely empty line and finished order before a new order can be started, meaning no data can be loaded until the line clearance is done.

## 4.2 CURRENT PRODUCTION AND SETUP

Four operators, with each operator having a designated role during production and setup, handle the present production and setup. During the setups everyone have predetermines activities to handle but today they are flexible in helping each other out to reduce setup time. The four operators at the machine switch roles in an interval of 50 minutes, on one hand to keep the knowledge of all the procedures regarding the machine as well as to not have too many repetitive tasks during a workday. There are technical specifications in the production that is of importance for the resetting procedure, if the product that is being produced is a box with two packages (2-product box) in them it's required that both box erectors are active during the production. If it's not a 2-product box it's a 4-product box and then the only need for the second box erector is a precaution.

### *4.2.1 PRODUCTION*

During the production in normal speed the different operators handles different tasks:

**Main server**

Main server handles replenishment of boxing material, monitoring the line and correct small errors. One common issue is that the boxes are not glued together correctly and the box erector requires adjustments. The main server also disposes of trash and helps out in replenishment of material to the depalletizer and PIL- feeder.

**Administrator**

There are a lot of administrative tasks during production to keep the line running as well as supportive tasks. The planning of what orders to produce and in what order is of great importance to achieve a high level of utilisation but at the same time producing the right products. The administrator is also in charge of reporting finished orders. Furthermore supportive tasks include putting in data in the automated production monitoring system.

**Inspector**

During production all products that pass the line are inspected to meet the requirements. The inspector is positioned in the beginning of the line, after the depalletizer, doing visual control of the packages and also re-entering rework into the line if necessary. The cause for the faulty products is also noted by the inspector and if there is a problem with the depalletizer the inspector supports the main server.

**Material planer**

To constantly support the line with material the material planer orders material from the warehouse, collects new material and also does the loading of the depalletizer. The material planer also refills the PIL-feeders.

### 4.2.2 *WORK SAMPLING*

The work sampling study reveals how the operators spend the time at the machine. For example a large proportion is spent on material handling. The result from the work sampling can be seen in figure 13, the legends are in the same order as they occur on the bar. It can be concluded from the work sampling study that the resetting procedures allocate a large portion of the available time, 23.5%. This shows on the need to reduce the time for format change and order change to achieve a higher level of capacity.

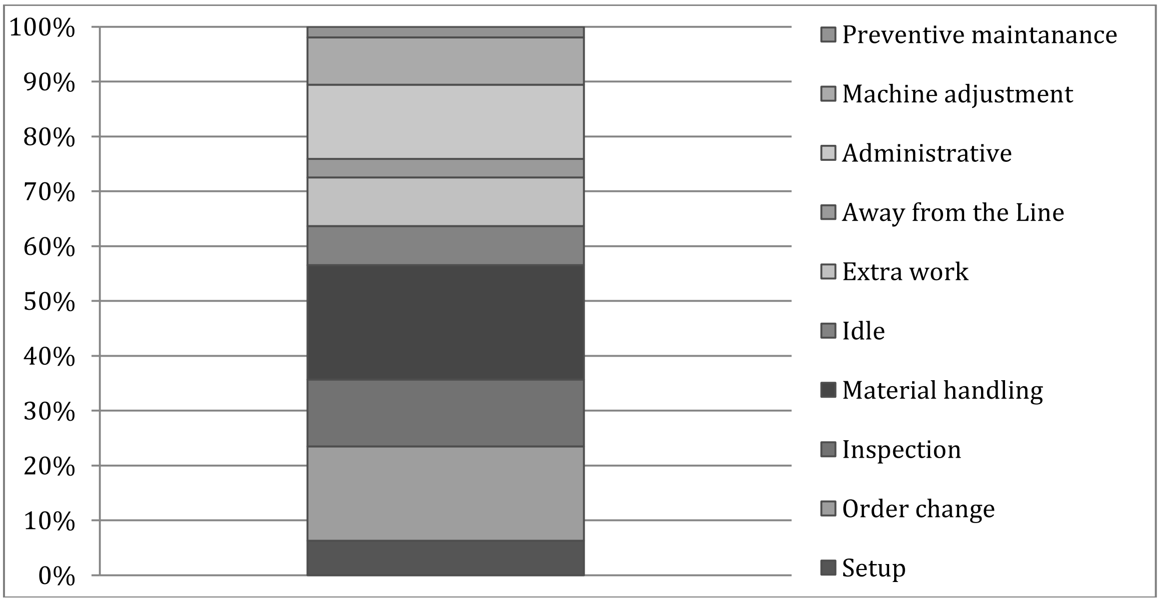



**Figure 13: Result from work sample study**

The work sampling study showed that there is idle time during the production to make external setup procedures. It's feasible to make as much external setup as possible to reduce the time for resetting the machine. The amount of order changes and format changes also correlate well to the historical data extracted, giving credit to the historical data. There hasn't been a work sampling study done on the resetting procedures specifically. Therefor statistics for the resetting procedure based on work sampling doesn't exist.

### 4.2.3 *RESETTING THE LINE*

There are two main categories of resetting procedures, a format change and order change.

**Format change**

The format change includes a lot of walking for the operators, the walking paths are illustrated in the spaghetti diagrams, see Appendix 3, a spaghetti diagram for the main server is shown in figure 14. The time for a format change today is 600 s

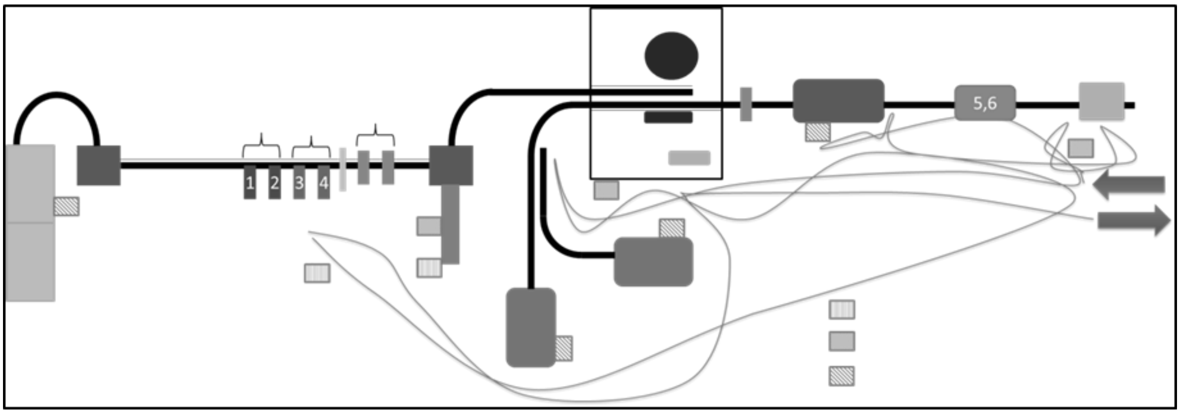


**Figure 14: Spaghetti diagram for the Main server during format change.**

The format change procedure is characterized by change of model. It involves at least one physical change. The possible physical changes are:

- Width of the guide rails
- Position of datamatrix
- Packaging tool for the robot
- Physical and software changes of the box erector
- Physical and software changes of the box sealer
- Change of position within the active sorting station
- Position for the loading station in robot cell 2, in the warehouse

In addition to the physical settings there are administrative tasks connected to the finishing of the last order as well as input of order data for the next order. The administrator also conducts quality assurance procedures together with a colleague to determine that the right products are produced in the right way. All the input of data is done on the main panel, after the data is loaded and the physical changes has to be receipted, that is done on the panel closest to where the physical changes were made and in general made by the operator who did the physical changes, a full description of the format change procedure can be found in Appendix 4. To illustrate the potential in the format change the time spent walking is 203 s and the idle time either spent waiting for a machine or another operator is 743 s., this is for all four operators This means that on average 31% of the time spent on the format change the operators are idle and 8,5 % of operators time is spent walking. The format change is sequence dependent and analyses have been done for all variants. To simplify the results only the sequences where all physical changes are performed is discussed, but the time for format change is a weighted average of all variants.

### Order change

The line produces the same product but to different customer and therefor there is a need to define these products with labels and new order data. When the line is setup to produce a new order of the same product but with a different market as customer it is called an order change.

In contrast to format change the order change doesn’t include any physical changes to the line other than changing the PIL and refill the feeders or turn on/off the feeder, but since there is no physical changes to the machine rather than add or remove these it’s defined separately from the regular setups. At the present state the order change takes an average of 600 s.

The result of the order change is that the line has new labels and (if needed) change PIL. The procedure includes change of data, these data changes has to be manually put in on the main panel. All these procedures are also included in a format change, as well as many administrative tasks. The total walking time during order change at present is 152 s and the total idle time 1445 s, leaving large room for improvement, for all four operators The idle time during order change is 60% of the total time and 6,3% is spent on walking, this is calculated by dividing the idle/walk time with the result from multiplying the number of operators with the total setup time..

# 5 IMPROVEMENTS

This chapter describes the results from the study and it is divided into four main areas; organisation, method improvements, technical improvement and savings. It should be noted that the process of developing these areas have been an iterative process where advancement in one area means a readjustment in another to achieve the best result in the final solution. The process of that illustrated in figure 9.

## 5.1 ORGANISATIONAL IMPROVEMENTS

For the organisation to be able to standardise the resetting process a standard has to be developed that covers as many variants of the setup as possible. A distinction has been made between order change and the format change to improve the organisation around an order change since this has the largest effect on the capacity for the line. The other variants have not been sub-optimised but rather a standard that gives the greatest total benefit was strived for.

### *5.1.1 SIGNIFICANT CHANGES*

The focus of the organisational change has been to reduce the amount of time spent walking and time spent waiting within the setup. The walking paths for the improved organisation are illustrated in the spaghettis diagrams in Appendix 5. To be able to reduce the time spent walking one solution was introduced in advance, a camera in the warehouse that monitors the final packaging of the order. This was done to eliminate the time spent by the main server just looking to see that the process was behaving as it should.

To deal with the long walking patterns the organisation was organisaed so that the operator that had to walk around and reset guide rail 1-4 and guide rail 5 would also walk into the warehouse, converting the time spent waiting to gain access into the robot cell in the warehouse to walking. The material planer was freed up as much as possible to ensure that if a box erector was to be done internally this would have as little effect on the setup as possible. To minimise the effects of the line clearance and loading of labels it is important that the administrator inputs the new order data as soon as this is possible. Many of the activities performed by the administrator risk creating confusion and the main panel becoming crowded if divided between more operators, the responsibilities for the administrator was not changed but focus was put on making the activities as tightly stacked as possible and converting those possible to external setup. A description of the setup can be seen in the standardised work sheets in Appendix 6 and standardised work combination tables in Appendix 7.

During the order change the focus has been to ensure that the activities performed by the administrator could be carried at the right time to start the loading of data as quickly as possible. Since many of the operators have little to do during the setup the administrator will get support in collecting the labels from the transport printer. A Standardised work sheet and work combination table for the order change can be found in Appendix 6 and Appendix 7.

### 5.1.2 *INTERNAL/ EXTERNAL*

The activities performed during a setup was analysed regarding its ability to be done as part of an external setup. Six activities were identified as being able to directly be turned into external setup. These six where:

Before setup

- Setup of box erector
- Prepare new order sheet
- Sign of order start
- Prepare pictures of labels

After setup

- Finishing documentation of order sheet
- Setup of box erector

It is only in setups where both the previous order and the next one are packaged with four cartons in each transportation box that both box erectors can be done externally. If the format change is from four in each box to two, or the other way around, only one box erector can be done externally. If the setup is between two orders with two cartons in each box none of the box erectors are external. This is due to the ability of the box erectors to feed the line.

## 5.2 SETUP TIME IMPROVEMENTS

The savings from the organisational changes are 11% for a format change and 1% for an order change, as illustrated in figure 15 and figure 16 respectively. The format changes are down to 531 seconds and the order change is down to 593 seconds.

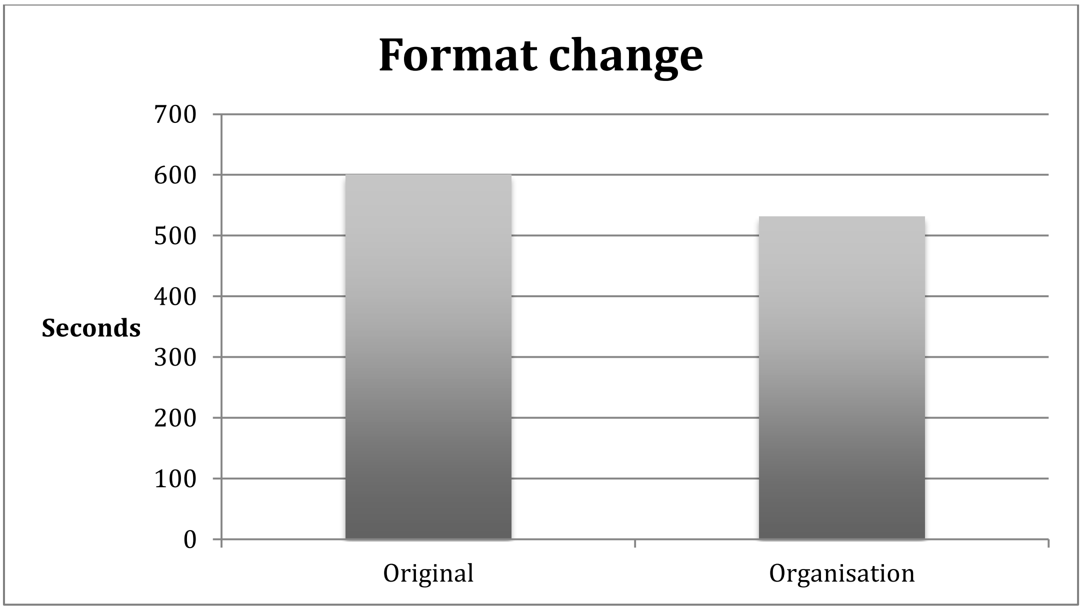



**Figure 15: Comparison between original time and organisation improvement, setup.**


**Figure 16: Comparison between original time and organisation improvement, order change.**

The organisational improvements have on their own only given a small improvement to setups, especially order change. Much smaller than what could be expected from the theory gathered. Looking at the work combination table it can be seen that many of the reasons are those of technical limitations. The variant analyses leading up to the time also clearly shows that a format change between two products which are packaged two packages in each transport box have a much larger setup time than any other. The total walking time in the new organisation is 190 seconds for the format change and 98 seconds for the order change, again for all four operators. This corresponds to an improvement of walking time of 6% for format change and 35% for order. The total idle time during the setup has strong correlation to the technical limitations and is 586 seconds for the format change and 1573 seconds for order change. For the order change this is an increase of 9%, time converted from walking to idle time. For the format change the idle time is decreased by 21 % in comparison to the original idle time.

## 5.3 Method Improvements

To reduce the setup the methods used during the process have been looked upon. As with the organisation the activities performed by the administrator after the new order data has been loaded was given consideration first. Secondly the function for each activity that is done have been questioned to see if it could be done more efficiently or possibly removed. All the method improvements with a detailed description can be found in Appendix 8. In an initial stage of the methods development several different solutions was considered, in most cases a single solution was deemed better than the others. However, in the case of resetting the guide rails three different solutions where analysed to establish the savings in relation to the investment cost. These represent different levels of automation and with that come pros and cons. As an example an automated solution must be very robust to handle the variations in incoming goods.

### *5.3.1 New methods on the line*

A camera is suggested to be installed in the warehouse, monitoring the robot packaging the transport boxes and the line leading up to it. This would enable the Administrator to register if there is a problem in the warehouse from the position at the main panel. This frees up the main server during the setups and enables a more efficient organisation. By choosing a wireless connection between the camera and the screen no wires have to be drawn in the ceeling, reducing the investment cost.

The operators wished for markings on the floor where the depalletizer is loaded with pallets, to enable an easier way to load the pallets. This solution would minimise the variation of the time that the loading takes by lowering the times that the pallet has to be re-entered because it has not been placed parallel to the feeding line of the depalletizer. The cost of the tape for the floor is negligible.

**Guide Rails**

Guide rail 5 is today changed to centre wide and narrow boxes into the robot cell. By instead placing the rail at its widest setting and let the upper guide rail in the robot cell centre all incoming boxes the format change of this rail can be removed. If this improvement is done when the new guide rails for the robot cell is introduced this can be done without any cost.

All the guide rails have been examined and it has been found that the current method to reset these have a large amount of variation and also takes quite some time to perform. Although equipped with one-hand screw releases they are often jammed and have to be changed at several positions iteratively to get a satisfying precision. To deal with this problem the rails should be set from single position for each rail, in a way that do not require extensive force and so that it could easily be displayed for the operators what width the rail is set to. To do this linear actuators are recommended to be installed to use for repositioning of the rails. Linear actuators come in all sizes and can be purchased from a wide range of producer. Linear actuators which are spindle driven are also self-locking, taking away the activity of locking the guide rails position. The wide range of actuators also means that it is possible to find ones that handle all forces required for the line. They can often be equipped with position indicators to display how wide the line is. They can also be either motor driven or bought together with a hand wheel. For the guide rail improvement three suggestions were prepared and analysed, all but one including linear actuators.

All the guide rails could be equipped with linear actuators that are driven by electric engines that automatically position themselves at the right distance from the drive belt based on information of the specific order, an illustration of this solutions can be seen in figure 17. This generates the most time-saving solution for the individual activities. It is although a prerequisite that all the incoming material holds a certain standard and that the data is continuously reviewed for changes in size of the product packages and boxes. Having automated rails also frees up the operators to perform other tasks during the format change but no rail will be set before the new order data is loaded.

**Figure 17: Illustration of guide rail 1-4 with linear actuators and motors.**

Instead all the guide rails could be equipped with linear actuators and hand wheels that the operators manually rotate to the designated width of the line, see figure 18. This increases the flexibility of the setup in comparison to motor driven rails. The time spent for the operators at each rail is also significantly reduced to the present method. Reducing the number of rails on the path by the first printers from four to three also reduces the time. Reducing the number of rails also ensures that only the middle rail in front of the printers has to absorb any force, saving cost for the other actuators.

Figure 18: Illustration of guide rail 1-4 with linear actuators and hand wheels.

An alternate solution is to install linear actuators and hand wheels on all rails but those today called guide rail 1-4, and instead use the same method as today but rebuild so that there are only three rails on the part of the line going past the department and top labels. This would reduce the time for the activity somewhat, at the same time as the activity is not limiting for the time of the setup.

**Administrative tasks**

One of the larger activities done by the administrator after the line clearance, the timeslot that is limiting improvements today, is quality assurance and receipt labels. By invoking in cooperation with the quality department this could be significantly reduced. The crucial activity of input of new order data could also be significantly reduced by installing a barcode scanner so that the data on the order sheet can be loaded via the barcode identification number. The reprogramming of the system to accept the barcode data as the order data will require negligible installation costs.

For the tasks where the administrator has to ensure that certain parts of the setup have been performed by the operators it would be beneficial to have a visual control system signalling the status of the setup. For guide rails 1-4 the signal post at the depalletizer has been chosen, signalling that it is ready to start if the rails have been changed. For the PIL the operator assigned to changing the PIL feeders will leave a small box of PILs for the rework, this will serve as a signal ("Kanban") to assure that the setup has been done.

### *5.3.2 SETUP TIME IMPROVEMENTS*

The savings generated on activities related to the administrator has effect on all setups but the savings related to the rails only come in effect on format changes and not order change. There they do so only if the administrative changes have been made, which changes the most critical operator role during a setup.

### Format change

The savings in time when introducing the new method has naturally the largest impact on the format changes where all the activities are performed. Whether or not the one or both box erectors have to be done internally also has an effect of the outcome. The variants where two box erectors need to be done internally are not a majority though, giving a lower impact of these large setups to the average time for a format change. Standardised work sheets for the hand wheel improvement can be found in Appendix 9 and a standardised work combination table can be found in Appendix 10. Figure 19 illustrate the different solutions improvement compared to the original time.

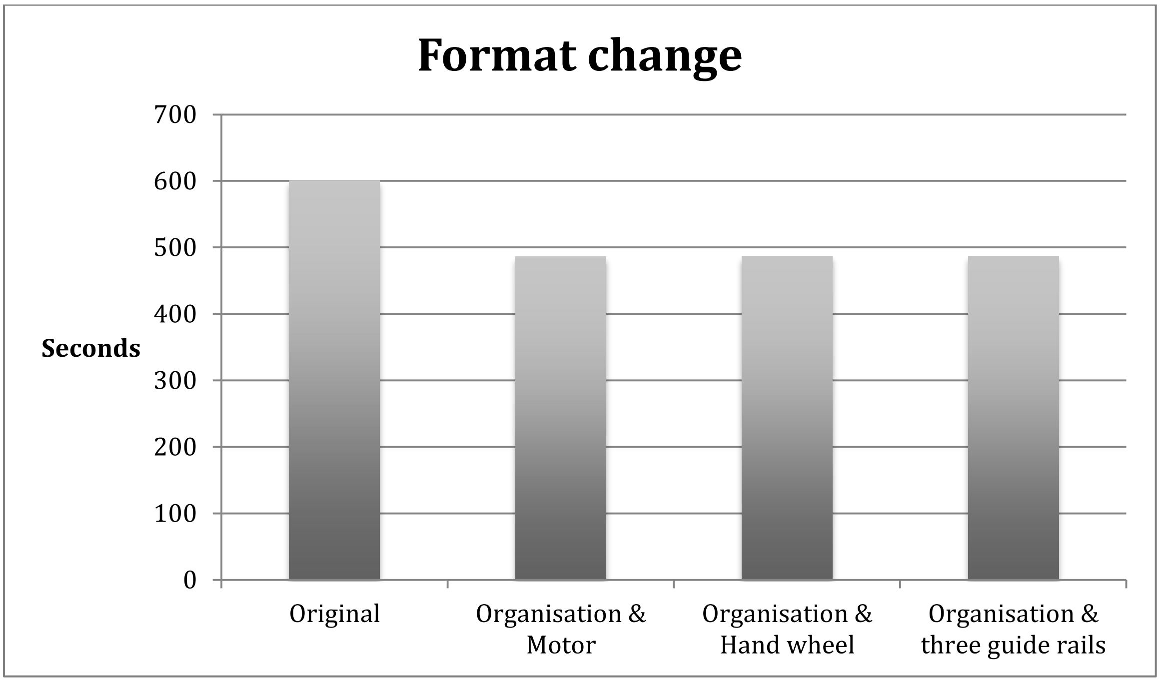



**Figure 19: Comparison in time between, original and different solutions, format change**

The improvements show that there is little variation in saved time between the three solutions and using a hand wheel on guide rail 1-4 or simply using the old method on fewer guide rails doesn't affect the setup time. The saving for the motor solution is 18,8% whereas the other two solutions have a decreased time of 18,7%. The total walking time for the improvements are the same as for organisational improvements for the solution with hand wheel and three guide rails, 6%. For the solution with motor the walking time is lowered even further, 15 % to the total original walking time. The idle times do not change significantly and this is due to that the material planer has been left with low utilization to be able to handle the variants of format change where box erectors must be setup internally.

### Order change

The most common setup is order change, this is where one would want the largest improvement to gain the largest capacity increase. It's also the most restricted area by the technical limitations of the line. The improvement from method and organisation can be seen in figure 20. The improvements of the order changes are 13%, corresponding to a decrease of 81 seconds.

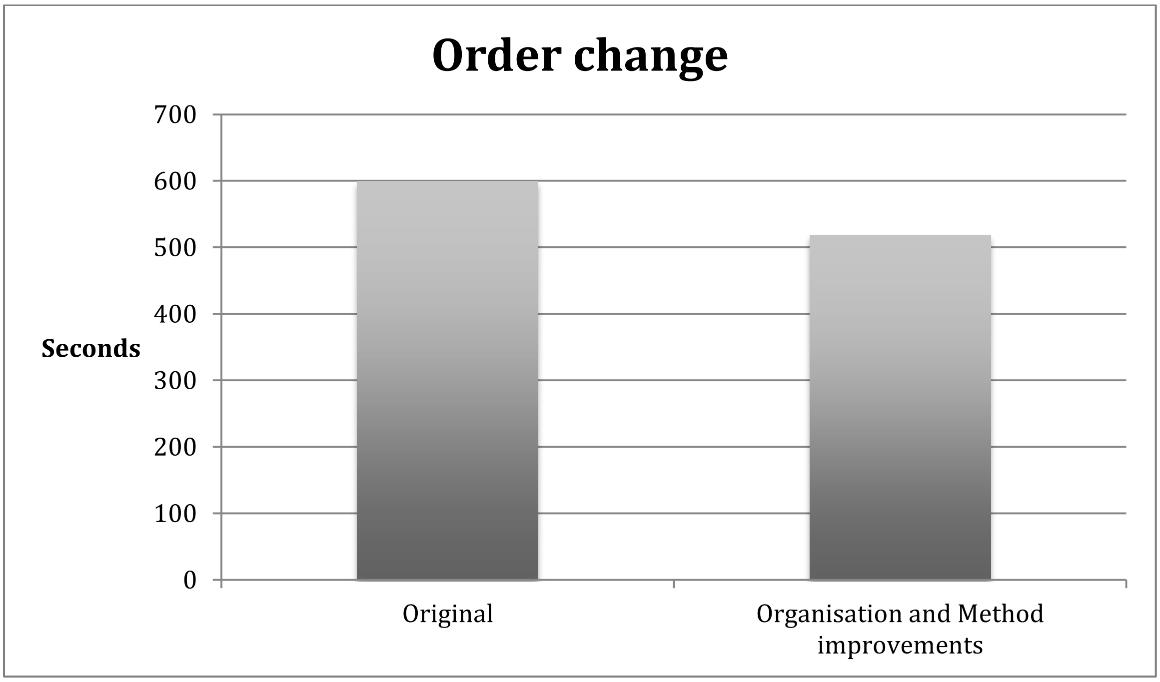



**Figure 20: Comparison between original time and improved time due to method, order change**

The walking time for the order is the same as for only the organisational improvement, the same improvement of 35%. The total idle time though is down to 1316 seconds, a decrease of 9% from the original idle time.

## 5.4 Technical Improvements

Several technical improvements have been addressed. To verify that these are possible to perform a programmer with recent experience from working with the line has been contacted. The programmer did not see any issues in implementing the suggested ideas although some required a large amount of programming hours.

### *5.4.1 Change order of printer loading*

To improve the time walking to and from printers a change of the order the loading of printers is done would be beneficial. The present solution where the printers for department-label and top-label are the first to receive new labels and the first to be able to print from makes it inefficient. Preferable the printers that handle transport-labels would be the first to receive new data and the first to be able to print the labels from.
In an order change procedure the main server is responsible for printing the labels from the transport-label printers. During the walk up to the station at the main panel where he/she will meet up with the administrator to hand over the printout, the administrator will print labels from the department and top label printers. The administrator will print from department- and top-label printers. The time saving is thus the time during the walking path from the transport-label printers and the main panel.

During a format change it's different since the administrator handles all the printouts, thus the time saving is that the loading of new labels to department and top-label printers is done during the walk from the transport-label printers.

The improvement is based on programming and further improvement on an organisational level. The programming is calculated to cost 12000 SEK. One big advantage is that improvements of the loading procedure will effect both the format change and order change processes.

### *5.4.2 Line clearance improvements*

A new line clearance procedure would focus on splitting the line and make it in to two parts that can be individually line cleared. Line 1 being from the start up to the final pusher, the active sorting station, and Line 2 being up until the end of the line. The present line clearance procedure, see figure 21, does have the function of indicating when the separate parts are empty, but it doesn't allow initiating the line clearance procedure, which is necessary to load new data and receipt physical changes.

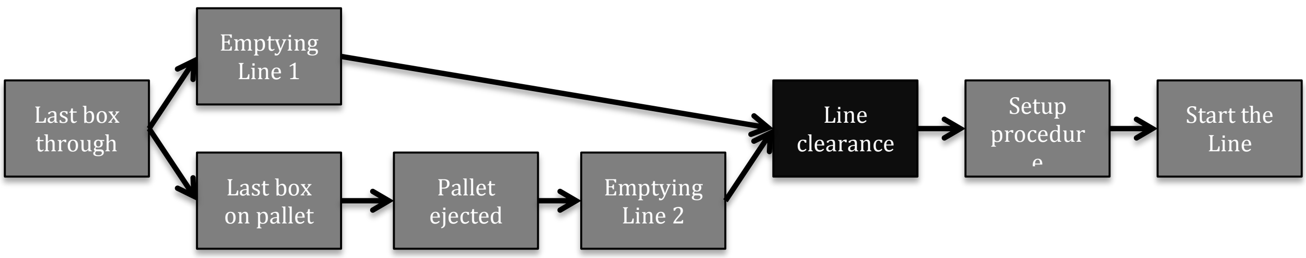



**Figure 21: Old Line Clearance procedure**

A split of the line would be done at the active sorting station, se figure 22. The change of precedence would effect when the Line Clearance is performed, see figure 23**.** This improvement is logical since there at that point are software functions at the present line configuration keeping track of boxes produced. The active sorting station also has physical functions within that would make it easier to program it, since it requires a physical push to allow boxes to continue into line 2. The two new parts of the line wouldn't function differently during normal production, it's only during resetting of the machine the new functionality would show.

A new line clearance procedure would allow the new design of the line to be line cleared separately. The positive effect would allow the operators to start the resetting procedure earlier. As soon as the first part of the line, before the active sorting box, is empty from boxes it would be possible to perform the line clearance procedure and after that start to load new data and do physical changes (if required).

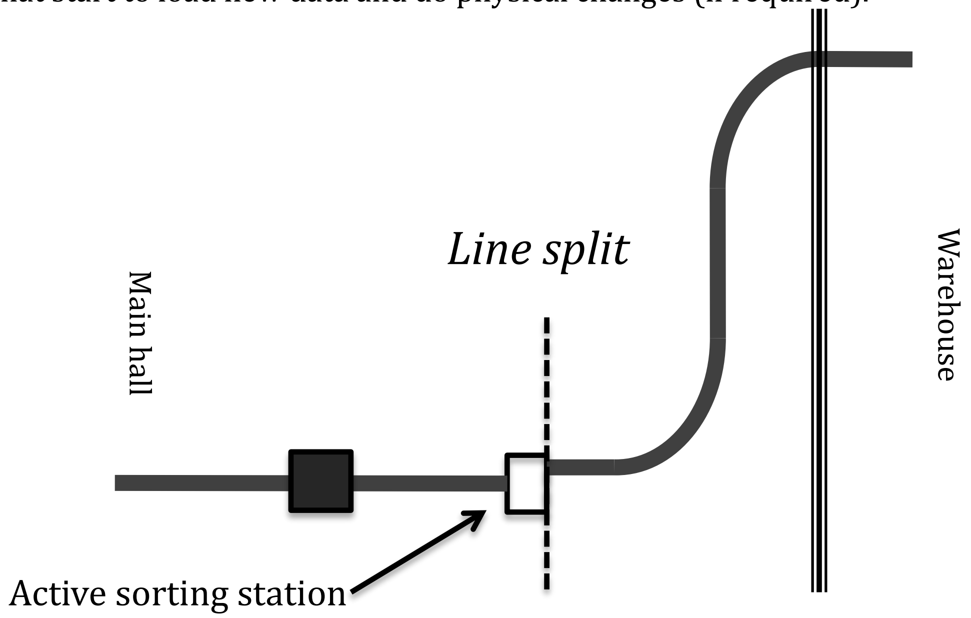



**Figure 22: Split point for improved Line Clearance procedure**

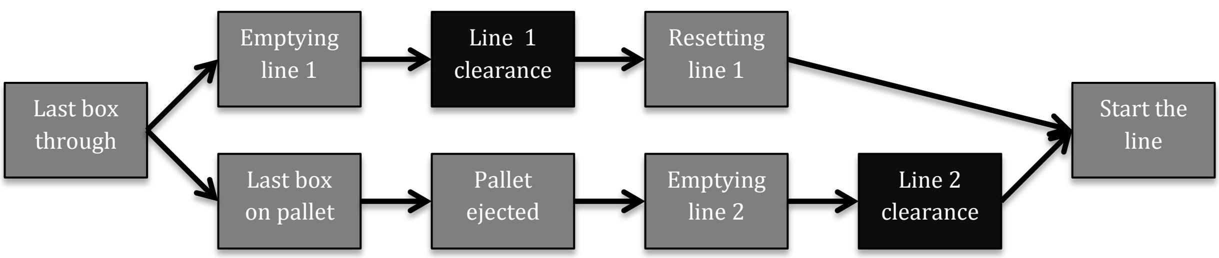



**Figure 23: New Line Clearance procedure.**

### 5.4.3 *SETUP TIME IMPROVEMENTS*

The large savings are that the time in the process of transporting the last box from the active sorting station till when the last pallet is ejected could be used for loading data, physical resetting and receipting of the first part of the line (in the main hall). These procedures are limitations in the process after organizational and method improvements and will have effect on the improvement potential.

The improvement potential from the Line Clearance improvement differs depending on which combination of other improvements (method and organisation) is chosen. Standardised work sheet and work combination table with technical improvements can be found in Appendix 11 and Appendix 12. The improvements in walking time are constant with the added technical solutions. The total reduced walking time of 35 % on order changes and 6 % for the format change gives each operator a reduction in yearly walking distance of 28 kilometres.

**Format change**

In the format change procedure there are large improvements from both organisational and method improvement. What is noticeable that depending on what method improvement that is chosen there are differences but no great differences. The savings from organisational improvement and technical improvements are calculated to 12.5%. If the method is added to that the savings reach 23.5 to 26% depending on method solution, see figure 24. The time for the improved format change with organisation, method (hand wheel) and technical improvement is 453 seconds. The average idle time is down by 3% from the original again due to the conscious decision to leave the material planer with low utilization to use when box erectors are made internally. This means that the idle time now is 33% of the total setup time if no box erectors are made internally.

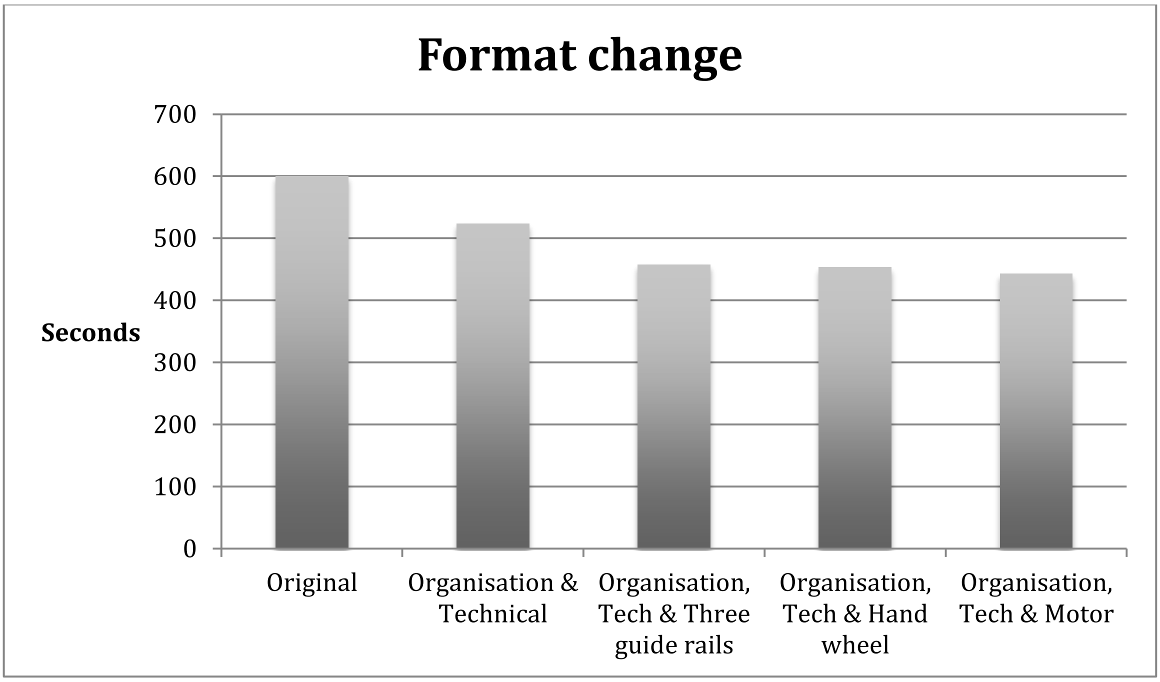



**Figure 24: Comparison between original time and improved time due to Line Clearance, setup**

**Order change**

The order change improvement is easier to overview since the method improvement isn't affected by which solution of guide rails that is chosen. The saving from changing organization and technical improvements would give an improvement of 19%, the time is possible to be seen in figure 25. What's important to notice is that order changes are the majority of the resetting procedures and would give a great effect. Together with the changes of method as well the time savings would reach 35%. The improved (organisation, method and technology) order change procedures reduce the time for the setup to 405 seconds. The idle time is a total of 897 seconds, a reduction from the original by 62%. This is still 55 % of the total time for an order change but much of this time will be spent doing regular production related activities.

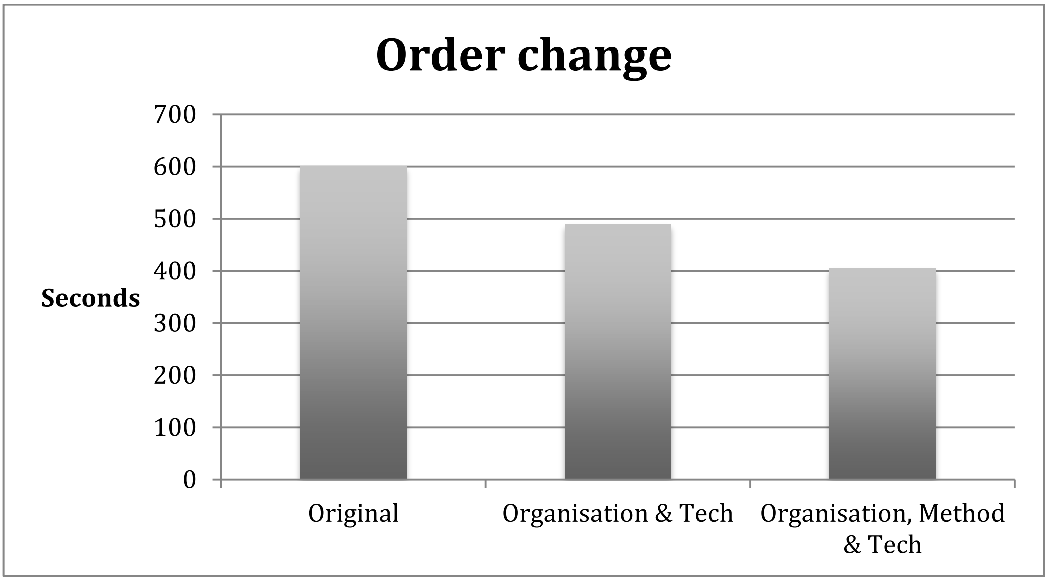



**Figure 25: Comparison between original time and improved time due to Line Clearance, order change**

### 5.4.4 *Cost*

The price for implementing Line Clearance improvements is based on programing hours since it's a software development project that has to be carried out. After consulting a programmer that has been handling programing of the line previously the estimated time for program and quality assure the new Line Clearance procedure is 24 hours. The cost per hour is based on other consultancy fees and is an estimate, the cost can be seen in table 1.

**Table 1: Cost due to Line Clearance improvement**

| Title | Hours | Cost/Hour (SEK) | Total (SEK) |
|---|---|---|---|
| Program the LC | 24 | 1000 | 24000 |
| Total | | | 24000 |

### 5.4.5 *Variation in printer loading*

A major disturbance today is the difference in time of loading the printers with new labels. It varies probably due to the printer's connection to the servers. An improvement that stabilizes the loading procedure would give a more stable process that would make it easier to standardise the resetting procedures. The variation in the process affect both the format change and order change process, therefore changes to the loading system will give large effect on the capacity. A simple variation analysis has been done on the effects of the variation in printer loading during order changes, shown in table 2, showing that it to a large extent effects the time for orders. The fact that improved order change and increase in printer time has the largest effect on the time also stresses the importance in dealing with the problem.

**Table 2: Effect of changes of printer loading time.**

| Printer time % | Original order change | Fully improved order change |
|---|---|---|
| -50% | -7,1% | -5,4% |
| -10% | -1,4% | -2% |
| +10% | +1,4% | +2,1% |
| +50% | +7,2% | +10,5% |

# 6 COST AND CAPACITY ANALYSIS

The time saved during a resetting procedure is based on the combination of organisational, method and technical improvements. The savings these improvements would give the company has to be calculated against the extra cost that would occur if they wouldn't be implemented.

The increase in capacity due to the improvements has to be calculated against the additional cost that another solution for capacity increase would incur. If the market grows the company will have to adopt and increase the capacity. If the suggested improvements wouldn't be implemented an extra shift would have to be activated. An extra shift isn't only extra production personnel but also production management and technicians. The calculations for those personnel are calculated in table 3 and the total cost for those personnel is 2 Units per year.

**Table 3: Cost for extra personal due to an extra shift, full time a year.**

| Title | No. | Salary/person (Units) | Cost (Units) |
|---|---|---|---|
| Production | 4 | 297 567 | 1 190 268 |
| Technician | 1 | 371 179 | 371 179 |
| Management | 1 | 438 553 | 438 553 |
| Total | 6 | | 2 000 000 |

## 6.1 COST

**Organisational**

The costs for organisational improvements are none since there are no investments. Due to it being free it's assumed that the organisational improvement is included in all improvement proposals.

**Method**

The major investment cost for the method improvement is the linear actuators. These are expensive but improve the speed of the format changes and they also stabilize the process to avoid variance in the process.
There are three variants of the method improvements, including the organisation improvements, the different costs and capacity increase can be seen in table 4.

**Table 4: Cost compared to capacity increase.**

| Title | Cost (SEK) | Capacity increase |
|---|---|---|
| Suggestion1 (MOTOR) | 142 455 | 6.66% |
| Suggestion2 (Hand wheel) | 131 100 | 6.65% |
| Suggestion3 (3 GR + HW) | 99 831 | 6.65% |

### Technical

The technical improvements are expensive, that's due to the extensive amount of programing that's required to make the new Line Clearance procedure functional. The time spent on programming the new line clearance and change order of loading the printers is estimated by the programmer to 36 hours. With an estimated consultancy fee of 1000 SEK/hour the total investment for the technical improvements will be 36000 SEK.

### Total cost

The total cost is depending on what method improvement that's chosen. As in the technical solution the programing for the motor solutions is expensive and thus is the motor solution expensive. The total capacity increase that's achieved by implementing all three improvements (organisation, method and technical) is a synergy effect and can't be added together by looking at individual solutions. The combined effect on capacity and combined cost is showed in table 5.

The method chosen is the hand wheel improvement proposal since that gives large improvement to reasonable cost.

**Table 5: Cost compared to capacity increase depending on which improvement suggestion**

| Title | Cost (SEK) | Capacity increase |
|---|---|---|
| Organisation | 0 | 1.1% |
| Organisation & Method improvement | 131 100 | 6.65% |
| Organisation, Method & Technical improvement | 167 100 | 15.7% |

## 6.2 Capacity increase

To be able to calculate the result of 15.7% capacity increase some prerequisites had to be considered. First an assumption of having the same relation between order and format change had to be taken, furthermore it was assumed that the lot sizes was the same as for the historical data. The reasons for these prerequisites were to be able to compare the capacity for the present state and the improvement suggestion. It's also important to note that the time used for the format change is the calculated mean time for a format change. Since the tempo of the line is known the time it takes for an average order to pass the system was known. Adding the setup time to these orders had to be done taking in to consideration the amount of order changes and format changes. In the end that was an equation depending on two variables that were the time for order and format change.

Input data:

Capacity increase = A
New Number of packages = B
Old number of Packages = C
Preventive maintenance = D
Stop time = E
Time for order change = F
Number of order changes = G
Time for format change = H
Number of format changes = I

$$Capcity\ increase = A = B/C$$

$$B = available\ time - D - E - F * G * A - H * I * A$$

To achieve the result for the present state the present time for the setup procedures were used and gave us a total number of packages that could be done. After that inserting the new setup time gave us the number of packages produced by using the time for the improvement suggestion. One factor that had to be taken in to the calculation was that it had to be iterative since the increase of capacity affected the number of setups. Then the fraction between the improved and the present state were taken to get the capacity increase. The validity of the calculations are good, but it has to be noted that it's simplified especially since the mean for the format change is used, but due to the fact that the format change is more seldom than the order change it doesn't affect as much as if the same simplification had been done to order change.

# 7 DISCUSSION

The overall reception of the project among the operators on the floor has been better than could be anticipated. Almost no one has shown scepticism against the work that was performed on shop floor level. This might have its reason in the quality of the setups that where being performed at the start of the study. According to the experience of Kaiser (2002) the variation and time from the organisation of the setup was to be the single largest. This has proven to not be the case, although optimising the setup for the solutions regarding methods and technical system the saving from the organisational area was not large at all, see figure 26 and figure 27.

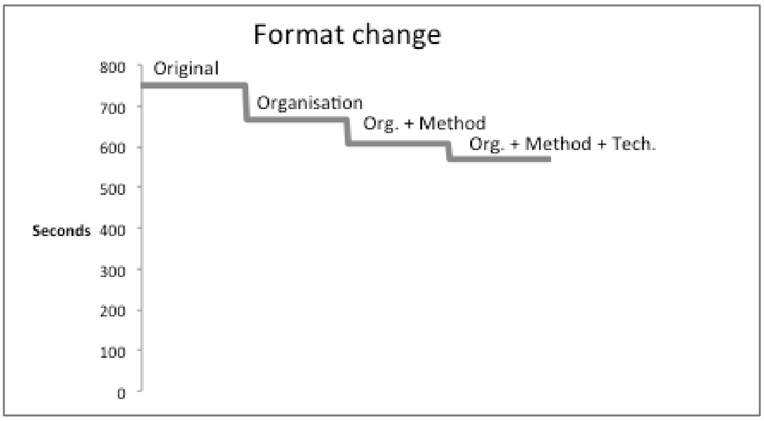



**Figure 26: Improvement suggestions effect on time of a format change**

Mere seconds on the dominant version of setup defined as order changes would not have led to the capacity increase finally achieved. And in that the study validated the operator's view of technical and methodological hinders to reach better setups. This is even clearer when comparing the results of the study with other studies on setup time reduction. Zandin (2001) describes a general saving in setup time from internal activities to external activities is 30-50%. This study only gained 11% for the format change. In a study on resetting time of a printer circuit board machine (PCB) performed by Trovinger & Bohn (2005) they were able to reduce the setup time by 78%. From 127 minutes to 27 minutes. A large part of the 78% was saved due to external setup of the machine, for instance more staff had to be hired to cover the activities performed during external setup of the machine.

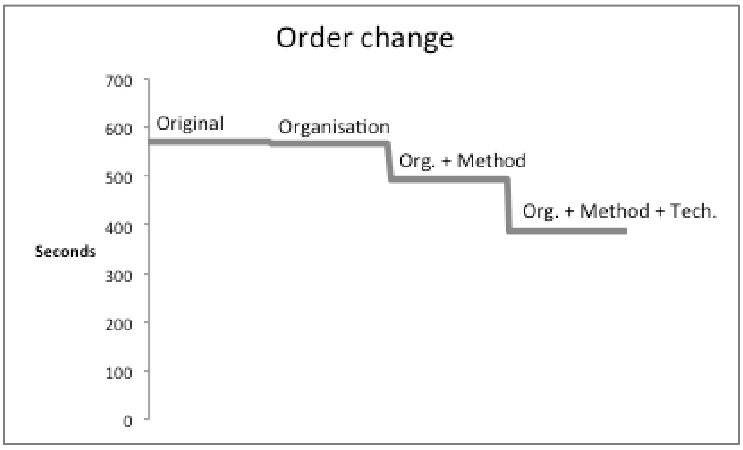



**Figure 27: Improvement suggestions effect on order change**

The explanation might lie in the type of production used as a basis for the research by Kaiser (2002). It is not uncommon in classical machine shops that the setups are performed by one or two operators perhaps working on different machines. This does not enable them to directly see when someone is waiting on an activity being performed to continue. The standardisation of where to have the tools needed for the setup is also often an easy improvement at these shop floors. In this project there are four operators working in an environment where they almost always have visual contact. This has led to a setup organisation that has evolved into helping each other out and thus creating a good organisation. Helping another operator with different tasks was mostly present during uncommon variants, which the self-evolved setup organisation did not have a standard for handling. For this study this well-functioning setup organisation without any tools used means that the larger improvements comes a cost. It is not possible to gain significant improvement without also investing in the line, an investment that is well under the alternative of introducing another shift.

It is not only for the organisation that the description of variation and time allocation by Kaiser (2002) differs from the results. It is almost as if the organisational and technical potentials have switched place. The technical system of today has not only been proven to be a large part of the setup and creating waiting within the setup but also has a large degree of variation. During many occasions as the setups have been studied the problems with the variation of loading the printer data has skewed the result of the ongoing measurements. Although problematic, the method variation has been hard to identify when looking at the setup as a whole, much of it is absorbed during the waiting to performed activities blocked by the technical system. This together with the rigorous quality control and traceability of medical products has also resulted in small result from the classical SMED methodology. What quickly could be identified was a small amount of administrative tasks. Many questions was raised of potential improvement, for example preloading one of the printers in a pair, but had to be abandoned to ensure quality. The safety of the customer is after all the most important factor of the company. The times that are set to build up the Avix analyses are based on the recorded setups. These filming sessions have been done on operators who are comfortable with the tasks they perform but the data we build the analyses on are still from one occasion. There is a validity problem with this which could have been solved by converting all tasks into SAM sequences. This was not done partly because this was not how they used Avix at the company and partly because the software version used during the study did not come with a SAM module. The test however showed that the data used was not off by much. Another set of data that could be questioned is the amount of down time on the line due to rework and failures. This is manually feed into a document today which means that there is potential for very high variation but software that automatically measures the stoppage time is being implemented at the line already. This will hopefully be used constructively to ensure the operators support and seriousness of the manual classification of stoppages.

Standardised work will be crucial to achieve the calculated times of the setups. It will also be the key instrument to improving it further, both by establishing a new standard but also to help give validity of setting of time for trying new solutions. At the company they use work rotation not only within the line but also between lines, here the standardised work will be a powerful tool in helping operators who have not been at the wet line in a long time or is being trained in managing the line.

The use of spaghetti diagrams has been a great asset in helping to further get the operators to accept the solutions. Not only is it amusing to see walking patterns that one self has walked countless of times, it is also a valuable motivator and communication tool. The spaghetti diagrams shows the more reasonable walking patterns, this means less time spent walking, better for the setup and for the workers. This is in part coupled to the ergonomics of the operators. Although ergonomics never have been an expressed area during the project it is a prerequisite for new solutions at Wellspect Healthcare. This has also been expressed during discussions with the operators, for example the stress subjected to the wrist when handling the snap locks of the current guide rails has been an issue as well as the old setup of the pickup table in the warehouse where the stressed operator often bent in harmful postures instead of walking an extra distance.

The work sampling performed during the early part of the project was very useful to gain insight booth into the normal procedures during production and also during setup. It has also been helpful to verify the times spent on format changes and order changes by using this data. To gain more valuable information from this method it should have been more focused on the setup and main activities performed within these. Since this is a very time consuming study one would like to get as much useful result from it as possible. To achieve a statistically valid result that is not based on cyclical behaviour 2500 randomized times where prepared. The measurement was carried out during five workdays with different randomized times. The purpose of the randomized times was smaller risk of sampling errors. To determine the number of observations the following equation was used (Zandin, 2001):

$$n = \frac{z^2 * p * (1-p)}{\sigma^2}$$

n = number of observations
p = probability of single occurrence
σ = Acceptable limit of error
Z = confidence interval
The smallest category had the probability of 6.28% this together with an acceptable limit of error at 90% (Z=1.645) gave the acceptable limit of error:

$$\sigma = \sqrt{\frac{z^r * p * (1-p)}{n}} = 0{,}0080059$$

Corresponding to an acceptable limit of error, percentagewise, at:

$$\left(\frac{\sigma}{p}\right) * 100 = \left(\frac{0{,}0080059}{0{,}0628}\right) * 100 = 12{,}74\%$$

The acceptable limit of error was chosen to be quite high. This was due to the extensive number of observations that was required if the wanted level of probability and acceptable limit of error should be reached. The results, however, correlated with the historical data, giving higher validity. The lack of experience in conducting work sample studies also suggested a lower number of samples to get quality in the samples.

## 7.1 Recommendations

For the company to gain as much as possible from this study it is important that the results from the study is allocated to someone responsible for improving the line so that it does not become neglected or forgotten if the improvements recommended are not implemented simultaneously or further in the future. No process owner for the line existed at the start of the study but a person filled this position at the end of the project and will hopefully take ownership of the suggested improvements. It would also be beneficial to add new data to the study as other projects are completed, for example the software measuring stoppages will help calculating capacity even more precisely.

Since the company has previous experience with working towards standardised work it is recommended that this is implemented for the wet line as well. In this process it is important to setup an auditing scheme and ensure that this is followed to improve minor flaws in the organisation of the setup immediately.

Several of the tasks performed by the administrator today are directly connected to quality control that is decided upon by the quality department and rules and legislation connected to the product. To open up a communications channel to that department and gain understanding between departments would be very valuable in the future looking into further externalisation of many of the administrative tasks.

The standard times calculated during this project will also be helpful for other departments and it would be beneficial to make them accessible. The most valuable order size can be gained for individual variants helping to achieve better planning. The gained capacity can also be used in taking in smaller orders that today are processed outside of the line, opening up for a capacity increase the manual packaging station.

For further research within the area of setup time reduction it would be useful to look at how different industries affect the acknowledged models within the area. The same analysis could be done while taking into account quality regulations that has had a large influence on how the production system has been setup.

# 8 CONCLUSIONS

The purpose of the study has been to analyse the current the planned stoppages at the packaging line. To help guide the study two research questions were stipulated.

1. What is the capacity increase possible by looking at reduction of setup time?

The capacity increase possible has been found to be 15,7 % if organisational, method and technical improvements are made. Not a large number compared to other studies but corresponding to a large increase in sales. This was mainly reached by improvements for the order change.

2. What is the cost of the capacity increase?

The investment cost for the capacity increase is 167 100 SEK, excluding time for training operators in the new standard. A small sum compared to the alternative cost of 2 Units annually.

The decrease of time usage for the resetting procedures is of course depending on the combination of the suggested improvements. If the suggested improvements would be implemented a significant decrease would perceive. The time for a format change would be 453 seconds compared to the original time of 600 seconds, see figure 28. The same calculations for order change gives a time for the improved setup of 405 seconds compared to the original order change time of 600 seconds, this is illustrated in 29.

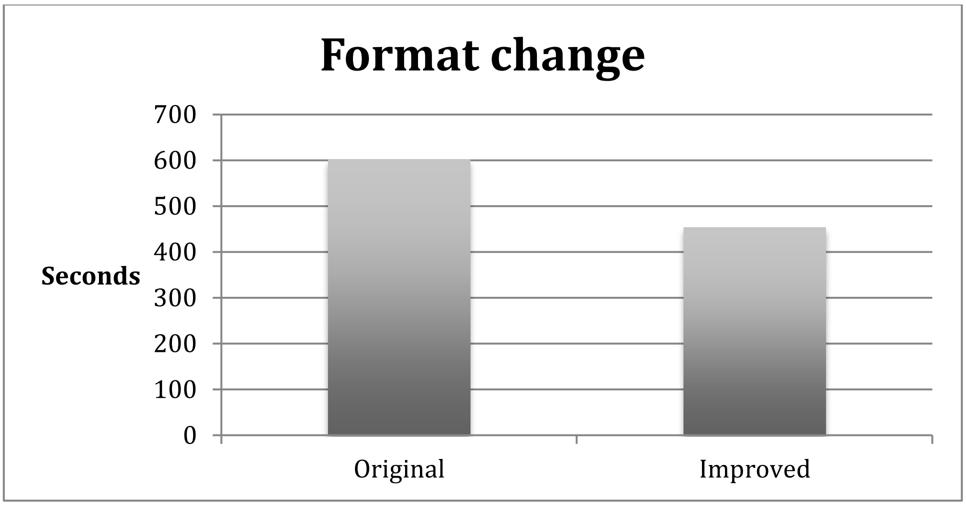



**Figure 28: Comparison of format change time between original and improvement**

Since the format change is less frequent compared to order change the effect of setup isn't as high as on order change even though the time saved per format/order change is equal


**Figure 29: Comparison of order change time between original and improvement**

The capacity increase is dependent on the amount of resetting procedures, if the proportion is the same as previously the expected increase from the improvements would be 15.7%. This capacity increase is possible to use differently depending on the purpose, increase the amount of resets and make smaller batches or increase the number of sales, if the market requires it. Since the underlying purpose for the project was to prevent an extra shift due to increased sales it's feasible to use the extra time to increase the output and meet customer demand.

One surprise for the project was the fact that the organisation of the wet line was efficient as it is. The personnel is aware of what tasks that requires more time and are helpful to each other and strive to minimize the time for resetting procedures. Due to this the optimisation from the organisational development wasn't as big as predicted ahead, but the committed personal increases the chances for a successful implementation.

The wet line has technical limitations that if they were solved would increase the chance for a feasible implementation. The organisational changes suggested would have larger effect and the total savings in time would increase.

To handle the large variance in setup procedures, depending on between which products the setup is done, there is need to have a flexible organisation. Therefor there is what seems like an extra person but those setups where one box erector is internally done that specific operators utilizations is high but if the erectors is done externally it's low. The resetting procedure is thus robustly designed to give little variation in output from large input variations.

The savings for the company is large, especially if the consequence of an increase in market demand would be an extra shift. If it's possible to avoid an extra shift the investment cost is saved rapidly due to the increase in capacity from the improvement suggestion.

# 9 SOURCES


Almström, P. (2012) Productivity measurement and improvements: A theoretical model and applications from the manufacturing industry. *Proceedings of the International Conference on Advances in Production Management Systems APMS.* 24-26 September , 2012, Rhodes, Greece.

Allahverdi, A; Soroush, H. M. (2008). The significance of reducing setup times/setup costs. *European Journal of Operational Research*, vol. 187, pp. 978-984.

Internaional MTM Directoratel (2004) *SAM Manual*

Johansson, B; Kaiser, J. (2002) Turin lost production into profit: Discrete event simulation applied on resetting performance in manufacturing systems. At *Proceedings of the 2002 Winter simulation conference*; December, 2002, pp 1065-1072.

Kaiser, J. (2002) *Evaluation of resetting performance in cellular manufacturing systems.* Gothenburg: Chalmers school technology. (Doctoral at Department of product and production development).

Liker, J K;Meier, D. (2006) Establissh standardized processes and procedures. In *The Toyota way fieldbook,* pp.111-144. New York, McGraw-Hill.

Matksberyy, P; Rammohan, R; Vu, D. (2011) A systems study on standardised work : a Toyota perspective. *International journal of productivity and quality management,* vol.7, No. 3, pp 287-303.

McIntosh, R.I., Culley S.J., Gest G.B., Mileham A.R., Owen G.W. (1996) An assessment of the role of design in the improvement of changeover performance, *International Journal of Operations and Production Management,* vol. 9, nr.9 ,pp.5-22.

McIntosh,R; Owen,G; Culley,S; Mileham,T.(2007), *Changeover improvement: Reinterpreting Shingo´s "SMED" Methodology* ,IEEE Transactions on engineering management, vol. 54, no. 1, pp. 98-111.

Olhager, J. (1993) Manufacturing flexibility and profitability. *International Journal of Production Ergonomics*, vol. 30-31, pp. 67-78.

Shiego S. (1985), *Shingo: A revolution in manufacturing: The SMED system*, USA, Productivity Inc, ISBN 0-915299-03-8

Da Silveira, G; Borenstein, D; Fogliatto, F. S. (2001) Mass customization: Literature review and research directions. *International Journal of Production Ergonomics*, vol. 72, pp 1-13.

Trovinger, S. C.; Bohn, R. E. (2005). Setup Time Reduction for Electronics Assembly: Combining Simple (SMED) and IT-Based Methods. *Production and Operations Management* , vol 14, pp. 205–217

Zandin, Kjell B. (2001) Work sampling and group timing technique. In *Maynard's Industrial Engineering Handbook*, McGraw-Hill Professional

Zandin, Kjell B. (2001) Setup time reduction. In *Maynard's Industrial Engineering Handbook*, McGraw-Hill Professional

Zandin, Kjell B. (2001) Purpose and justification of engineering labour standards. In *Maynard's Industrial Engineering Handbook*, McGraw-Hill Professional
.

# APPENDIX 1

A description of the work sampling tasks measured during the work sampling study.

### Format change

A format change is connected to an order change, but compared to a standard order change the format change, alters which kind of product is being produced. Products are defined by model, length, box size, country code.

### Order change

If there is a new order but no format change is performed. It involves a line clearance followed by loading new labels and input of information in the main panel.

### Inspection

One person inspect the incoming goods, the optical inspection determines if there are any flaws with the packages. If there is a problem that package is pulled out from the line, either manually repacked or if there is a minor problem the operator fix the box and let it in the line again.

### Material handling

Material handling includes pick up goods from the warehouse, load goods, fill up on box material, fill up the patient information leaflet making sure there is enough glue and so forth.

### Idle time

When an operator is waiting for something to happen.

### Scheduled maintenance

Scheduled maintenance is planned for two hours every week. This is not calculated as up-time.

### Machine adjustment

When an operator makes any kind of setting to the machine, either physical or a software change, during production.

### Extra work

Operations that isn't necessary to keep the machine running but necessary to keep the right amount of finished products. An example could be to manually repack packages.

### Not at the machine

When the operators aren't at the machine, could possibly be meetings or breaks if there is no one to replace the operator who is on break. Also includes allowances.

### Admin

Administrative tasks such as planning orders, printing orders and putting in data in the Axxos system.

# APPENDIX 2

Visual representation of the line and its sub parts.

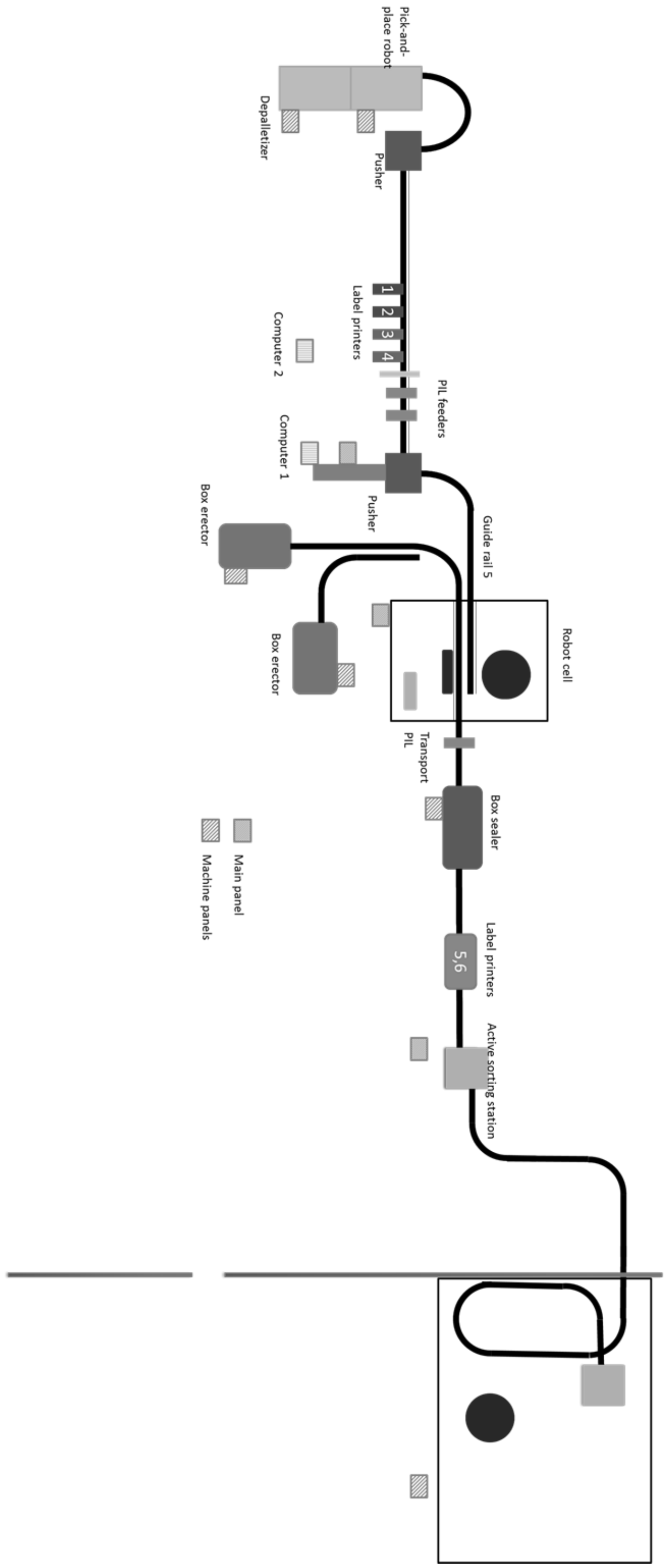



**Figure 1: Description of the entire line with description of sub-elements**

# APPENDIX 3

Spaghetti diagram of the setup procedure, divided by operator role.

**Administrator**

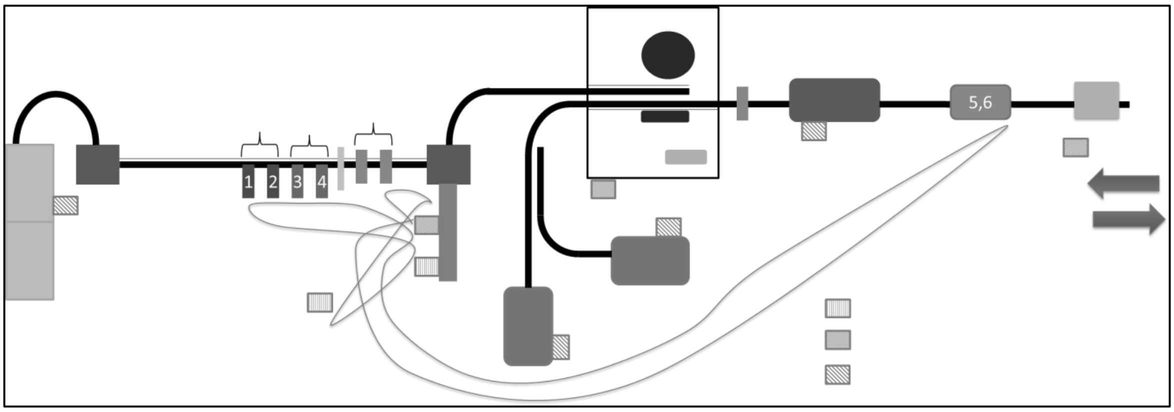



**Figure 2: Spaghetti diagram for the Administrator during setup.**

**Inspector**

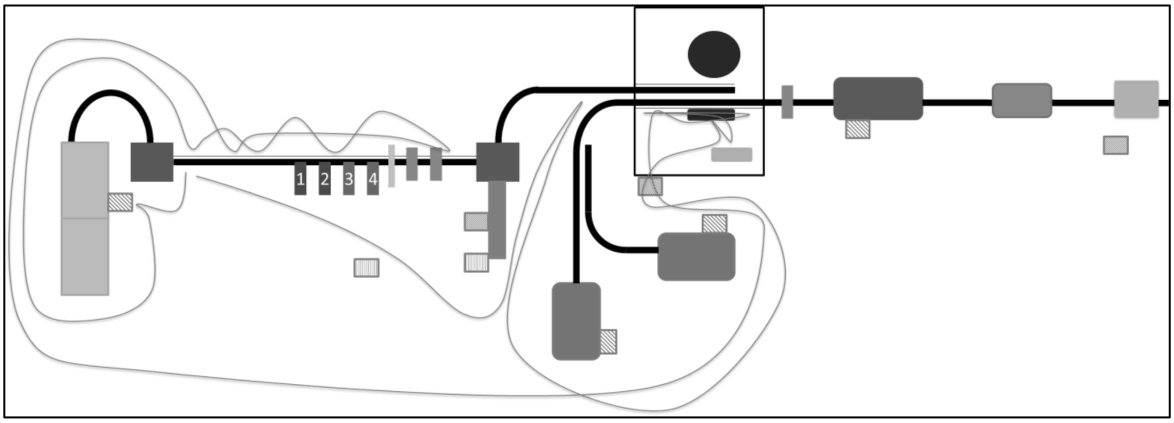



**Figure 3: Spaghetti diagram for the Inspector during setup.**

## Main server

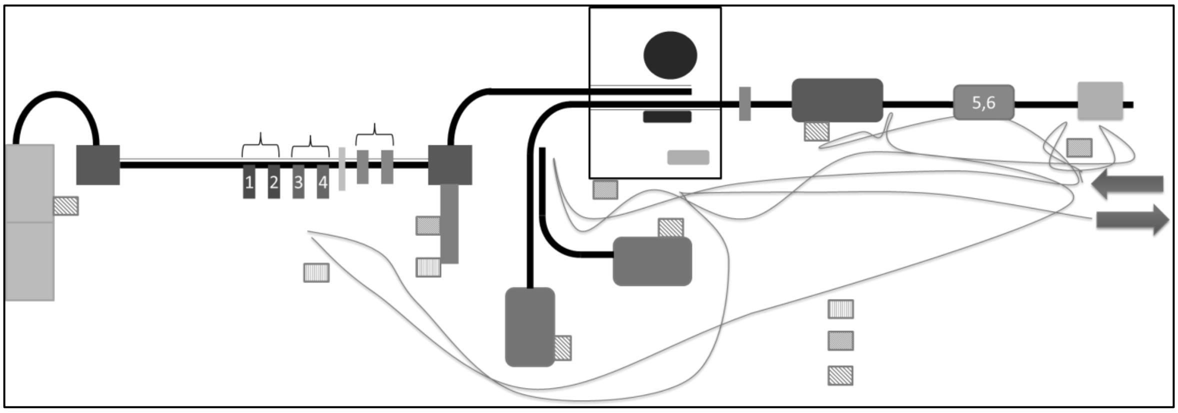



**Figure 4: Spaghetti diagram for the Main server during setup.**

## Material planer

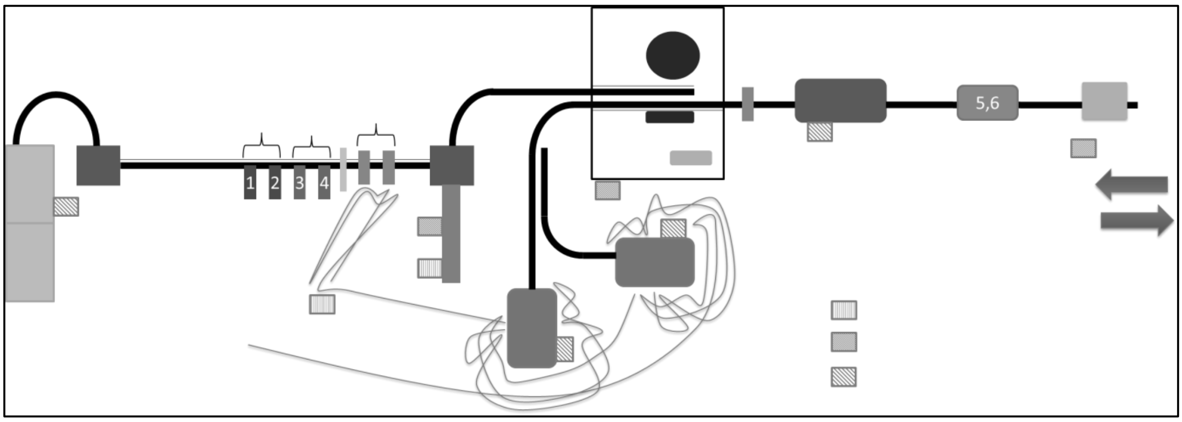



**Figure 5: Spaghetti diagram for the Material planer during setup.**

# APPENDIX 4 – ROLES OF THE OPERATORS

What's described below is a format change procedure that includes all parts of the machine divided into the operators performing the tasks during a format change.

**Material planer**

The material planer has the main responsibility for the two box erectors and the resetting of these during setup operations. The amount of time needed varies between setups since there is not always a need to reset both machines to keep the line loaded with a sufficient amount of boxes thus there's sometimes resetting procedures done externally.

The resetting procedure of one box erectors is:

- Remove old box material from the feeder side.
- Walk around the machine to the machine panel
- Take the worksheet with the measurements for the box size to be produced.
- Adjust the measurements 1-4 on the front of the machine
    - Walk around the machine to the feeder side
    - Adjust measurement 1 if it's supposed to be changed, check on the worksheet that the new measurement is correct
    - Walk to the other side of the feed tray
    - Adjust measurement 3 if it's supposed to be changed, check on the worksheet that the new measurement is correct
    - Adjust measurement 4 if it's supposed to be changed, check on the worksheet that the new measurement is correct
- Walk around the machine to the backside of the erector
- Adjust the measurements 5-10 on the machine.
    - Open the door to the machine
    - Determine which measurements that are supposed to be changed
    - Determine on the worksheet what the new measurement supposed to be
    - Change the ones of 5-10 that are supposed to be changed
- Take a wrench for use of resetting measurement 11-13
    - The wrench is located in the machine
    - Determine on the worksheet which measurements that are supposed to be changed
    - Change the ones of 11-13 that are supposed to be changed
    - Return the wrench
- Walk around the machine to the feeder side
- Take the pallet jack with the old material and raise it
- Pull the pallet jack to the designated place for the material being pulled away
- Lower the pallet jack
- Move the pallet jack to the pallet with material for the boxes the machine has been setup to produce
- Raise the pallet
- Pull the pallet to machine

- Load the machine with material
    - If the boxes are wrapped in plastic
        - Remove the wrapping material
        - Grab the scissors located next to the feeder tray
        - Cut open the ribbons holding the box material together with the pallet
        - Return the scissors
    - Take on stack of boxes and place on feeder tray
    - Grab the scissors next to feeder tray
    - Cut open the stack with scissors
    - Return the scissors
- Put the material information from the pallet on the machine
- Walk around the machine to the machine panel
- Adjust measurement 14, which is the format on the machine. This is done on the panel.
- Do a test run of the machine.
- Walk to the end of the machine and grab the box that has been produced
- Inspect the box
- Adjust if necessary otherwise the machine is ok and ready start

This procedure is repeated for the other box erector.

**Administrator**

The administrator performs the following tasks during a format change:

- Log in to the main panel
- Finish the current order on the panel
- Walk to the workbench next to the panel
- Fill out the order form of the old order
- Prepare the new order form
- Walk to the administrative computer
- Open the description of the labels
- Sign the start of the order on the order form
- Walk over to the main panel
- Enter the data of the new order on the main panel
- Walk to department printer 1
- Print department label: Push the eject button and at the same time catch the label that's being printed.
- Walk to department printer 2
- Print department label: Same procedure as previous
- Walk to top printer 1
- Print top label: Same procedure as previous
- Walk to top printer 2
- Print top label: Same procedure as previous
- Paste the labels on the back of the order form
- Walk to transport printer 1
- Print transport label: Same procedure as previous

- Walk to transport printer 2
- Print transport label: Same procedure as previous
- NOTE: It's important to keep the labels separated; being able to identify which printer printed which label is crucial.
- Walk from the transport printers to the administrative computer
- Paste the transport and department labels on the back of the order form
- Control the labels against the label descriptions.
- Sign the labels
- Find a co-worker to quality assure the printed labels.
- Walk to the co-worker or the co-worker walk to the administrator
- Read the label data to the co-worker checking it correlates to a package from the order
- Walk to the main panel
- Sign off the format in the main panel
- Turn on/off the PIL feeders
- Sign off, in the main panel, on reading label data to co-worker and controlling the labels
- Start the line

### Main server

The responsibility for the main server during a format change procedure:

- Walk to the warehouse panel, located at robot cell 2.
- Wait for line to be emptied.
- Request and wait for access to robot cell 2
- Walk from entrance of robot cell 2 to pickup table for the robot
- Set measurement 1 in robot cell 2
- Set second measurement in the robot cell 2
- If the product being produced is or if it was the widest variant and being changed to a different kind, walk around pick up place to the guide rail.
    - Set the guide rail to designated width.
    - Walk back to the pickup table
- Walk from pickup place to entrance of robot cell 2
- Close door to robot cell 2
- (at the panel) Wait for format to load and sign off the changes (observe that the guide rail for the widest products isn't possible to sign off)
- Walk from warehouse panel to transport panel
- Check measurement on the transport panel.
- Walk to guide rail for the active sorting station
- Untighten the fasteners of the guide rail, than set the guide rail to the right width thereafter tighten the fasteners.
- Walk to the active sorting station
- Set the ruler in the active sorting station
- Walk to the transport panel
- Sign of the changes made to the guide rail in to the active sorting as well as for the ruler in the active sorting station
- Check new measurement for the box closer
- Walk to box closer
- Set measurement 4 in box closer
- Set measurement 1 in box closer

- Set measurement 2 in box closer
- Walk to box closer panel
- Set measurement 3 on the panel
- Walk to guide rail 6
- Untighten the fasteners of the guide rail 6, than set guide rail 6 to the right width thereafter tighten the fasteners.
- Walk to guide rail 7
- Untighten the fasteners of the guide rail 7 in to the active sorting, than set guide rail 7 to the right width thereafter tighten the fasteners.
- Walk to transport panel
- Sign off changes for box closer and guide rail 6 & 7
- Walk to end of box erector
- Check the quality of the boxes that has been processed in the box erector
    - If problem - solve
- Walk to robot cell 1
- Follow packages being loaded in to boxes
    - If problem - solve
- Follow boxes from robot cell 1 to the box closer
    - If problem - solve
- Follow boxes from box closer to active sorting station
    - If problem - solve

**Inspector**

The inspector assignment includes many long walking paths, which makes the time usage large. Main tasks include the change of the five first guide rails and the changes whit in robot cell 1, located in the main hall.

The inspector has the following tasks during a format change:

- Rework of products that has been rejected in the second pusher or by the inspector. Also document how many packages that has been reworked and reason for the rejection. Furthermore documentation regarding stoppages and reason for them. These stoppages are transferred in to the Axxos system afterwards.
- Walk from the inspection position to guide rail 1.
- Check the width of the guide rail (1) and what the new measurement is going to be.
- Release the two fasteners and put the guide rail in to the right position. Than tighten the fasteners and determine that it is the right width.
- Walk from guide rail 1 to guide rail 2
- Same procedure as for previous guide rail.
- Walk from guide rail 2 to guide rail 3
- Same procedure as for previous guide rail.
- Walk from guide rail 3 to guide rail 4
- Same procedure as for previous guide rail but with 15mm extra width.
- Walk from guide rail 4 to the datamatrix
- Check placement of the datamatrix, screw the adjustment wheel and determine that the right position is reached via the indicator.
- Walk from datamatrix to the depalletizer panel
- Log on to the depalletizer panel
- Load new recipe
- Walk from depalletizer panel to forklift for loading material in to the depalletizer
- Load the pallet in to the depalletizer.
- Walk from depalletizer loading dock to the packaging robot located in robot cell 1

- Request and wait for access to robot cell 1
- Walk to the box filling tool
- Remove the confirmation cord attached to the box filling tool
- Remove the old tool for filling boxes
- Hang this tool on the rack
- Take the new tool from the rack
- Place this tool at position
- Attach confirmation cord to the new tool
- Walk to the guide rails in robot cell 1
- Grab reference tool for the upper guide rail
- Set upper guide rail
- Put back reference tool for upper guide rail
- Grab reference tool for lower guide rail
- Set the lower guide rail
- Walk from robot cell 1 to guide rail 5
- Set guide rail 5
- Receipt the setup on the panel of robot cell 1
- Wait for the separation to get in to position

# APPENDIX 5

Spaghetti diagram of the organisationally improved setup procedure, divided by operator role.

**Administrator**

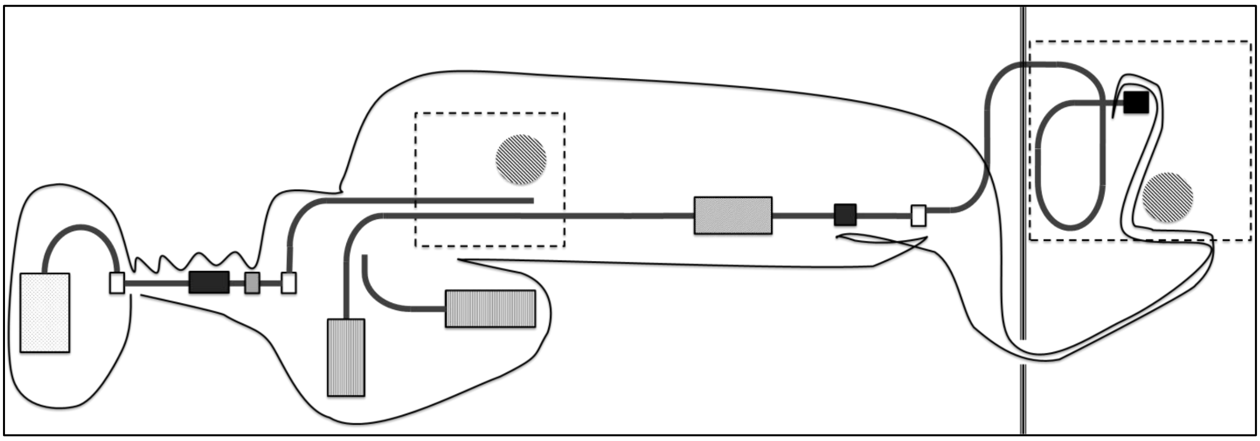


**Figure 6: Spaghetti diagram for the Administrator during setup.**

**Inspector**

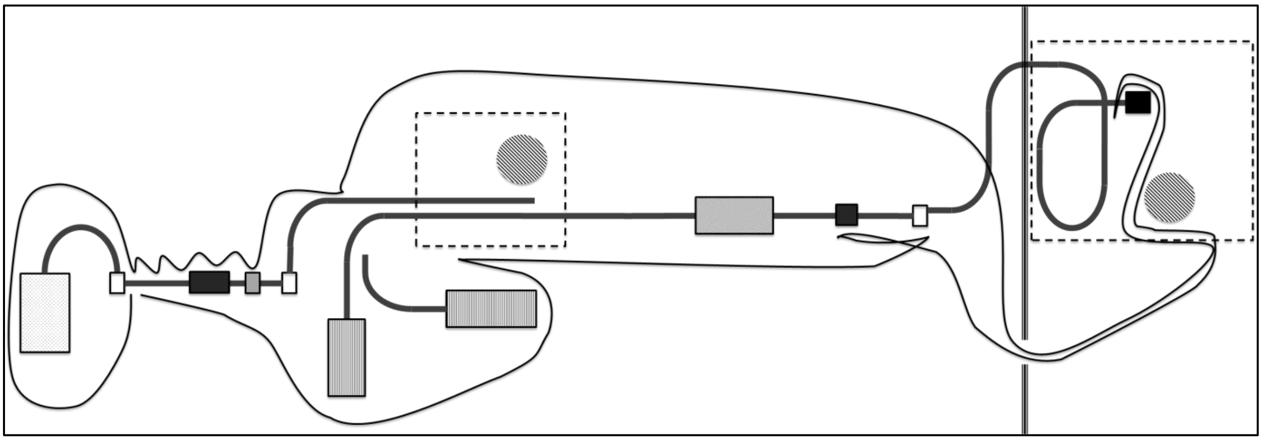


**Figure 7: Spaghetti diagram for the Inspector during setup.**

## Main server

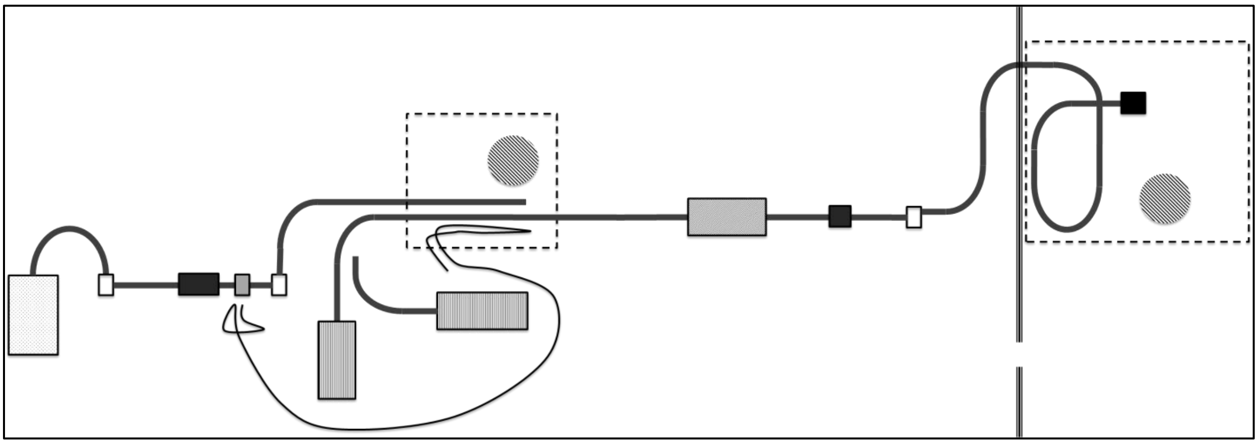


**Figure 8: Spaghetti diagram for the Main server during setup.**

## Material planer

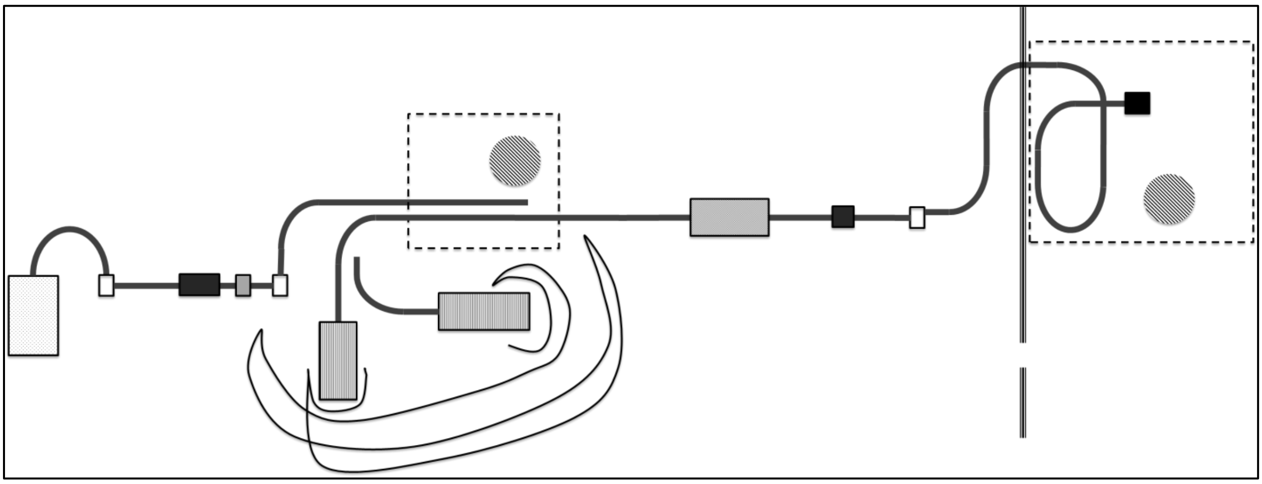


**Figure 9: Spaghetti diagram for the Material planer during setup.**

# APPENDIX 6

The organisational changes suggested would give these Standard Work Sheets.

**Format change:**

**Administrator**

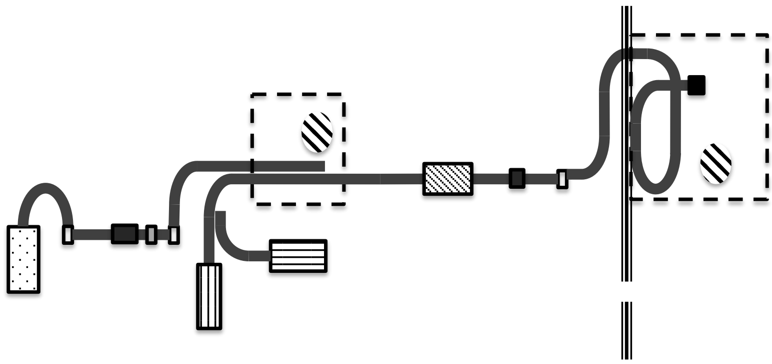
Standardised;work;sheet;];Formatomställning;(organisation)

Linje: Våta | Datum 10/5/14

Titel: Orderhanterare | Issued;by: Josefsson&Ödebrink

Tid(s) 609

| # | Operation | Work | Walk |
|---|---|---|---|
| 1 | Förbered;nytt;orderblad;(start;102s;innan) | 18.8 | |
| 2 | Signera;orderstart | 14.2 | 0 |
| 3 | Ta;fram;etiketter,;adm.;dator | 69.2 | 0 |
| 4 | Logga;in;på;depalleterare | 14.2 | 6.4 |
| 5 | Nytt;recept;depalleterare | 27.9 | 0 |
| 6 | Logga;in;på;huvudpanel | 17 | 6.4 |
| 7 | Avsluta;order;huvudpanel | 7.1 | 0 |
| 8 | Ladda;depalleterare | 20.9 | 14 |
| 9 | Avsluta;order,;dokument | 75.2 | 14 |
| 10 | Mata;in;orderdata | 40.1 | 0 |
| 11 | Skriv;ut;avd.;etikett | 9.5 | 4.9 |
| 12 | Skriv;ut;topp.;Etikett | 7.3 | 0 |
| 13 | Klistra;avd.;&;topp.;Etikett;på;orderblad | 12 | 2.3 |
| 14 | Skriv;ut;trp.;Etikett | 16 | 18 |
| 15 | Klistra;transp.etikett | 9.4 | 18 |
| 16 | Läsa;av;etiketter;mot;medarbetare* | 27.5 | 0 |
| 17 | Kontrollera;och;kvittera;etiketter | 59 | 0 |
| 18 | Kvittera;formatomst.;Räcken | 29 | 0 |
| 19 | Kvittera;formatomst.;Bipack | 31.4 | 0 |
| 20 | Stäng;av/på;bipack | 10 | 0 |
| 21 | Kvittera;formatomst.;&;etiketter | 8.7 | 0 |
| 22 | Starta;line | 1.3 | 0 |
| | total | 524 | 85 |



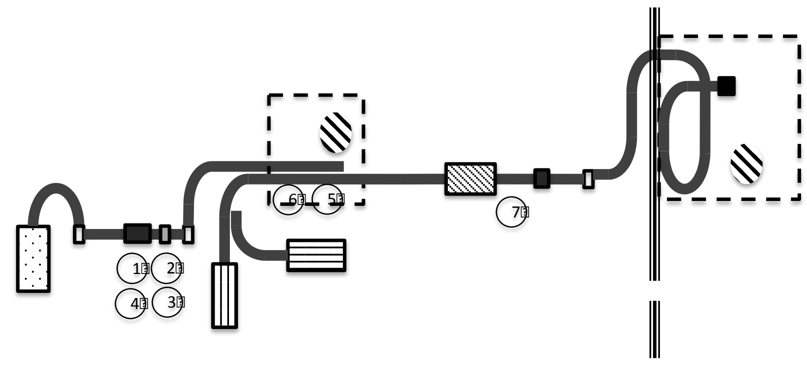
* Behov;av;hjälp;från;kollega.

**Figure 10: Standardised work sheet for the Administrator during setup.**

## Main server

| Standardised work sheet – Formatomställning (organisation) | | | |
|---|---|---|---|
| Linje: Våta | | Datum | 10/5/14 |
| Titel: Huvudservare | | Issued by: | Josefsson&Ödebrink |
| Tid(s): 540.5 | | | |

| # | Operation | Work | Walk |
|---|---|---|---|
| 1 | Gå till Bipack matare 1 | 18.5 | |
| 2 | Töm bipackmatare | 77 | |
| 3 | Jämför PIL mot order | 15 | |
| 4 | Fyll bipackmatare | 143 | 19 |
| 5 | Byt formverktyg | 59 | |
| 6 | Ställ räcke buren | 95 | 9 |
| 7 | Ställ räcke 6 & 7 | 105 | |
| 8 | | | |
| 9 | | | |
| 10 | | | |
| 11 | | | |
| 12 | | | |
| 13 | | | |
| 14 | | | |
| 15 | | | |
| 16 | | | |
| 17 | | | |
| 18 | | | |
| 19 | | | |
| 20 | | | |
| 21 | | | |
| | total | 513 | 28 |




* Behov av hjälp från kollega.

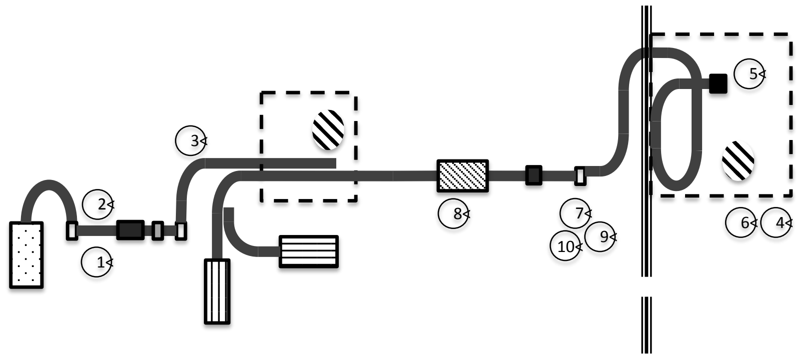
**Figure 11: Standardised work sheet for the Main server during setup.**

## Inspector

**Standardised work sheet – Formatomställning (organisation)**

| | | | |
|---|---|---|---|
| Linje: | Våta | Datum | 10/5/14 |
| Titel: | Avsynare | Issued by: | Josefsson&Ödebrink |
| Tid(s): | 576.9 | | |

| # | Operation | Work | Walk |
|---|---|---|---|
| 1 | Avslutande dokumentering | 29.6 | 28.8 |
| 2 | Ställ räcke 1-4 & Data matrix | 149 | 4.3 |
| 3 | Ställ räcke 5 (med tolk) | 61.2 | 29.9 |
| 4 | Begär & invänta tillträde robotcell (lager) | 7.1 | |
| 5 | Ställ robotcell (lager) | 61.9 | 10 |
| 6 | Kvittera formatomställ robotcell | 15.2 | 21.2 |
| 7 | Ställ aktivsorteringsbox | 21.2 | 3.1 |
| 8 | Ställ kartongförslutare | 40.6 | 3.1 |
| 9 | Kvittera formatomställ. Kartongförslutare | 12.1 | |
| 10 | Kvittera omställn för aktivsortering?????? | 11.3 | 6 |
| 11 | Kvitera format buren | 61 | |
| 12 | | | |
| 13 | | | |
| 14 | | | |
| 15 | | | |
| 16 | | | |
| 17 | | | |
| 18 | | | |
| 19 | | | |
| 20 | | | |
| 21 | | | |
| | total | 471 | 106 |




* Behov av hjälp från kollega.

**Figure 12: Standardised work sheet for the Inspector during setup.**

## Material planer

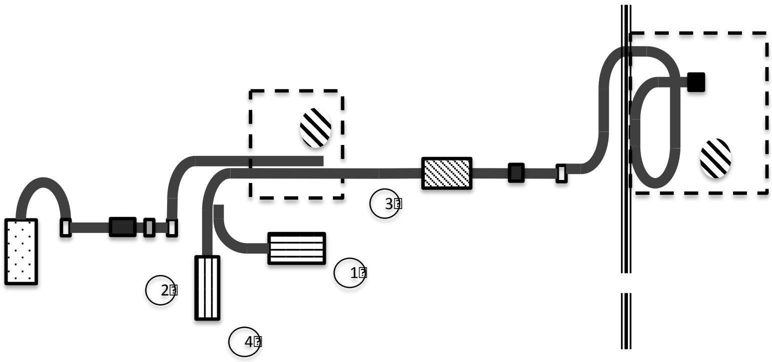
Standardised work sheet – Formatomställning (organisation)

Linje: Våta | Datum 10/5/14

Titel: Materialplanerare | Issued by: Josefsson&Ödebrink

Tid(s): 1026.7 | Total tid:

| # | Operation | Work | Walk |
|---|---|---|---|
| 1 | Ställ kartongresare 2 (start 468s innan) | 469 | |
| 2 | Läs av etikett mot medarbetare* | 28 | 20 |
| 3 | Töm och stäng av trp bipack matare | 25 | |
| 4 | Ställ kartongresare 1 | 485 | |
| 5 | | | |
| 6 | | | |
| 7 | | | |
| 8 | | | |
| 9 | | | |
| 10 | | | |
| 11 | | | |
| 12 | | | |
| 13 | | | |
| 14 | | | |
| 15 | | | |
| 16 | | | |
| 17 | | | |
| 18 | | | |
| 19 | | | |
| 20 | | | |
| 21 | | | |
| | total | 1007 | 20 |




* Behov av hjälp från kollega.

**Figure 13: Standardised work sheet for the Material planer during setup.**

## Order change:

## Administrator

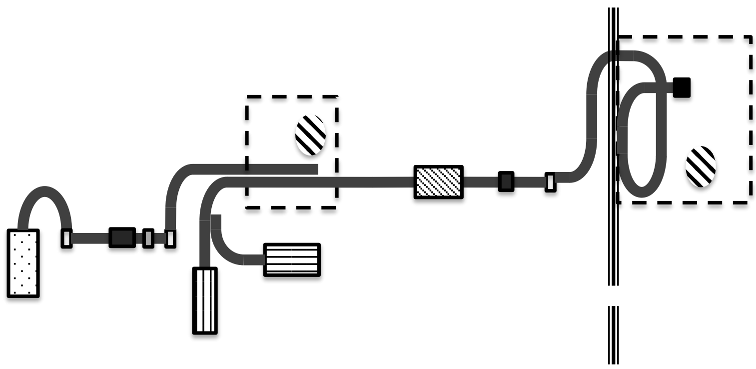
**Standardised work sheet – Orderbyte (organisation)**

Linje: Våta — Datum 10/5/14

Titel: Orderhanterare — Issued by: Josefsson&Ödebrink

Tid(s) 421.6

| # | Operation | Work | Walk |
|---|---|---|---|
| 1 | Förbered nytt orderblad (start 2 min innan) | 20 | |
| 2 | Signera orderstart | 15 | 0 |
| 3 | Ta fram etiketter, adm. dator | 69 | 0 |
| 4 | Logga in på huvudpanel | 17 | 0 |
| 5 | Avsluta order huvudpanel | 7.2 | 0 |
| 6 | Avsluta order, dokument | 75 | 0 |
| 7 | Mata in orderdata | 40.2 | 0 |
| 8 | Skriv ut avd. etikett | 9.6 | 4.8 |
| 9 | Skriv ut topp. Etikett | 9.6 | 0 |
| 10 | Klistra avd. & topp. Etikett på orderblad | 12 | 0 |
| 11 | Klistra transportetikett* | 9.6 | 0 |
| 12 | Läsa av etiketter mot medarbetare* | 27.6 | 0 |
| 13 | Kontrollera och kvittera etiketter | 58.8 | 0 |
| 14 | Kvittera bipacksedelmatare | 31.2 | 0 |
| 15 | Stänga av/på bipacksedelmatare | 10.2 | 0 |
| 16 | Kvittera ny orderdata (onställning) | 8.4 | 0 |
| 17 | Starta line | 1.2 | 0 |
| 18 | | | 0 |
| 19 | | | 0 |
| 20 | | | 0 |
| 21 | | | 0 |
| 22 | Starta line | | 0 |
| | total | 422 | 4.8 |



* Behov av hjälp från kollega.

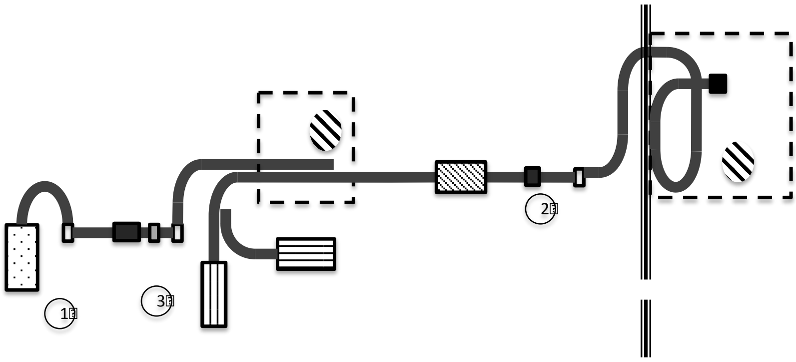
**Figure 14: Standardised work sheet for the Administrator during order change.**

## Main server

Standardised work sheet – orderbyte (organisation)

Linje: Våta — Datum 10/5/14
Titel: Huvudservare — Issued by: Josefsson&Ödebrink
Tid(s): 64.2

| # | Operation | Work | Walk |
|---|---|---|---|
| 1 | Ladda depaliterare | 21 | |
| 2 | Skriv ut trp. Etikett | 15.6 | 32 |
| 3 | Läs av etikett mot medarbetare | 27.6 | 17.4 |
| 4 | | | |
| 5 | | | |
| 6 | | | |
| 7 | | | |
| 8 | | | |
| 9 | | | |
| 10 | | | |
| 11 | | | |
| 12 | | | |
| 13 | | | |
| 14 | | | |
| 15 | | | |
| 16 | | | |
| 17 | | | |
| 18 | | | |
| 19 | | | |
| 20 | | | |
| 21 | | | |
| | total | 64.2 | 49.4 |




* Behov av hjälp från kollega.

**Figure 15: Standardised work sheet for the Main server during order change.**

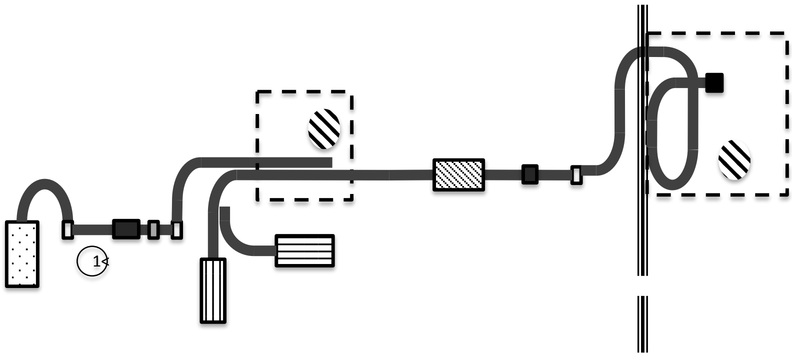
## Inspector

**Standardised work sheet – Order change (organisation)**

Linje: Våta
Titel: Avsynare
Tid(s): 29.6

Datum 5/10/14
Issued by: Josefsson & Ödebrink

| # | Operation | Work | Walk |
|---|---|---|---|
| 1 | Avslutande dokumentering | 29.6 | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| 6 | | | |
| 7 | | | |
| 8 | | | |
| 9 | | | |
| 10 | | | |
| 11 | | | |
| 12 | | | |
| 13 | | | |
| 14 | | | |
| 15 | | | |
| 16 | | | |
| 17 | | | |
| 18 | | | |
| 19 | | | |
| 20 | | | |
| 21 | | | |
| | total | 29.6 | 0 |




* Behov av hjälp från kollega.

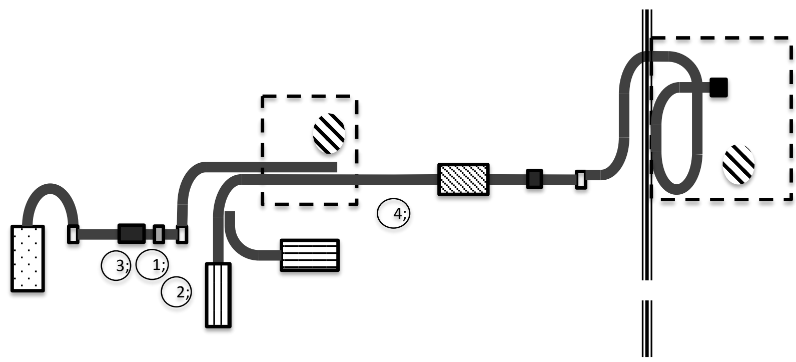
**Figure 16: Standardised work sheet for the Inspector during order change.**

## Material planer

Standardised;work;sheet;[;Order;change;(Organisation)

| | | | |
|---|---|---|---|
| Linje: | Våta | Datum | 10/5/14 |
| Titel: | Materialplanerare | Issued;by: | Josefsson;&;Ödebrink |
| Tid(s): | 259.8 | Total;tid: | |

| # | Operation | Work | Walk |
|---|---|---|---|
| 1 | Töm;bipacksedelmatare | 76.8 | |
| 2 | Jämför;bipacksedel;med;order | 15 | 20 |
| 3 | Fyll;bipacksedelmatare | 143 | 19.8 |
| 4 | Töm;och;stäng;av;transport;Bipack | 24.6 | |
| 5 | | | |
| 6 | | | |
| 7 | | | |
| 8 | | | |
| 9 | | | |
| 10 | | | |
| 11 | | | |
| 12 | | | |
| 13 | | | |
| 14 | | | |
| 15 | | | |
| 16 | | | |
| 17 | | | |
| 18 | | | |
| 19 | | | |
| 20 | | | |
| 21 | | | |
| | total | 260 | 39.8 |




* Behov;av;hjälp;från;kollega.

**Figure 17: Standardised work sheet for the Material planer during order change.**

# APPENDIX 7

Standardised work combination table format change and order change with organisational improvements.

**Format change**

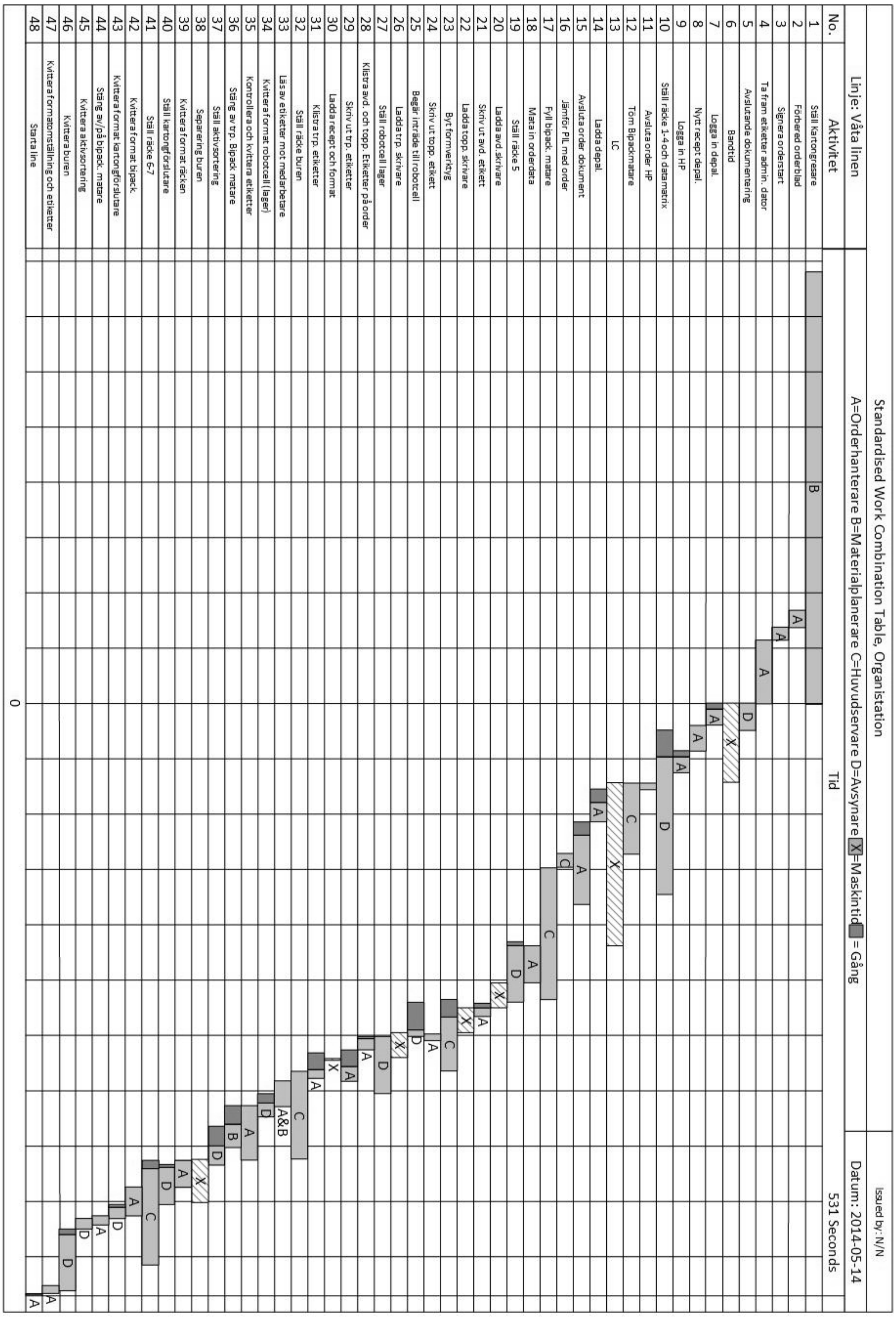



**Figure 18: Standardised work combination table for setup.**

## Order change

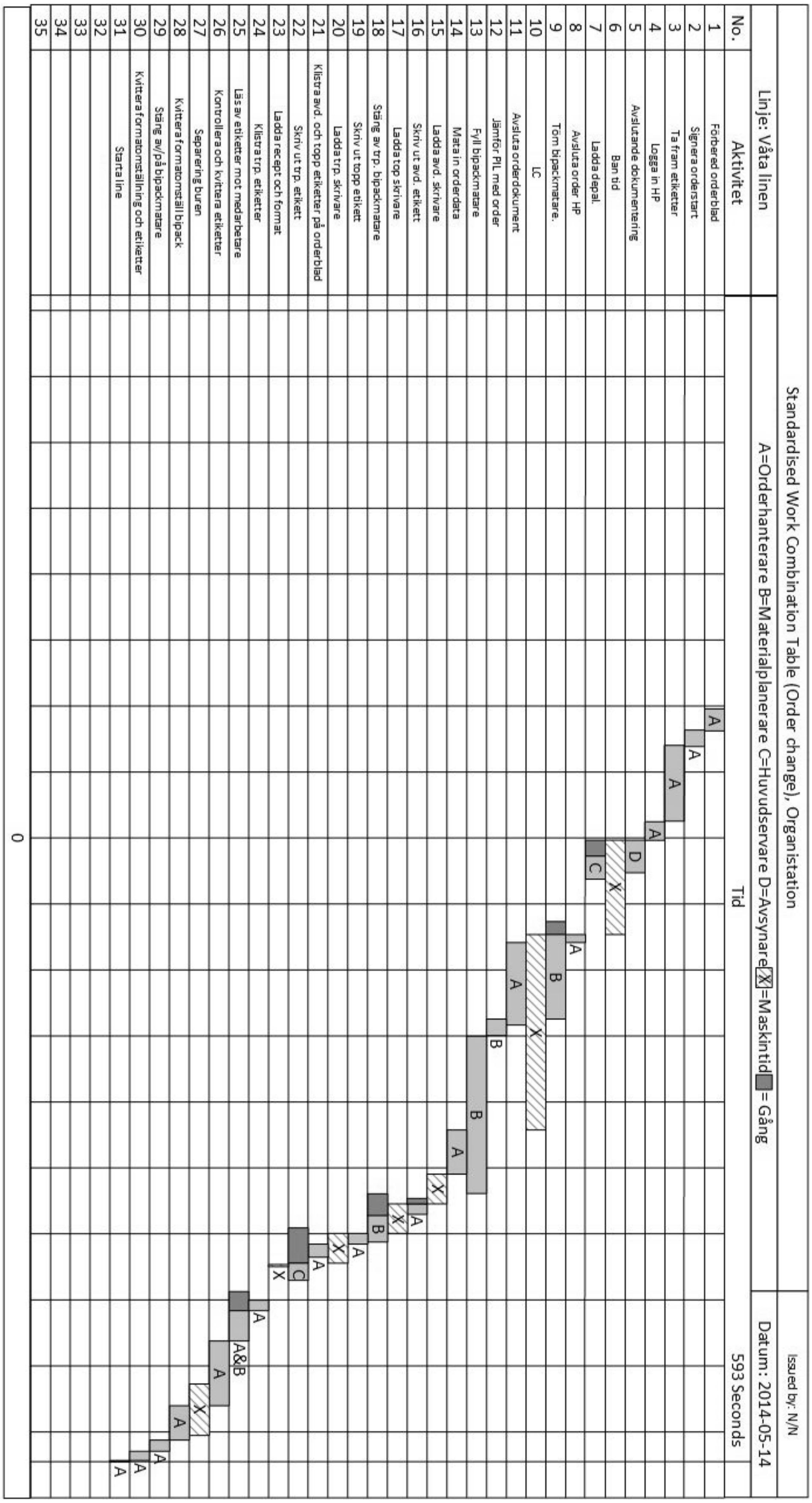



**Figure 19: Standardised Work Combination Table for Order Change with Organisational improvement.**

# APPENDIX 8

The following appendix is composed of more detailed explanations of the methods improvements considered.

# CAMERA IN THE WAREHOUSE

At present the main server is supervising the last packages leaving the warehouse to be able to quickly spot any problems. This is done by walking out into the warehouse as the last box enters the warehouse. By installing a camera overlooking the robot in the warehouse and connected to a screen by the main operator panel the administrator can supervise the warehouse freeing up the main server. Only a real-time feed from the camera is shown and no video is recorded.

### Time

The time for the activity before was 263,7s and consists almost exclusively of waiting time during the majority of setups, when no breakdown occurs.

### Investment

As an example a complete wireless camera system including a 7-inch LCD screen has been chosen. Adjustments such as contrast, brightness and colour can be changed on the screen menu.

**Table 1: Investment cost for camera.**

| Activity | Improvement | Parts | No. | Activities | Hours | Cost/Hour (SEK) | Cost (SEK) | Total cost (SEK) |
|---|---|---|---|---|---|---|---|---|
| **Monitoring wharehouse** | Camera in the warehouse | Camera and monitor | 1 | Buy | - | - | 5251 | 5751 |
| | | Installation | 1 | - | 1 | 500 | 500 | |

# LOAD PALLET IN TO THE DEPALITIZER

Marking on the floor to guide the fork lift in the right position, marked with tape one and a half pallet distance from the loading dock. These markings will help lower variation in the activity as well as decreasing the number of times the activity has to be done again if the pallet comes in at an angle the first time. It has not been determined how often the activity has to be redone, but since the solution to the problem was suggested from the operator it can be assumed to be a frequent issue. The investment cost is also negligible.

### Time

There is no change in time for the activity.

# QUALITY ASSURE AND RECEIPT LABELS

### Stamping the labels

Today all six labels are signed individually by the operator. By introducing a date stamp to be used instead of signing on five of the six labels on the back of the order card, a time saving quality control is achieved. At the same time the single personal signature makes it possible to identify the operator who performed the quality control thus keeping the high quality standard. The date stamp is kept at computer 2 and a safety stock of at least one extra stamp should be kept at hand to reduce the amount of deviations from practice if a stamp is consumed.

### Writing in only one place

Today all six labels are signed individually by the operator. By introducing a new standard where the operators only sign once on the back of the order card a time saving method is achieved. Clearly communicating that once the personal signature is made the operator assures that all labels have been quality checked according to standard the high quality is kept.

### Time

The comparison of real labels and the pictures represent a large amount of the time but it is not something that can be improved from the current method. Taking a pen and signing one label only takes a few seconds. When signing only one label both has better improvement potential and at no cost this method is recommended and further analysed.

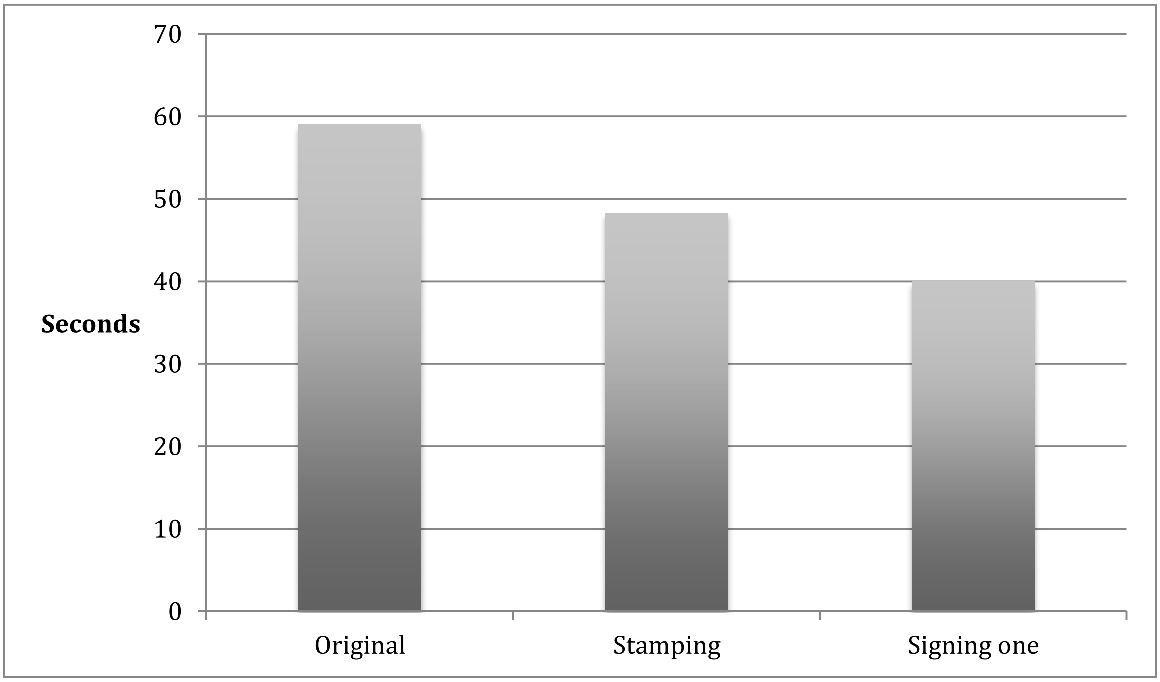



**Figure 20: Comparison of time for receipting labels.**

### Calculated time

The stamping time is calculated with SAM on the premises that force has to be applied to each label to transfer the ink.

$$GS45 + PP45 + AF = 14 \text{ factors}$$
$$3 * (PP10 + AF) = 24 \text{ factors}$$
$$PP10 + AF + PD45 = 11 \text{ factors}$$
$$46 \text{ factors} = 8{,}28\text{s}$$

### Investment

The cost for a stamp varies greatly, a simple stamp with only date can start at 400 SEK whereas a more advanced stamp with the company logo is around 1000 SEK.

# RECEIPT SETUP OF THE GUIDE RAILS

To ensure that the guide rails opposite of the label printers have been adjusted for the new product the administrator can use the light beacon at the depalletizer as a marker that all is ready for the start of production. Since the depalletizer previously has been loaded it would have triggered an alarm if the first guide rail had not been changed when new material is loaded. If the guide rails instead have been changed the beacon will give a blue signal, telling the operator that it is ready to start. Thus the administrator knows that the guide rails have been adjusted. The improvement requires no investment.

**Time**

The improvement from the original time is not only an improvement, the method has smaller variation than previously where the administrator choose where to look at the guide rail or yelled at another operator.

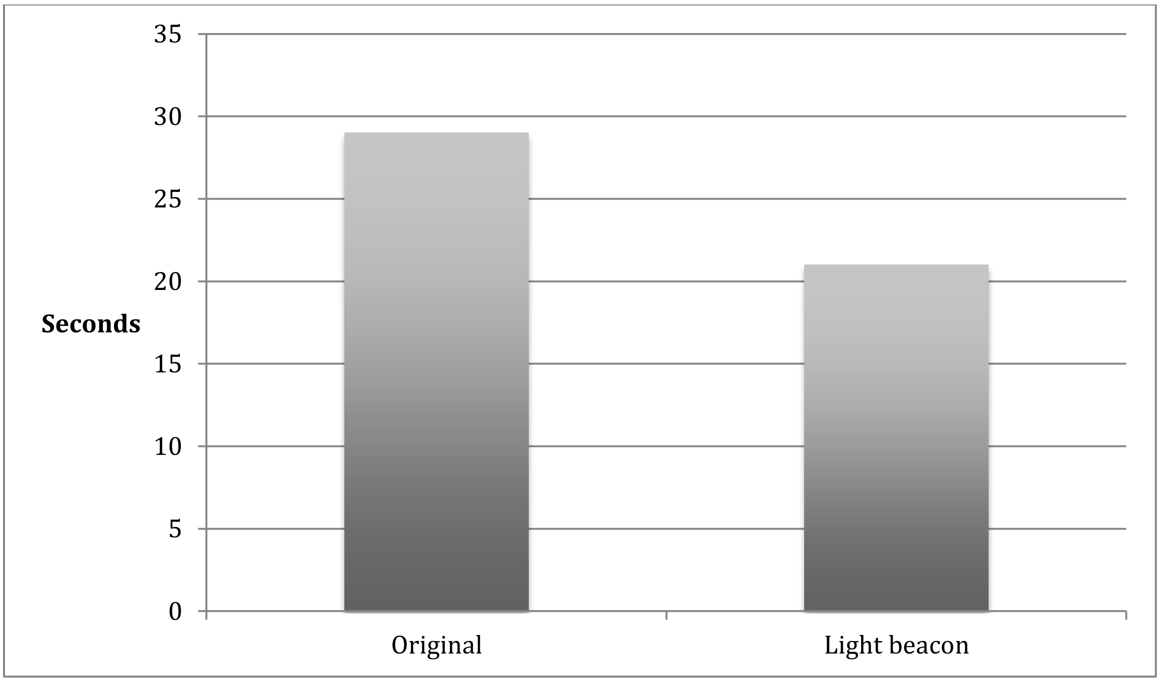



**Figure 21: Comparison of time for receipting guide rail setup.**

**Calculation of registering light beacon**

The added time for turning around and register the colour of the beacon is:

$$2 * S + RD + 2 * S = 15\ factors$$
$$15\ factors = 2{,}7s$$

# RECEIPT SETUP PIL

To simplify controlling that the correct PIL have been loaded into the PIL feeders a system where the material planer leaves a confirmation for the administrator. Once the PIL feeders have been loaded the material planer changes PILs in the small blue container where PILs are stored for use in rework. Once the content of the box has been changed the material planer places it at the desk by the administrator. When the administrator is going to receipt the PILs the administrator can easily take a card from the container and control that the right PILs are loaded into the feeders. After a completed setup the administrator returns the blue container to its natural position during production. This solution requires no investment.

**Time**

In addition to the time spent by the administrator the material planer must move the box to the desk by the administrator. This takes only a small amount of time and allocating time spent by the administrator to other operators is beneficial. Returning the box to its position during production is part of the external setup.

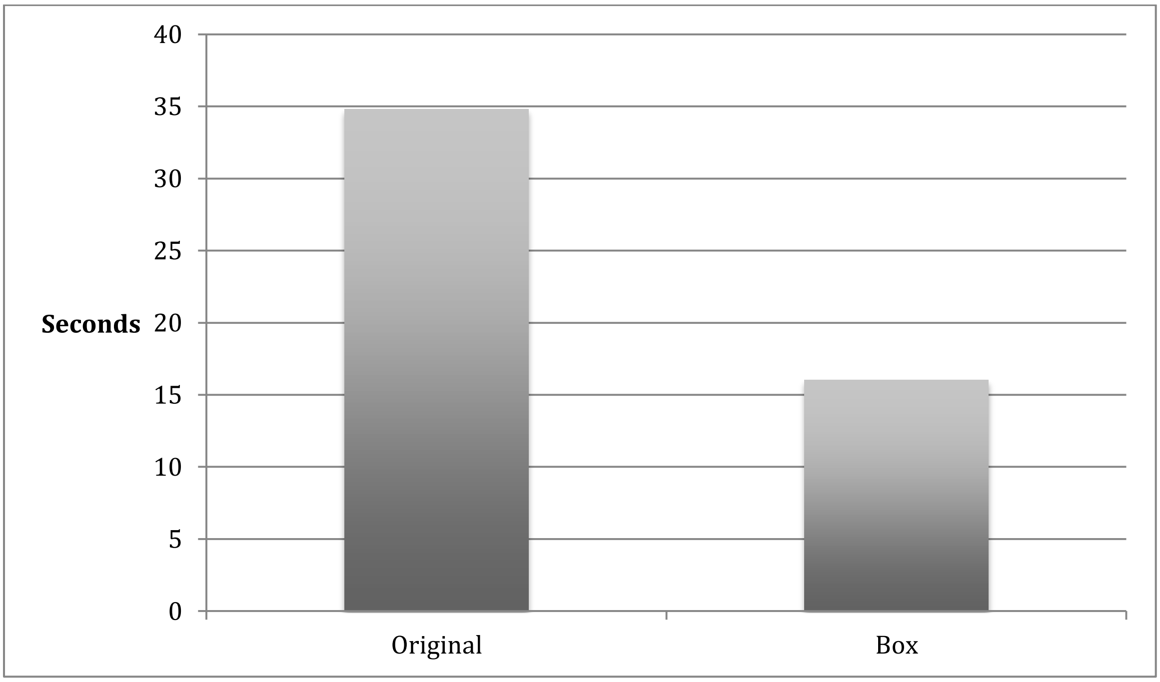



**Figure 22: Comparison of time for receipting change of PIL.**

**Calculated time**

Move the box to the desk is performed by the material planer:

$$GS45 + 6 * S + PD45 = 26\ factors$$
$$26\ factors = 4{,}68s$$

The time for checking the PILs in the box is performed by the administrator:

$$S + GS45 + 2 * RB + S = 28\ factors$$
$$28\ factors = 5{,}04s$$

Return the box to it place during production is performed by the administrator and is external setup:

$$GS45 + 6 * S + PD45 = 26\ factors$$
$$26\ factors = 4{,}68s$$

# SCAN THE ORDER DATA

At present the manufacturing order number, the part number and number of parts to be produced are entered into the main panel to start a new order. By simply scanning the barcode on top of the manufacturing order a large save in the activity time would be gained. This method also eliminates the possibility that the operator misreads the order sheet and inputs the wrong data.

**Time**

The time is based on the assumption that the loading of new data would not include any extra loading time, but simply consist of the actual scanning.

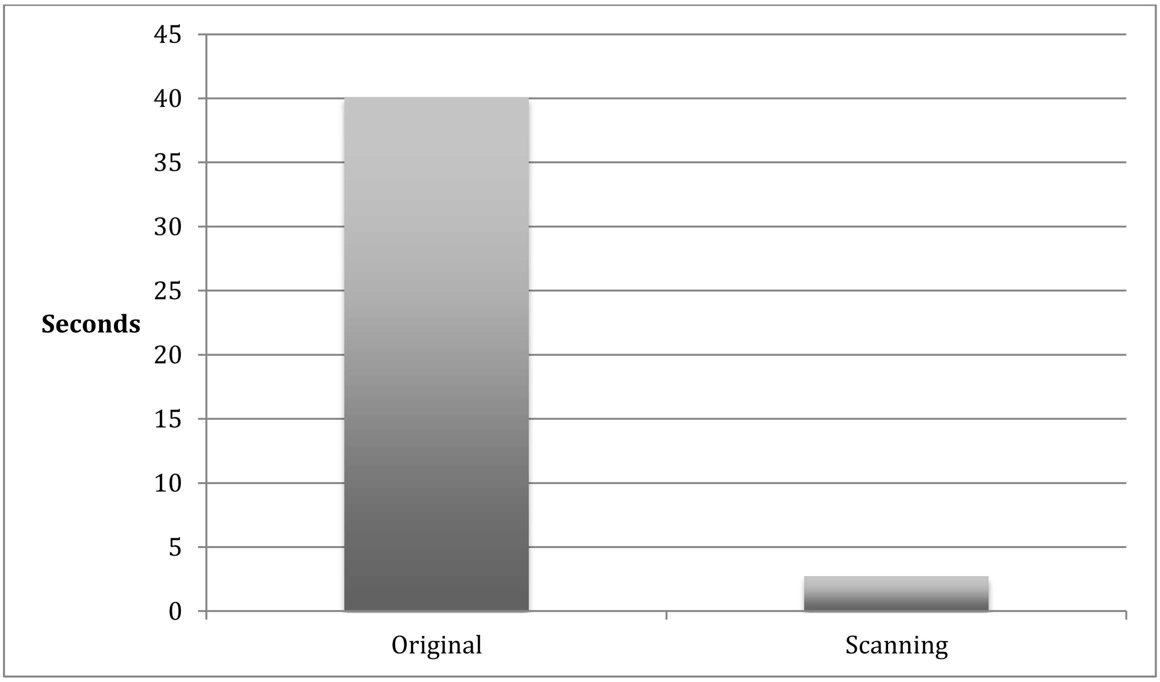



**Figure 23: Comparison of time for entering order data.**

**Calculated times**

$$GS45 + PD45 + AF + PP45 = 15\ factors$$
$$15\ factors = 2{,}7s$$

**Investment**

Programming on the line is needed to implement the solution. A programmer with experience from the line has been consulted to estimate the number of programming hours needed to implement the scanner solution, his guess was that a two hours would be sufficient. Depending on what quality and functions you think will be needed for the barcode scanner its price range will vary. To exemplify a simple scanner with wire and USB connection will cost 1074 SEK.

# SETUP OF GUIDE RAIL 1-4

Three solutions have been generated for this activity. Two of them are based on adding linear actuators, those solutions would be able to implement on guide rail 6 and 7 as well, regardless of type of control of the actuators. The investment budget should also be lower if it’s possible to buy a larger number. If the number of guide rails is changed rebuilding of the safety stop must be done to allow three guide rails. This means welding on extra length on already existing structures at the line.

**Automated guide rails**

The solution with the most potential for reduced format change time is to equip the guide rails with linear actuators connected to electrical engines. The engines are setup to communicate with the program loading the format for the product and automatically set the width of the rails at predetermined revolutions.

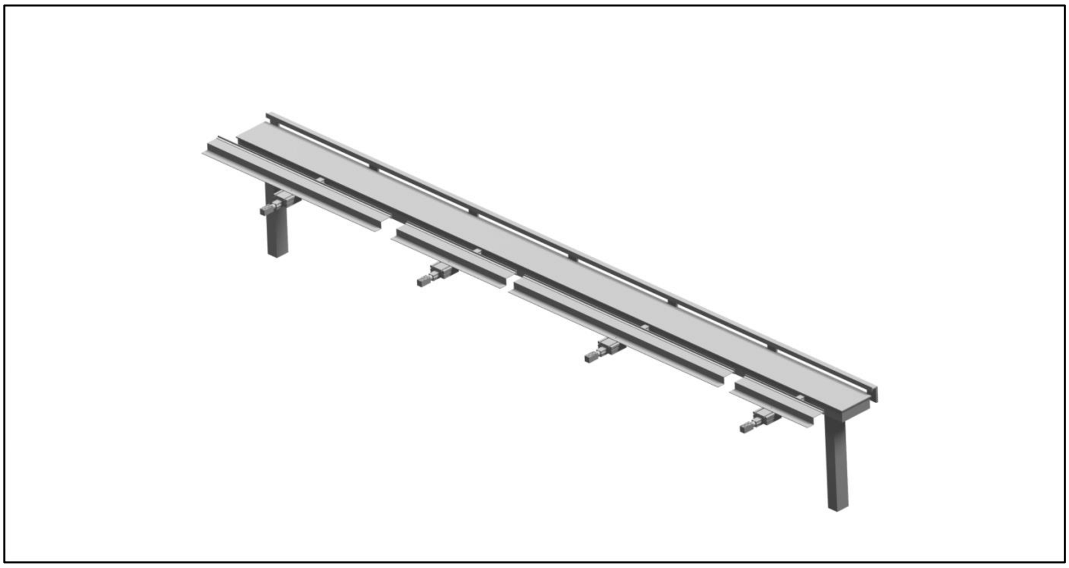


**Figure 24: A picture of guide rail 1-4 with motors.**

It is also possible to reduce the number of guide rails from the current four individual guide rails to three guide rails, by having one rail in front of the label printers and two other guide rails positioned by each conveyor pusher. Fewer rails than that would be problematic in regards to the flexibility of the line. Calculations show that the rails can be controlled with only one actuator per rail.

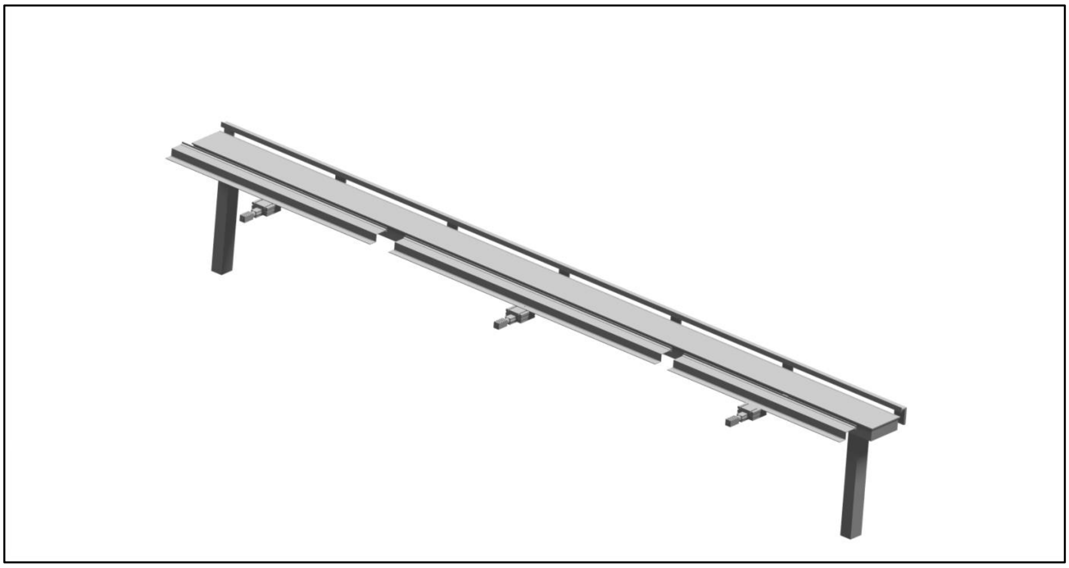


Figure 25: A picture of guide rail 1-4 with motors and three rails.

### Hand wheel

By installing linear actuators that the guide rails are positioned on, which are driven by a hand wheel and has a position indicator the setup of the guide rails could be reduced. Calculations show that the rails can be controlled with only one actuator per rail.

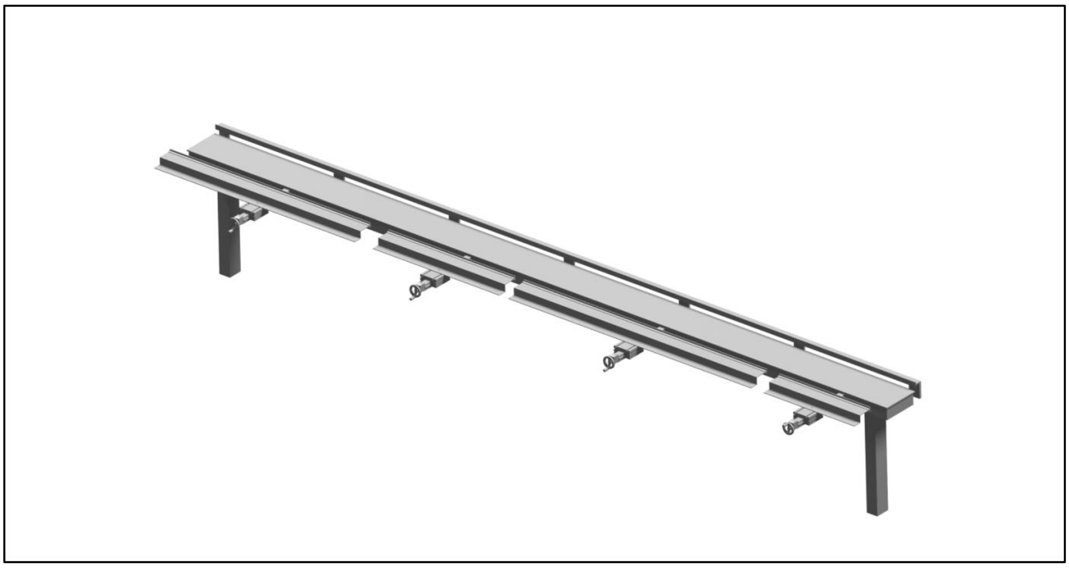


Figure 26: A picture of guide rail 1-4 with hand wheels.

It is also possible to reduce the number of guide rails from the current four individual guide rails to three guide rails, by having one rail in front of the label printers and two other guide rails positioned by each conveyor pusher. Fewer rails than that would be problematic in regards to the flexibility of the line.

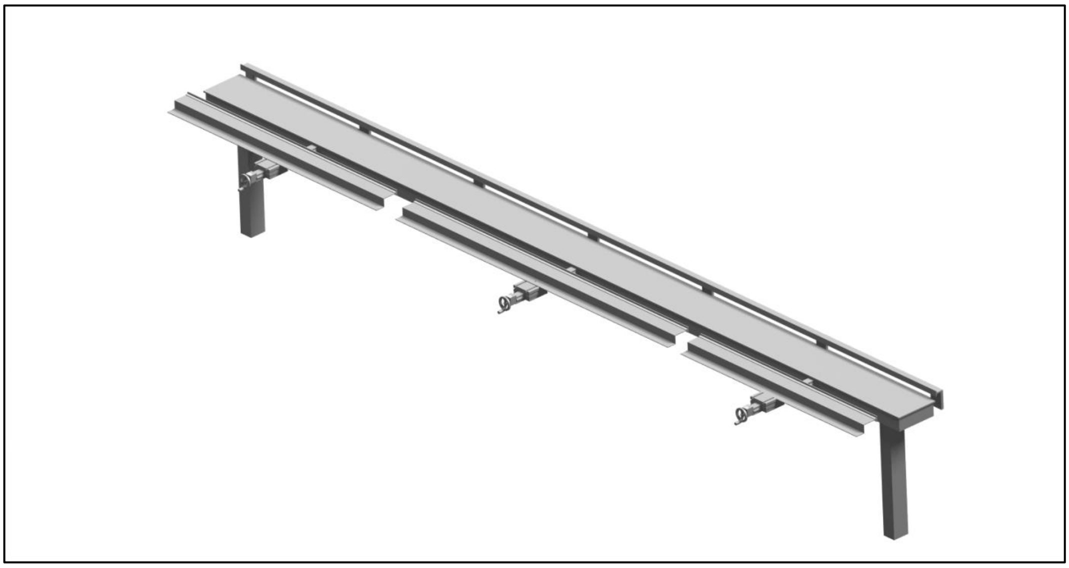


Figure 27: A picture of guide rail 1-4 with hand wheels and three rails.

### Three guide rails

The simplest improvement of the guide rail setup would be to lubricate the glide paths of the rails frequently and to agree on the most beneficial way to tighten the rails. It is a simple solution that would save some amount of time. Also here the number of rails can be reduced to three rails.

### Time

The time for the different activities are displayed in figure **9**, showing that for the individual activity the motor driven rails have by far the largest potential. Adding linear actuators and hand wheels to the current amount of rails is slower than the small investment of converting the rails into three guide rails and just doing the setup as today. The solution with four rails, actuators and hand wheels have therefore not been analysed further.

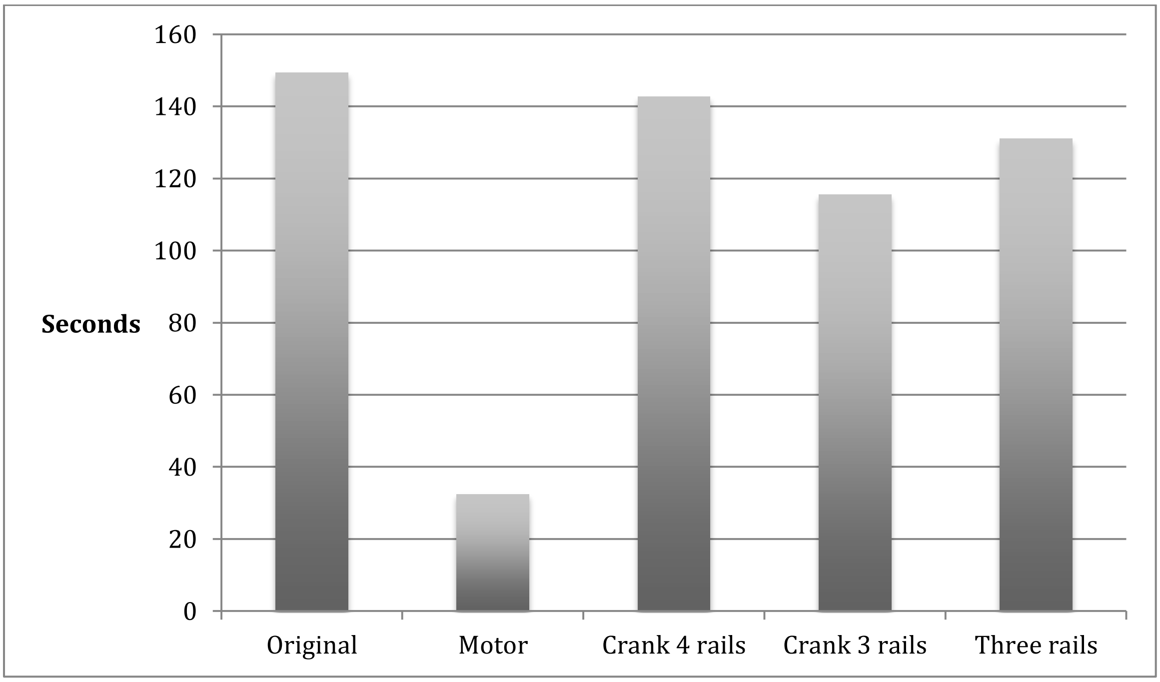



Figure 28: Comparison of time for resetting guide rail 1-4.

### Calculated times

If four guide rails are used the largest distance from a rails edge to the centre is 1,15 meters and the maximum force that the labels are applied with has been calculated to no more than 196,2 Newton. This gives a momentum in Z of 225,63 Nm and a force of 196,2 N in X that the linear actuator must handle during production. If three guide rails are used the distance from the centre of the middle rail to the end is 1,3 meters and the maximum force that the labels are applied with are 196,2 Newton. This gives a momentum in Z of 255 Nm and a force of 196,2 N in X that the actuator must absorb during production.

With the longest guide rail setup being from 308,9 to 488 = 179,1. 179,1/3= 60+1 revolutions for the data matrix. The Linear actuator has a screw lead of 4 mm. 179,1/4= 45+1 revolutions.

### Automated line

The short distance moved and the precision required means that the acceleration and deceleration distances will be long in relation to the total travel length. If the average rpm is assumed to end up being equal to that of an operators this would mean 111 rpm. Giving a total time to set the data matrix, this has 60 revolutions as its longest distance, to:

$$Time = \frac{revulotions}{rpm} * 60 = \frac{60}{111} * 60 = 32{,}43s$$

Since all rails are changed simultaneously the total time equals the time to set one rail.

### Hand wheel

*Four guide rails:*

$$2 * RA = 4\,factors$$
$$GS45 + 46 * CA = 142\,factors$$
$$2 * RA = 4\,factors$$
$$S + GS45 + 61 * CA = 190\,factors$$
$$3 * (3 * S + GS45 + 46 * CA) = 453\,factors$$
$$793\,factors = 142{,}74s$$

*Three guide rails:*

$$2 * RA = 4\,factors$$
$$GS45 + 46 * CA = 142\,factors$$
$$2 * RA = 4\,factors$$
$$S + GS45 + 61 * CA = 190\,factors$$
$$3 * S + GS45 + 46 * CA = 148\,factors$$
$$5 * S + GS45 + 46 * CA = 154\,factors$$
$$642\,factors = 115{,}56s$$

## Three guide rails

*New middle rail:*

$$GS45 + AF + 2*SB + 3*S + GS45 + AF + 2*SB = 51\ factors$$
$$GS10 + (\sout{GS10}) + PP45 + PP10 + RC = 22\ factors$$
$$3*S + GS45 + (\sout{GS10}) + PP45 + PP10 + RC = 33\ factors$$
$$GS10 + 2*SB + AF = 19\ factors$$
$$3*S + GS45 + 2*SB + AF = 30\ factors$$
$$155\ factors = 27{,}9s$$

## Investment

**Table 2: Investment cost for new guide rails.**

| Activity | Improvement | Parts | No. | Activities | Hours | Cost/Hour (SEK) | Cost (SEK) | Total cost (SEK) |
|---|---|---|---|---|---|---|---|---|
| **Setup rail 1-4** | Only three rails | Guide rails | 3 | Drawing | 2 | 500 | 1000 | 3900 |
| | | Safetybrackets | 2 | Production | 4 | 350 | 1400 | |
| | | | | Assembly | 3 | 500 | 1500 | |
| | | | | | | | | |
| | | | | | | | | |
| | Hand wheel three rails | Guide rails | 3 | Drawing | 2 | 500 | 1000 | 35168,67 |
| | | Safetybrackets | 2 | Production | 4 | 350 | 1400 | |
| | | | | Assembly | 3 | 500 | 1500 | |
| | | | | | | | | |
| | | Linear actuators | 3 | Buy | - | | 26151,84 | |
| | | Hand wheel | 3 | - | - | | 994,41 | |
| | | Position indicator | 3 | - | - | | 4122,42 | |
| | | | | | | | | |
| | | | | | | | | |
| | Motor on three rails | Guide rails | 3 | Drawing | 2 | 500 | 1000 | 32141,84 |
| | | Safetybrackets | 2 | Production | 4 | 350 | 1400 | |
| | | | | Assembly | 3 | 500 | 1500 | |
| | | | | | | | | |
| | | Linear actuator | 3 | Buy | - | - | 26151,84 | |
| | | Motor | 3 | Buy | - | - | 1590 | |
| | | | | Assembly | 1 | 500 | 500 | |

# SETUP OF GUIDE RAIL 5

### Remove the resetting procedure

If the rail would be modified with a wide entrance and narrower in the end but wide enough for the largest package the function of the guide rail would be the same but no changes would have to be done when resetting the machine between different packages. This solution requires that the first rail in the robot cell is set to the right measurement and matched to the width in the end of guide rail 5.

### Time

The time for the activity before was 61,2s and now the activity is removed.

### Investment

**Table 3: Cost for removing guide rail 5.**

| Activity | Improvement | Parts | No. | Activities | Hours | Cost/Hour (SEK) | Cost (SEK) | Total cost (SEK) |
|---|---|---|---|---|---|---|---|---|
| **Setup rail 5** | Remove rail | New rail in cage | 1 | New plastics | - | - | 300 | 800 |
| | | | | Production | 1 | 500 | 500 | |

# SETUP OF GUIDE RAIL 6

### Automated guide rail

The guide rails can be repositioned to be placed upon linear actuators connected to an electrical engine. The engine is setup to communicate with the program loading the format for the product and automatically set the width of the rails at predetermined revolutions.

**Figure 29: A picture of guide rail 6 with motor.**

### Hand wheel

By installing a linear actuator that the guide rail is positioned on, which is driven by a hand wheel and has a position indicator the setup of the guide rail can be reduced. Calculations show that the rail can be controlled with only one actuator per rail.

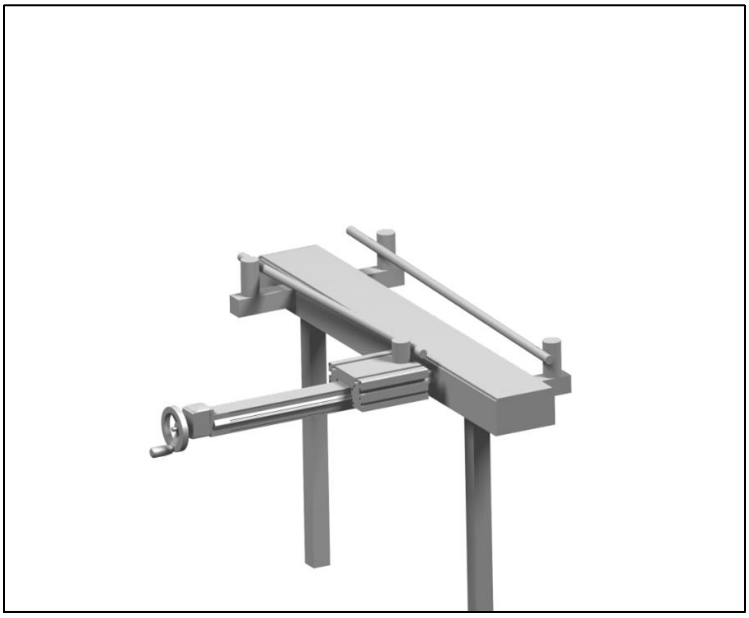


**Figure 30: A picture of guide rail 6 with hand wheel.**

### Time

The motor driven solution takes almost half as much as the hand operated one. But it comes at a larger investment.

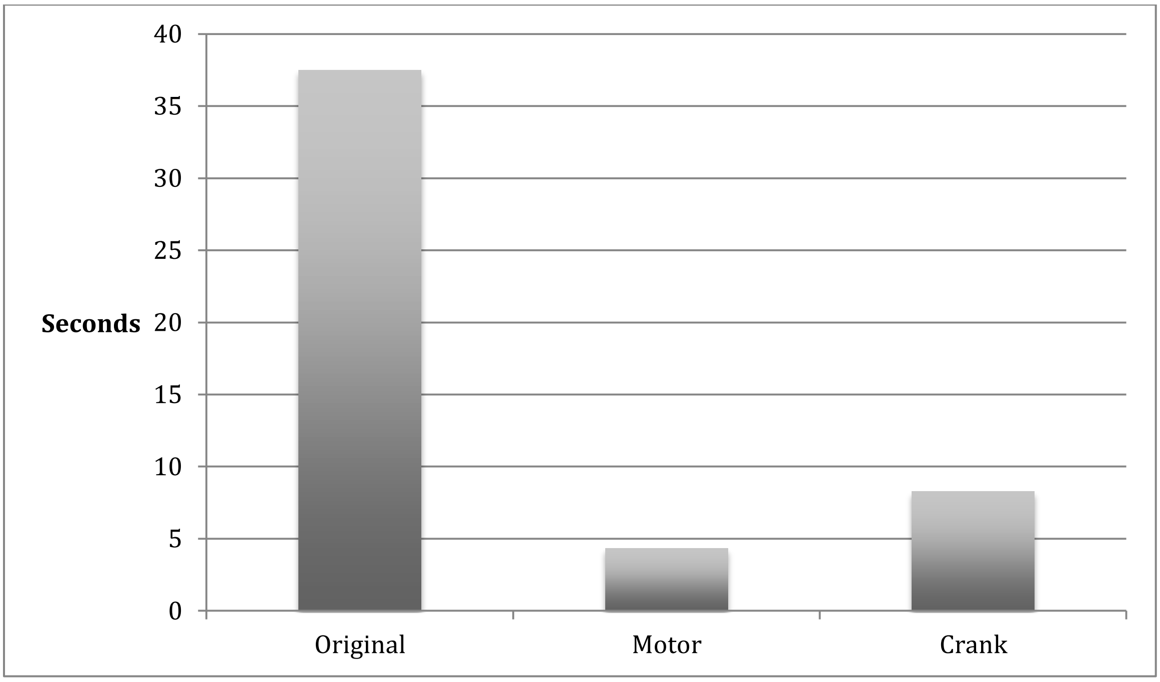



**Figure 31: A comparison of improvements to guide rail 6.**

### Calculated time

The largest difference in width is 31 mm. With a screw lead of 4 mm per revolution the needed revolutions are 8 full revolutions. The short distance moved and the precision required means that the acceleration and deceleration distances will be long in relation to the total travel length. If the average rpm is assumed to end up being equal to that of an operators this would mean 111 rpm. Then the time to change the rails becomes:

$$Time = \frac{revolutions}{rpm} * 60 = \frac{8}{111} * 60 = 4{,}32s$$

One single hand wheel controlling the entire length of the rail and the largest difference in width is 31 mm. With a screw lead of 4 mm per revolution the needed revolutions are 8 full revolutions. The time to bend down and turn the hand wheel then becomes with SAM:

$$B + GS80 + 9 * CA + RA = 46\, factors$$
$$46\, factors = 8{,}28s$$

## Investment

**Table 4: Cost for improving guide rail 6.**

| Activity | Improvement | Parts | No. | Activities | Hours | Cost/Hour (SEK) | Cost (SEK) | Total cost (SEK) |
|---|---|---|---|---|---|---|---|---|
| **Setup guide rail 6** | Motor driven | New rail | 1 | Drawing | 1 | 500 | 500 | 12447,28 |
| | | | | Production | 2 | 350 | 700 | |
| | | | | Assembly | 1 | 500 | 500 | |
| | | | | Materials | - | - | 1000 | |
| | | | | | | | | |
| | | Linear actuator | 1 | Buy | - | - | 8717,28 | |
| | | Motor | 1 | Buy | - | - | 530 | |
| | | | | Installations | 1 | 500 | 500 | |
| | | | | | | | | |
| | Hand wheel | New rail | 1 | Drawing | 1 | 500 | 500 | 12622,89 |
| | | | | Production | 2 | 350 | 700 | |
| | | | | Assembly | 1 | 500 | 500 | |
| | | | | Materials | - | - | 500 | |
| | | | | | | | | |
| | | Linear actuators | 1 | Buy | - | | 8717,28 | |
| | | Hand wheel | 1 | - | - | | 331,47 | |
| | | Position indicator | 1 | - | - | | 1374,14 | |

# SETUP OF GUIDE RAIL 7

### Automated guide rail

The guide rails can be repositioned to be placed upon linear actuators connected to an electrical engine. The engine is setup to communicate with the program loading the format for the product and automatically set the width of the rails at predetermined revolutions.

**Figure 32: A picture of guide rail 7 with motor.**

### Hand wheel

By installing a linear actuator that the guide rail is positioned on, which is driven by a hand wheel and has a position indicator the setup of the guide rail can be reduced. Calculations show that the rail can be controlled with only one actuator per rail.

**Figure 33: A picture of guide rail 7 with hand wheel.**

## Time

The overall improvement on the original time is very large and as can be expected the automated solution with the electric engine is the quickest solution. Furthermore that solution does not require any active actions from the operators.

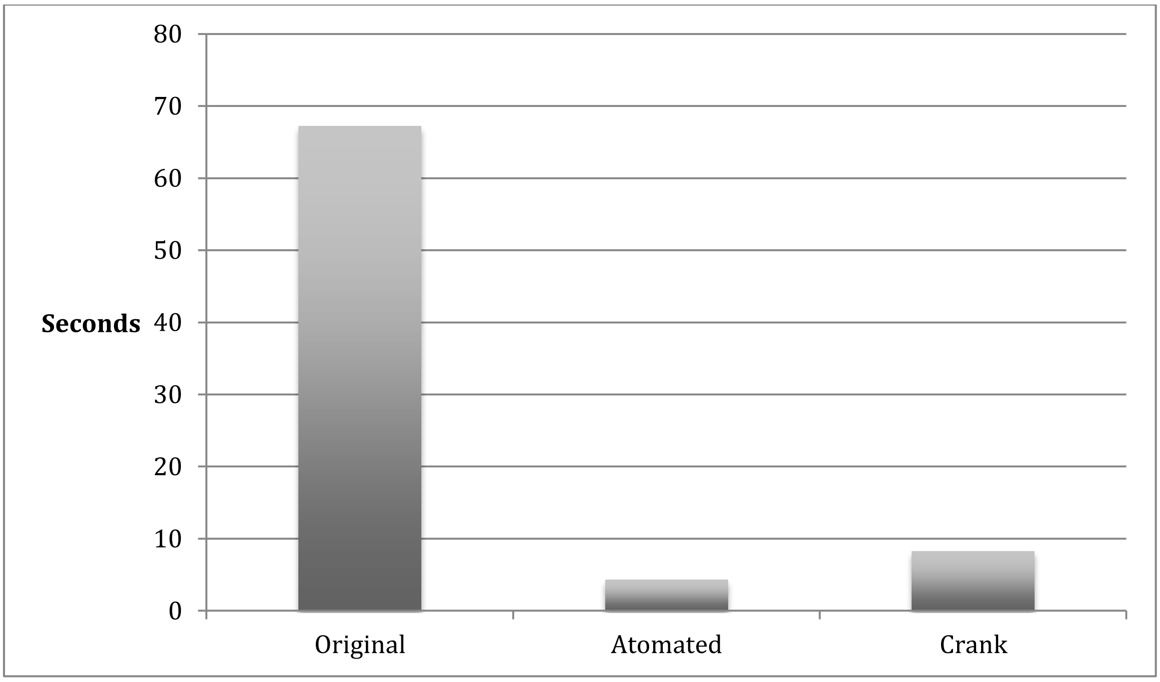



**Figure 34: A comparison of improvements for guide rail 7.**

## Calculated times

The largest difference in width is 31 mm. With a screw lead of 4 mm per revolution the needed revolutions are 8 full revolutions. The short distance moved and the precision required means that the acceleration and deceleration distances will be long in relation to the total travel length. If the average rpm is assumed to end up being equal to that of an operators this would mean 111 rpm. Then the time to change the rails becomes:

$$Time = \frac{revolutions}{rpm} * 60 = \frac{8}{111} * 60 = 4{,}32s$$

One single hand wheel controlling the entire length of the rail and the largest difference in width is 31 mm. With a screw lead of 4 mm per revolution the needed revolutions are 8 full revolutions. The time to bend down and turn the hand wheel then becomes with SAM:

$$B + GS80 + 9 * CA + RA = 46\, factors$$
$$46\, factors = 8{,}28s$$

## Investment

**Table 5: Cost for improving guide rail 7.**

| Activity | Improvement | Parts | No. | Activities | Hours | Cost/Hour (SEK) | Cost (SEK) | Total cost (SEK) |
|---|---|---|---|---|---|---|---|---|
| **Setup guide rail 7** | Motor driven | New rail | 1 | Drawing | 1 | 500 | 500 | 12447,28 |
| | | | | Production | 2 | 350 | 700 | |
| | | | | Assembly | 1 | 500 | 500 | |
| | | | | Materials | - | - | 1000 | |
| | | | | | | | | |
| | | Linear actuator | 1 | Buy | - | - | 8717,28 | |
| | | Motor | 1 | Buy | - | - | 530 | |
| | | | | Installations | 1 | 500 | 500 | |
| | | | | | | | | |
| | Hand wheel | New rail | 1 | Drawing | 1 | 500 | 500 | 13122,89 |
| | | | | Production | 2 | 350 | 700 | |
| | | | | Assembly | 1 | 500 | 500 | |
| | | | | Materials | - | - | 1000 | |
| | | | | | | | | |
| | | Linear actuators | 1 | Buy | - | | 8717,28 | |
| | | Hand wheel | 1 | - | - | | 331,47 | |
| | | Position indicator | 1 | - | - | | 1374,14 | |

# SETUP OF GUIDE RAIL IN THE ROBOT CELL

The space in the robot cell is limited and with a lot of equipment needing clear paths to perform the packaging special consideration must be taken to any alteration of the guide rails.

**Automated guide rails**

The solution with the most potential for reduced format change time is to equip the guide rails with linear actuators connected to electrical engines. The engines are setup to communicate with the program loading the format for the product and automatically set the width of the rails at predetermined revolutions.

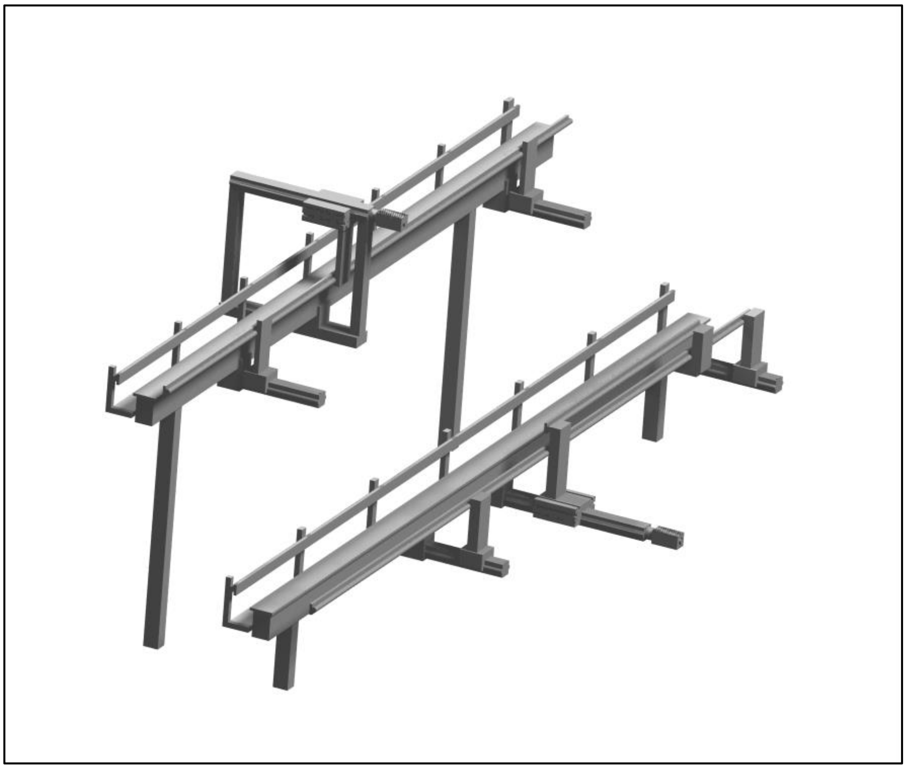


**Figure 35: A picture of guide rails in the robot cell with motors.**

To provide clearance between the lower track and the upper actuator the rail must be supported from above on the actuator position. Both the upper and lower rail is also supported at each end by linear roller guides. This is to ensure that friction between the rails and any supporting surface does not cause the rails to be out of position. Calculations show that the rails can be controlled with only one actuator per rail.

### Hand wheel

By installing linear actuators that the guide rails are positioned on, which are driven by a hand wheel and has a position indicator the setup of the guide rails could be reduced. Calculations show that the rails can be controlled with only one actuator per rail. To provide clearance between the lower track and the upper actuator the rail must be supported from above on the actuator position. Both the upper and lower rail is also supported at each end by linear roller guides. This is to ensure that friction between the rails and any supporting surface does not cause the rails to be out of position.

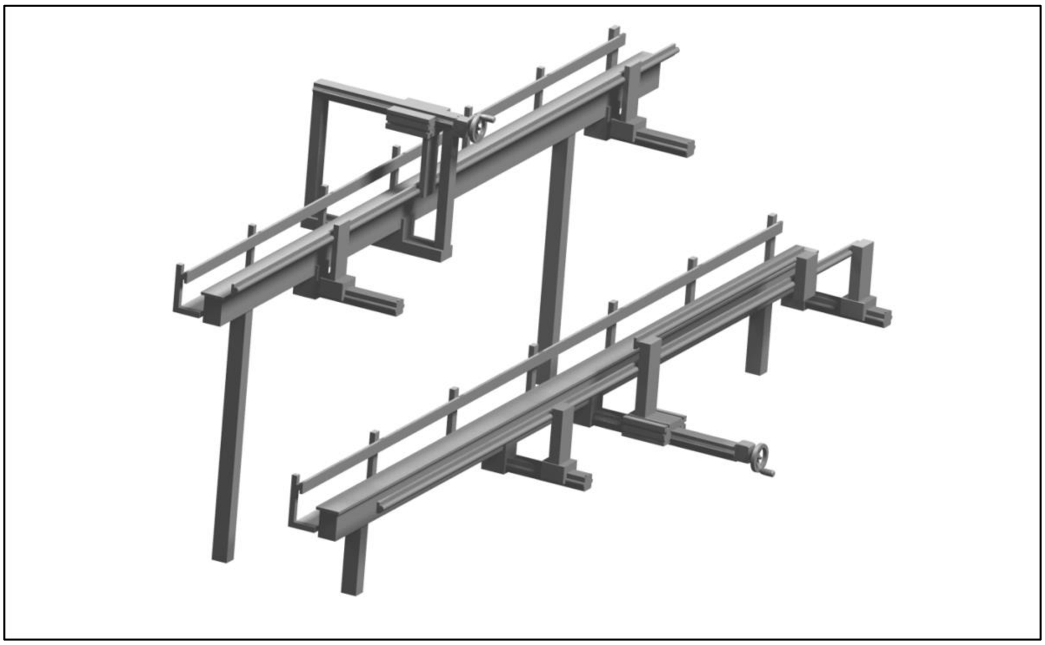


**Figure 36: A picture of guide rails in the robot cell with hand wheels.**

### Time

The elimination of using the gauging tools and quality checks gives a large improvement in the activity when using the actuator together with a hand wheel.

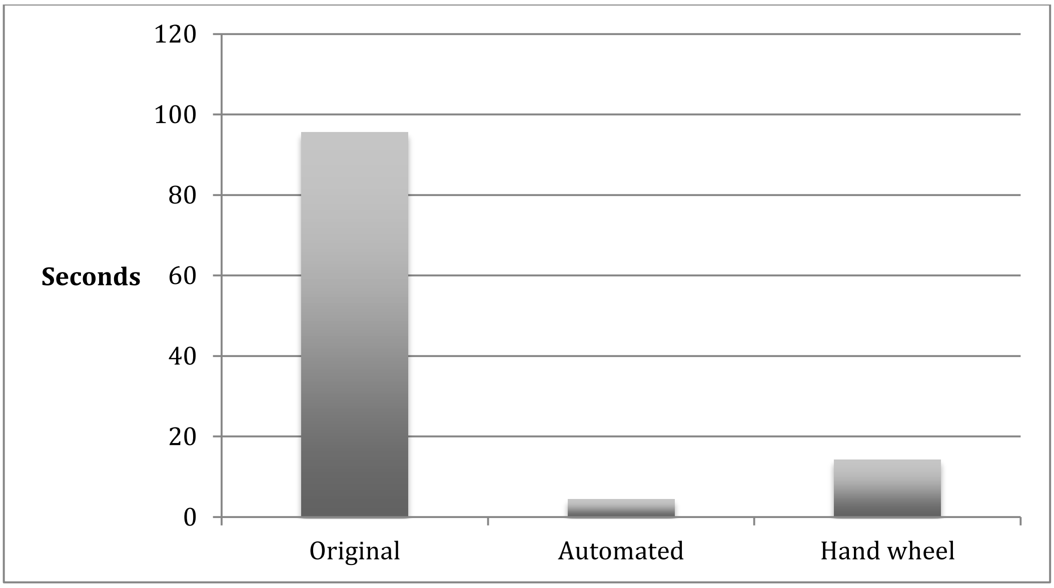



**Figure 37: A comparison of improvements to the guide rails in the robot cell.**

### Calculated times

The largest difference in width is 31 mm. With a screw lead of 4 mm per revolution the needed revolutions are 8 full revolutions. The short distance moved and the precision required means that the acceleration and deceleration distances will be long in relation to the total travel length. If the average rpm is assumed to end up being equal to that of an operators this would mean 111 rpm. Then the time to change the rails becomes:

$$Time = \frac{revolutions}{rpm} * 60 = \frac{8}{111} * 60 = 4{,}32s$$

With hand wheel controlling the entire length of the upper rail and one for the lower rail the time based on SAM are:

Upper rail:

$$GS45 + 9 * CA + RA = 33\ factors$$
$$33\ factors = 5{,}94s$$

Lower rail:

$$B + GS80 + 9 * CA + RA = 46\ factors$$
$$46\ factors = 8{,}28s$$

### Investment

**Table 6: Cost for improving guide rails in robot cell.**

| Activity | Improvement | Parts | No. | Activities | Hours | Cost/Hour (SEK) | Cost (SEK) | Total cost (SEK) |
|---|---|---|---|---|---|---|---|---|
| Setup Robotcell | Motor driven | New rail | 2 | Drawing | 1 | 500 | 1000 | 36517,6 |
| | | | | Production | 2 | 350 | 1400 | |
| | | | | Assembly | 1 | 500 | 1000 | |
| | | | | Materials | - | - | 2000 | |
| | | | | | | | | |
| | | Linear actuator | 2 | Buy | - | - | 17434,56 | |
| | | Glidesleigh | 4 | Buy | - | - | 11623,04 | |
| | | Motor | 2 | Buy | - | - | 1060 | |
| | | | | Installations | 2 | 500 | 1000 | |
| | | | | | | | | |
| | Hand wheel | New rail | 2 | Drawing | 4 | 500 | 2000 | 38018,82 |
| | | | | Production | 3 | 350 | 1050 | |
| | | | | Assembly | 3 | 500 | 1500 | |
| | | | | Materials | - | - | 1000 | |
| | | | | | | | | |
| | | Linear actuators | 2 | Buy | - | | 17434,56 | |
| | | Glidesleigh | 4 | Buy | - | - | 11623,04 | |
| | | Hand wheel | 2 | - | - | | 662,94 | |
| | | Position indicator | 2 | - | - | | 2748,28 | |

# SETUP OF ROBOT CELL IN WAREHOUSE

### Automatic setup

By mounting the rail on a linear actuator that is driven by a electrical engine the guide rail can be changed between its two positions. The engine communicates with the main program loading the format to know which of the two positions it should be on. The rails in the warehouse are all connected to each other. To enable automatic setup the rail has to be separate from the rest of the rail on the line. This is simply done by splitting the rail and supporting the end that is not motor driven with a bearing allowing the far end of the rail to be angled outwards for larger packages. To compensate for the longer distance of the rail when it is angled the rails will be built up out of two separate rails that slide into each other.

### Wheel handle

The guide rails can be mounted on linear actuators which are connected to a hand wheel that are turned by the operator to angle out the far end of the rail. The actuator is also hindered to go any further than the two designated positions, eliminating any need for a position indicator. The rails in the warehouse are all connected to each other. To enable an angle adjustment the rail has to be separate from the rest of the rail on the line. This is simply done by splitting the rail and supporting the end that is not motor driven with a bearing allowing the far end of the rail to be angled outwards for larger packages. To compensate for the longer distance of the rail when it is angled the rails will be built up out of two separate rails that slide into each other. To allow access to the wheel for the operator a couple of actuators will be lead below the picking table for the robot and come out where the operator is doing the rest of the setup in the cell.

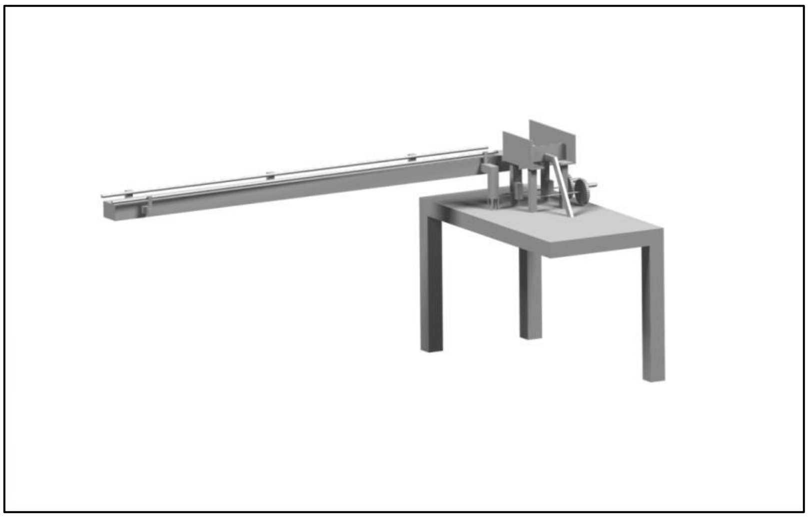


**Figure 38: A picture of guide rail in the warehouse with hand wheel.**

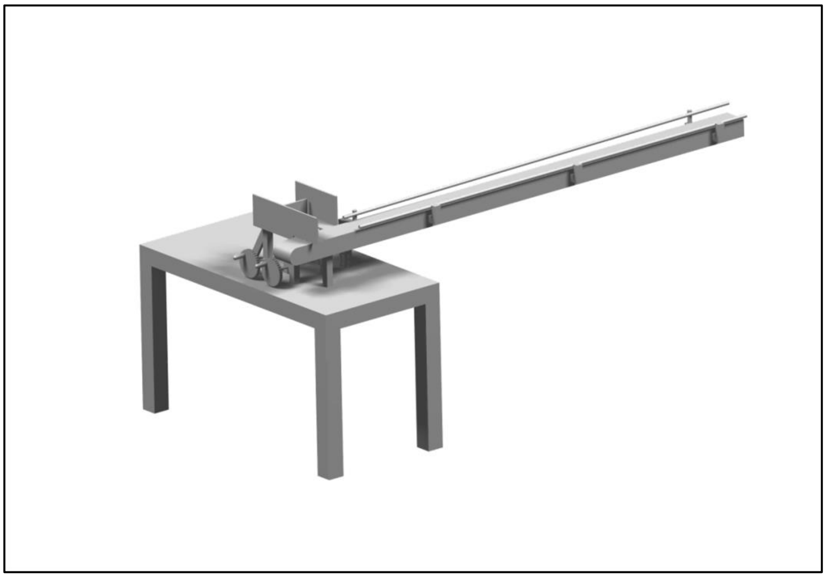


**Figure 39: A picture of guide rail in the warehouse with hand wheel.**

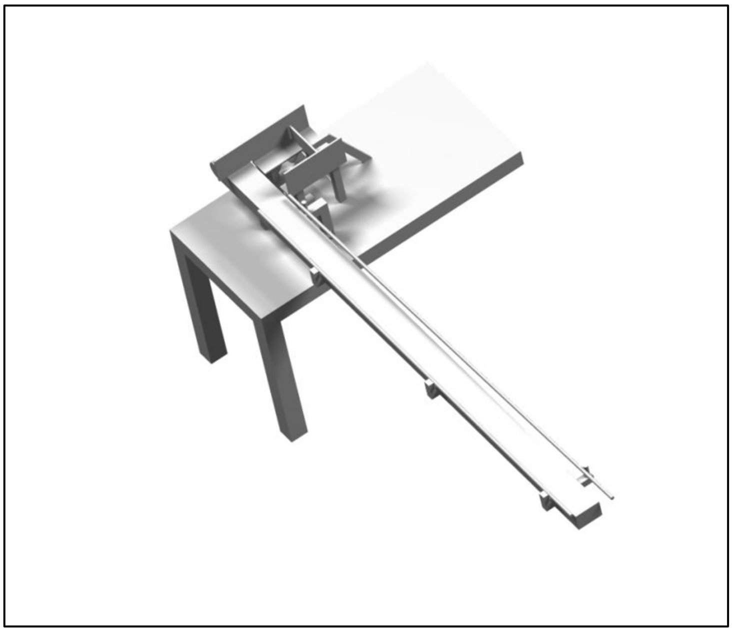


**Figure 40: A picture of guide rail in the warehouse with hand wheel.**

**Time**

The spring driven alignment will completely remove the activity but the other improvements are also very large in comparison to the original time.

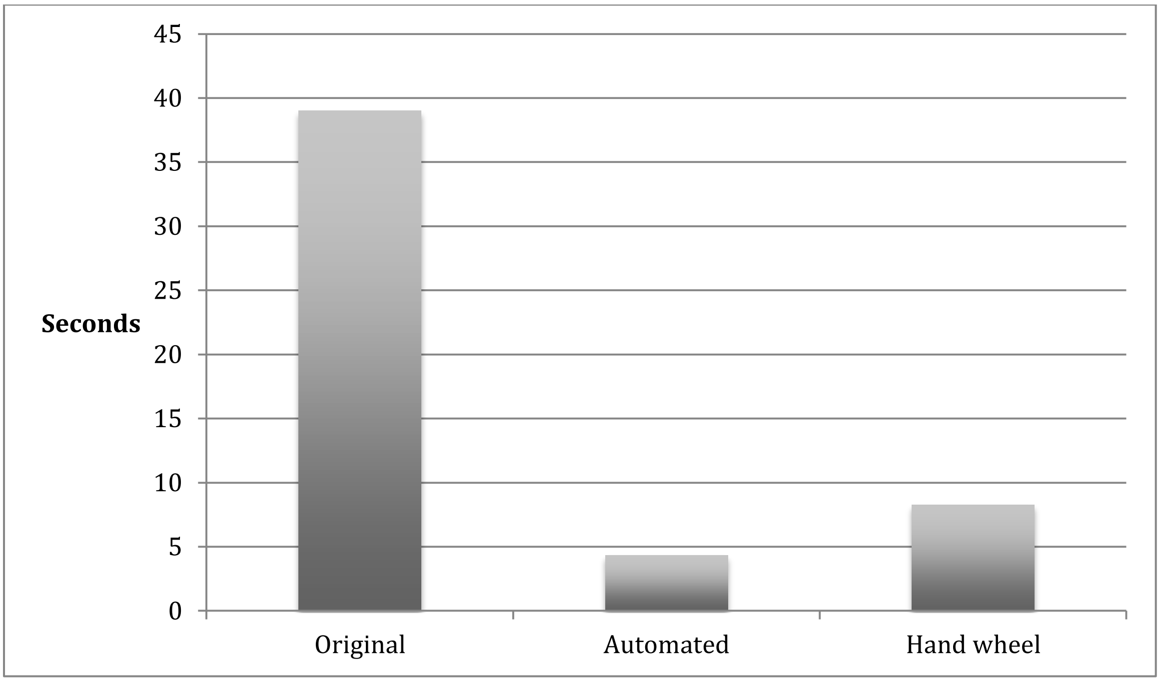



**Figure 41: A comparison of improvements to the guide rail in the warehouse.**

**Calculated times**

The largest difference in width is 31 mm. With a screw lead of 4 mm per revolution the needed revolutions are 8 full revolutions. The short distance moved and the precision required means that the acceleration and deceleration distances will be long in relation to the total travel length. If the average rpm is assumed to end up being equal to that of an operators this would mean 111 rpm. Then the time to change the rails becomes:

$$Time = \frac{revolutions}{rpm} * 60 = \frac{8}{111} * 60 = 4{,}32s$$

One single hand wheel controlling the entire length of the rail and the largest difference in width is 31 mm. With a screw lead of 4 mm per revolution the needed revolutions are 8 full revolutions. The time acquired by SAM analysis becomes:

$$B + GS80 + 9 * CA + RA = 46\,factors$$
$$46\,factors = 8{,}28s$$

## Investment

**Table 7: Cost for improving the guide rail in the warehouse.**

| Activity | Improvement | Parts | No. | Activities | Hours | Cost/Hour (SEK) | Cost (SEK) | Total cost (SEK) |
|---|---|---|---|---|---|---|---|---|
| **Setup Robotcell Warehouse** | Motor driven | New rail | 1 | Drawing | 1 | 500 | 500 | 19485,24 |
| | | | | Production | 2 | 350 | 700 | |
| | | | | Assembly | 1 | 500 | 500 | |
| | | | | Materials | - | - | 1000 | |
| | | | | | | | | |
| | | Linear actuator | 1 | Buy | - | - | 8717,28 | |
| | | Extension | 1 | Buy | - | - | 6537,96 | |
| | | Motor | 1 | Buy | - | - | 530 | |
| | | | | Installations | 2 | 500 | 1000 | |
| | | | | | | | | |
| | Hand wheel | New rail | 1 | Drawing | 4 | 500 | 2000 | 22510,85 |
| | | | | Production | 3 | 350 | 1050 | |
| | | | | Assembly | 3 | 500 | 1500 | |
| | | | | Materials | - | - | 1000 | |
| | | | | | | | | |
| | | Linear actuators | 1 | Buy | - | | 8717,28 | |
| | | Extension | 1 | Buy | - | - | 6537,96 | |
| | | Hand wheel | 1 | - | - | | 331,47 | |
| | | Position indicator | 1 | - | - | | 1374,14 | |
| | | | | | | | | |
| | Spring driven | New rail | 1 | Drawing | 5 | 500 | 2500 | 7900 |
| | | | | Production | 4 | 350 | 1400 | |
| | | | | Assembly | 4 | 500 | 2000 | |
| | | | | Materials | - | - | 2000 | |

# APPENDIX 9

Standardised work sheets for the setup procedures with organisational and method improvements.

## Format change:

## Administrator

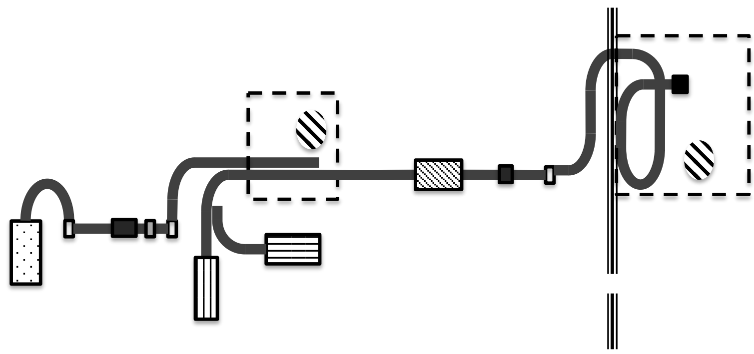
Standardised;work;sheet;Œormatomställning;(organisation+metod)

Linje: Våta — Datum 10/5/14

Titel: Orderhanterare — Issued;by: Josefsson&Ödebrink

Tid(s) 530.9

| # | Operation | Work | Walk |
|---|---|---|---|
| 1 | Förbered;nytt;orderblad;(Start;102s;innan) | 18.8 | 0 |
| 2 | Signera;orderstart | 14.2 | 0 |
| 3 | Ta;fram;etiketter,;adm.;dator | 69.2 | 6.4 |
| 4 | Logga;in;på;depalleterare | 14.2 | 0 |
| 5 | Nytt;recept;depalleterare | 27.9 | 6.4 |
| 6 | Logga;in;på;huvudpanel | 17 | 0 |
| 7 | Avsluta;order;huvudpanel | 7.1 | 14.3 |
| 8 | Ladda;depalleterare | 20.9 | 14.3 |
| 9 | Avsluta;order,;dokument | 75.2 | 0 |
| 10 | Mata;in;orderdata | 3 | 4.9 |
| 11 | Skriv;ut;avd.;etikett | 9.5 | 0 |
| 12 | Skriv;ut;topp.;Etikett | 9.5 | 2.3 |
| 13 | Klistra;avd.;&;topp.;Etikett;på;orderblad | 12 | 17.4 |
| 14 | Skriv;ut;trp.;Etikett | 16 | 17.4 |
| 15 | Klistra;transp.etikett | 9.4 | 0 |
| 16 | Läsa;av;etiketter;mot;medarbetare* | 27.5 | 0 |
| 17 | Kontrollera;och;kvittera;etiketter | 40.2 | 0 |
| 18 | Kvittera;formatomst.;Räcken | 21 | 0 |
| 19 | Kvittera;formatomst.;Bipack | 16.2 | 0 |
| 20 | Stäng;av/på;bipack | 10 | 0 |
| 21 | Kvittera;formatomst.;&;etiketter | 8.7 | 0 |
| 22 | Starta;line | 1.3 | |
| | total | 448 | 83.4 |



* Behov;av;hjälp;från;kollega.

**Figure 42: Standardised work sheet for the Administrator during setup.**

## Main server

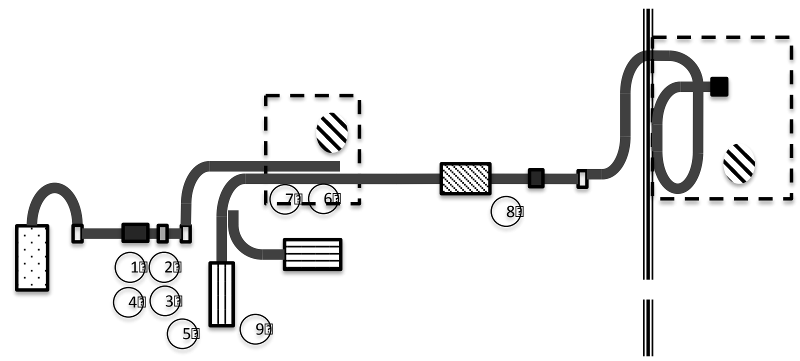
Standardised work sheet - Formatomställning (organisation+metod)

Linje: Våta — Datum 10/5/14

Titel: Huvudservare — Issued by: Josefsson&Ödebrink

Tid(s): 866.1

| # | Operation | Work | Walk |
|---|---|---|---|
| 1 | Gå till Bipack matare 1 | 18.5 | |
| 2 | Töm bipackmatare | 77 | |
| 3 | Jämför PIL mot order | 15 | |
| 4 | Fyll bipackmatare | 143 | |
| 5 | Flytta den blåa lådan (QA) | 9.6 | 18.6 |
| 6 | Byt formverktyg | 59.4 | |
| 7 | Ställ räcke buren | 14.4 | 9 |
| 8 | Ställ räcke 6 & 7 | 16.8 | |
| 9 | Ställ kartongresare 1 | 485 | |
| 10 | | | |
| 11 | | | |
| 12 | | | |
| 13 | | | |
| 14 | | | |
| 15 | | | |
| 16 | | | |
| 17 | | | |
| 18 | | | |
| 19 | | | |
| 20 | | | |
| 21 | | | |
| | total | 839 | 27.6 |



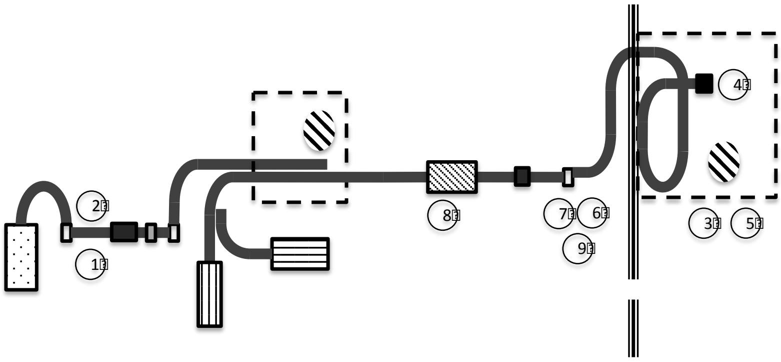

* Behov av hjälp från kollega.

**Figure 43: Standardised work sheet for the Main server during setup.**

## Inspector

| Standardised work sheet – Formatomställning (organisation+metod) | | | | |
|---|---|---|---|---|
| Linje: | Våta | | Datum | 10/5/14 |
| Titel: | Avsynare | | Issued by: | Josefsson&Ödebrink |
| Tid(s): | 451.4 | | | |

| # | Operation | Work | Walk |
|---|---|---|---|
| 1 | Avslutande dokumentering | 29.6 | 28.8 |
| 2 | Ställ täcke 1-4 & Data matrix | 115 | 34.2 |
| 3 | Begär & invänta tillträde robotcell (lager) | 7.2 | |
| 4 | Ställ robotcell (lager) | 31.2 | 10.2 |
| 5 | Kvittera formatomställ robotcell | 15 | 21 |
| 6 | Granska mått trp. Panel | 9.6 | |
| 7 | Ställ aktivsorteringsbox | 21 | 3 |
| 8 | Ställ kartongförslutare | 40.8 | |
| 9 | Kvittera formatomställ. Kartongförslutare | 12 | |
| 10 | Kvittera omställn för aktivsortering?????? | 12 | |
| 11 | Kvitera format buren | 60.6 | |
| 12 | | | |
| 13 | | | |
| 14 | | | |
| 15 | | | |
| 16 | | | |
| 17 | | | |
| 18 | | | |
| 19 | | | |
| 20 | | | |
| 21 | | | |
| | total | 354 | 97.2 |




* Behov av hjälp från kollega.

**Figure 44: Standardised work sheet for the Inspector during setup.**

## Material planer

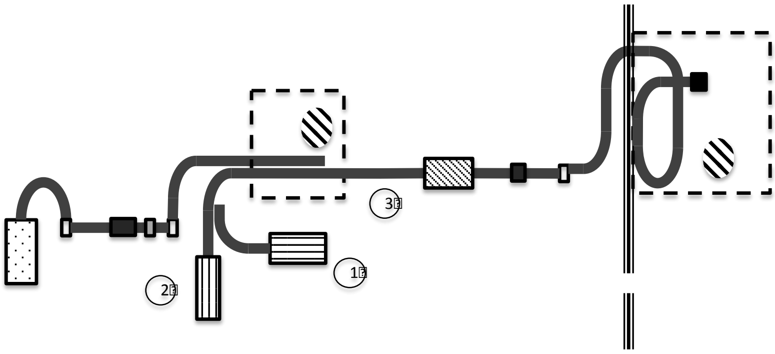
Standardised work sheet - Formatomställning (organisation+metod)

Linje: Våta — Datum 10/5/14

Titel: Materialplanerare — Issued by: Josefsson&Ödebrink

Tid(s): 541.7 — Total tid:

| # | Operation | Work | Walk |
|---|---|---|---|
| 1 | Ställ kartongresare 2 (Start 468s innan) | 469 | |
| 2 | Läs av etikett mot medarbetare* | 28 | 20 |
| 3 | Töm och stäng av rp bipack matare | 25 | |
| 4 | | | |
| 5 | | | |
| 6 | | | |
| 7 | | | |
| 8 | | | |
| 9 | | | |
| 10 | | | |
| 11 | | | |
| 12 | | | |
| 13 | | | |
| 14 | | | |
| 15 | | | |
| 16 | | | |
| 17 | | | |
| 18 | | | |
| 19 | | | |
| 20 | | | |
| 21 | | | |
| | total | 522 | 20 |




* Behov av hjälp från kollega.

**Figure 45: Standardised work sheet for the Material planer during setup.**

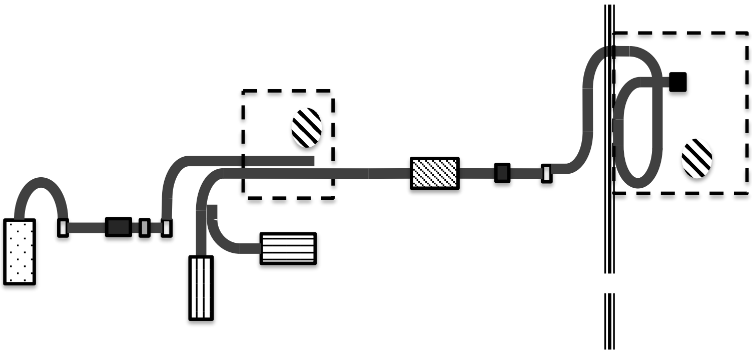
## Order change:

## Administrator

Standardised;work;sheet;Q̧Orderbyte;(organisation+metod)

| Linje: Våta | Datum 10/5/14 |
|---|---|
| Titel: Orderhanterare | Issued;by: Josefsson&Ödebrink |
| Tid(s) 348.8 | |

| # | Operation | Work | Walk |
|---|---|---|---|
| 1 | Förbered;nytt;orderblad;(start;120s;innan) | 18.6 | 0 |
| 2 | Signera;orderstart | 14.4 | 0 |
| 3 | Ta;fram;etiketter,;adm.;dator | 69 | 0 |
| 4 | Logga;in;på;huvudpanel | 17 | 0 |
| 5 | Avsluta;order;huvudpanel | 7.2 | 0 |
| 6 | Avsluta;order,;dokument | 75 | 0 |
| 7 | Mata;in;orderdata | 3 | 4.8 |
| 8 | Skriv;ut;avd.;etikett | 9.6 | 0 |
| 9 | Skriv;ut;topp.;etikett | 9.6 | 0 |
| 10 | Klistra;avd.;&;topp.;Etikett;på;orderblad | 12 | 0 |
| 11 | Klistra;transp.etikett* | 9.6 | 0 |
| 12 | Läsa;av;etiketter;mot;medarbetare* | 27.6 | 0 |
| 13 | Kontrollera;och;kvittera;etiketter | 40.2 | 0 |
| 14 | Kvittera;bipacksedelmatare | 16.2 | 0 |
| 15 | Stänga;av/på;bipacksedelmatare | 10.2 | 0 |
| 16 | Kvittera;ny;orderdata;(omställning) | 8.4 | 0 |
| 17 | Starta;line | 1.2 | 0 |
| 18 | | | 0 |
| 19 | | | 0 |
| 20 | | | 0 |
| 21 | | | 0 |
| 22 | Starta;line | | |
| | total | 349 | 4.8 |



* Behov;av;hjälp;från;kollega.

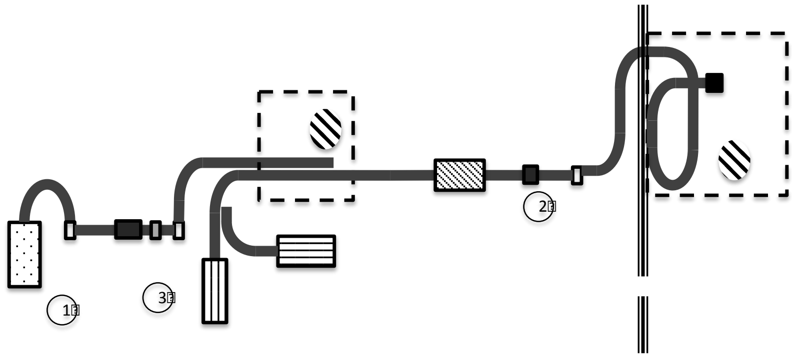
**Figure 46: Standardised work sheet for the Administrator during order change.**

## Main server

Standardised work sheet - orderbyte (organisation+metod)

Linje: Våta — Datum 10/5/14
Titel: Huvudservare — Issued by: Josefsson&Ödebrink
Tid(s): 64.2

| # | Operation | Work | Walk |
|---|---|---|---|
| 1 | Ladda depaliterare | 21 | 32 |
| 2 | Skriv ut frp. Etikett | 15.6 | 17.4 |
| 3 | Läs av etikett mot medarbetare | 27.6 | |
| 4 | | | |
| 5 | | | |
| 6 | | | |
| 7 | | | |
| 8 | | | |
| 9 | | | |
| 10 | | | |
| 11 | | | |
| 12 | | | |
| 13 | | | |
| 14 | | | |
| 15 | | | |
| 16 | | | |
| 17 | | | |
| 18 | | | |
| 19 | | | |
| 20 | | | |
| 21 | | | |
| | total | 64.2 | 49.4 |




* Behov av hjälp från kollega.

**Figure 47: Standardised work sheet for the Main server during order change.**

## Inspector

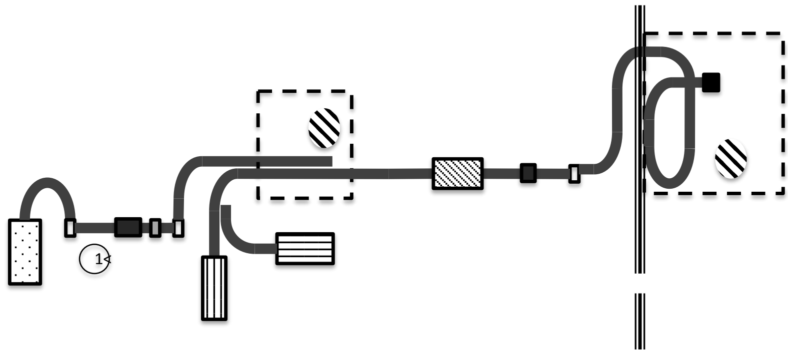
Standardised work sheet – Orderbyte (organisation+metod)

Linje: Våta — Datum 10/5/14

Titel: Avsynare — Issued by: Josefsson&Ödebrink

Tid(s): 29.6

| # | Operation | Work | Walk |
|---|---|---|---|
| 1 | Avslutande dokumentering | 29.6 | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| 6 | | | |
| 7 | | | |
| 8 | | | |
| 9 | | | |
| 10 | | | |
| 11 | | | |
| 12 | | | |
| 13 | | | |
| 14 | | | |
| 15 | | | |
| 16 | | | |
| 17 | | | |
| 18 | | | |
| 19 | | | |
| 20 | | | |
| 21 | | | |
| | total | 29.6 | 0 |




* Behov av hjälp från kollega.

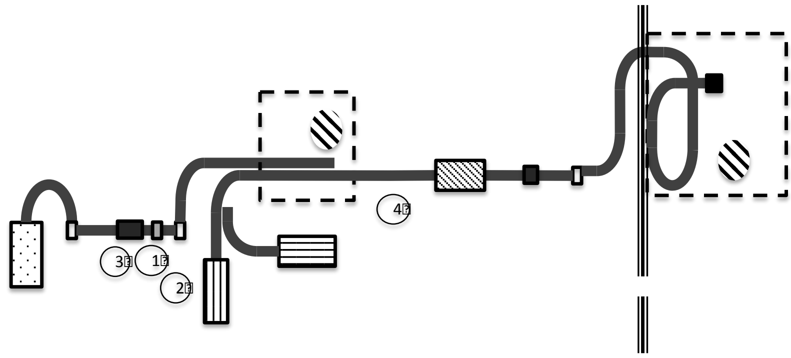
**Figure 48: Standardised work sheet for the Inspector during order change.**

## Material planer

**Standardised work sheet – Orderbyte (Organisation+metod)**

| | | | |
|---|---|---|---|
| Linje: Våta | | Datum | 10/5/14 |
| Titel: Materialplanerare | | Issued by: | Josefsson&Ödebrink |
| Tid(s): 259.8 | | Total tid: | |

| # | Operation | Work | Walk |
|---|---|---|---|
| 1 | Töm bipackmatare | 76.8 | |
| 2 | Jämför PIL med order | 15 | 20 |
| 3 | Fyll bipackmatare | 143 | 19.8 |
| 4 | Töm och stäng av trp. Bipack | 24.6 | |
| 5 | | | |
| 6 | | | |
| 7 | | | |
| 8 | | | |
| 9 | | | |
| 10 | | | |
| 11 | | | |
| 12 | | | |
| 13 | | | |
| 14 | | | |
| 15 | | | |
| 16 | | | |
| 17 | | | |
| 18 | | | |
| 19 | | | |
| 20 | | | |
| 21 | | | |
| | total | 260 | 39.8 |




* Behov av hjälp från kollega.

**Figure 49: Standardised work sheet for the Material planer during order change.**

# APPENDIX 10

Standardised work combination table for setup and order change with organisational improvements and methods improvements, with the hand wheel solution.

**Format change**

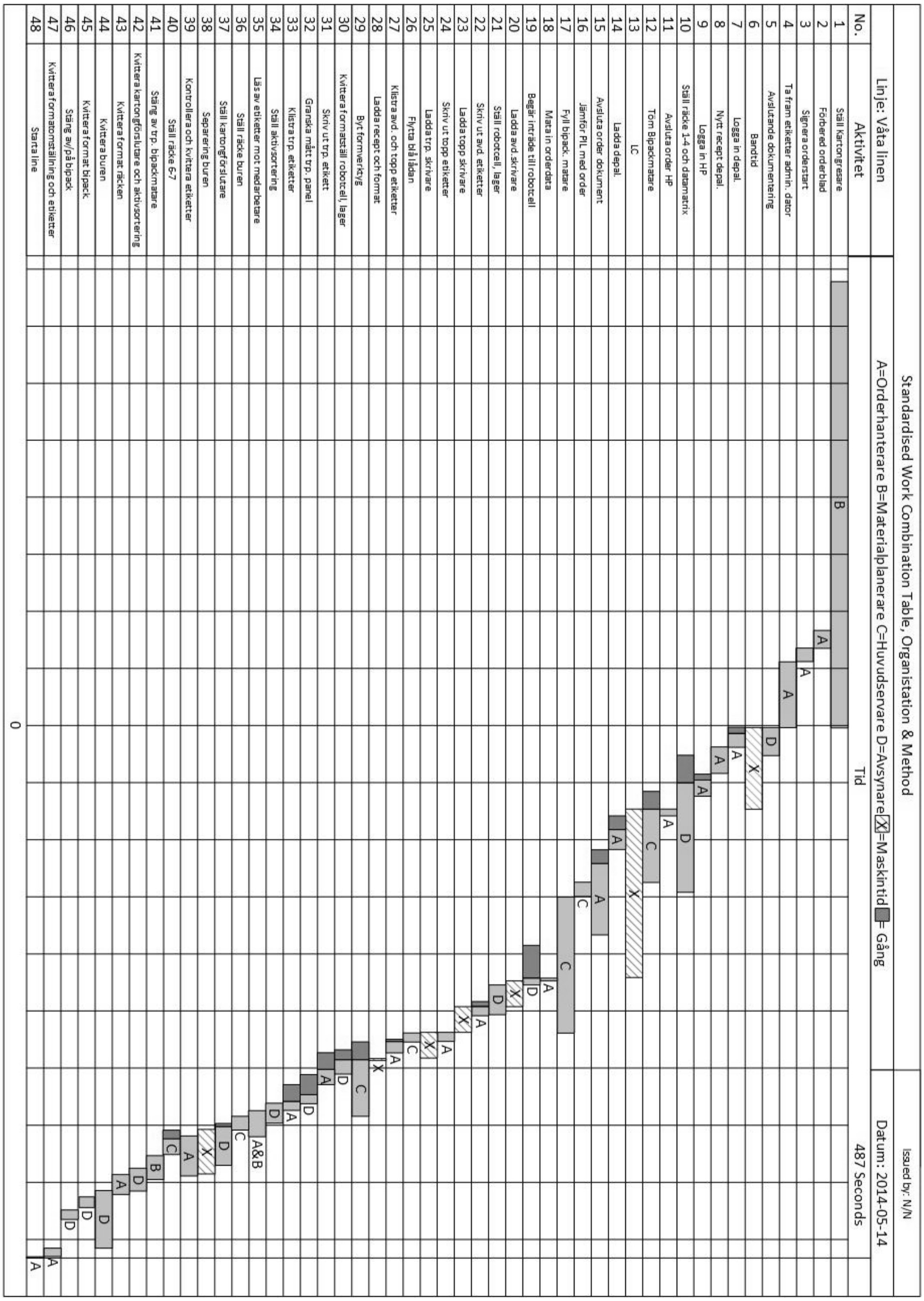



**Figure 50: Standardised Work Combination Table for the format change with organisational and method improvements.**

## Order change

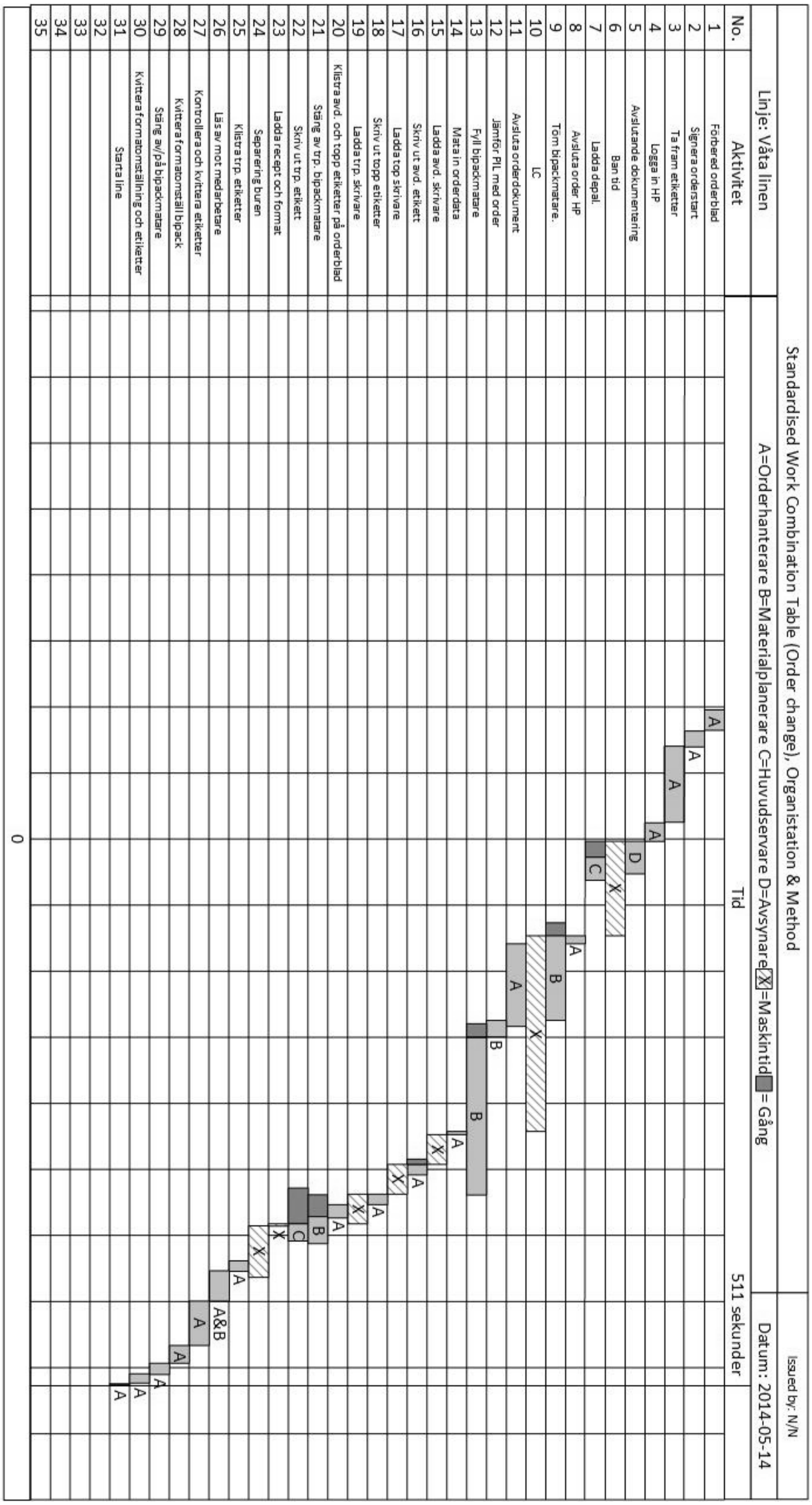



**Figure 51: Standardised Work Combination Table for the order change with organisational and method improvements.**

# APPENDIX 11

Standardised work sheets for the setup procedures with organisational, method and technical improvements.

## Format change

## Administrator

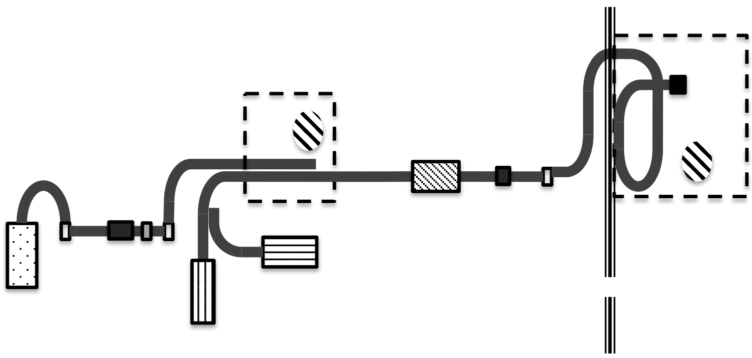
Standardised;work;sheet;];Formatomställning;(organisation+metod+Line;Clearance)

Linje: Våta — Datum 10/5/14

Titel: Orderhanterare — Issued;by: Josefsson&Ödebrink

Tid(s) 528.5

| # | Operation | Work | Walk |
|---|---|---|---|
| 1 | Förbered;nytt;orderblad;(starta;100s;innan) | 18.8 | 0 |
| 2 | Signera;orderstart | 14.2 | 0 |
| 3 | Ta;fram;etiketter,;adm.;dator | 69.2 | 6.4 |
| 4 | Logga;in;på;depalleterare | 14.2 | 0 |
| 5 | Nytt;recept;depalleterare | 27.9 | 6.4 |
| 6 | Logga;in;på;huvudpanel | 17 | 0 |
| 7 | Avsluta;order;huvudpanel | 7.1 | 14.3 |
| 8 | Ladda;depalleterare | 20.9 | 14.3 |
| 9 | Avsluta;order,;dokument | 75.2 | 0 |
| 10 | Mata;in;orderdata | 3 | 17.4 |
| 11 | Skriv;ut;trp.;Etikett | 15.6 | 17.4 |
| 12 | Klistra;trp.;Etikett | 9.6 | 4.8 |
| 13 | Skriv;ut;avd.;etikett | 9.6 | 0 |
| 14 | Skriv;ut;topp.;Etikett | 9.6 | 0 |
| 15 | Klistra;top;&;avd.;etiketter | 12 | 0 |
| 16 | Läsa;av;etiketter;mot;medarbetare* | 27.5 | 0 |
| 17 | Kontrollera;och;kvittera;etiketter | 40.2 | 0 |
| 18 | Kvittera;formatomst.;Räcken | 21 | 0 |
| 19 | Kvittera;formatomst.;Bipack | 16.2 | 0 |
| 20 | Stäng;av/på;bipack | 10 | 0 |
| 21 | Kvittera;formatomst.;&;etiketter | 8.7 | 0 |
| 22 | Starta;line | 1.3 | |
| | total | 448 | 81 |



* Behov;av;hjälp;från;kollega.

**Figure 52: Standardised work sheet for Administrator during setup.**

## Main server

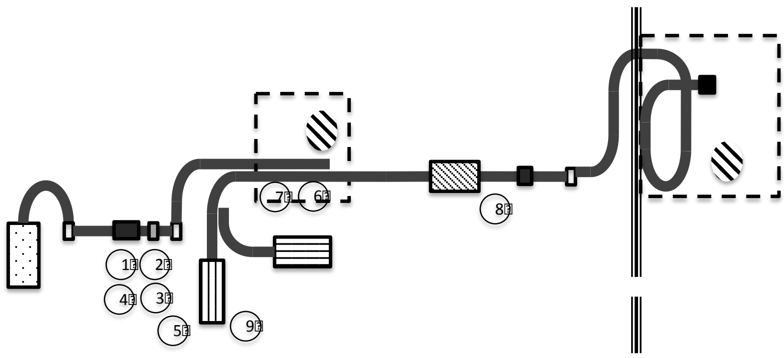
**Standardised work sheet – Formatomställning (organisation+metod+Line Clearance)**

Linje: Våta — Datum 10/5/14

Titel: Huvudservare — Issued by: Josefsson&Ödebrink

Tid(s): 866.2

| # | Operation | Work | Walk |
|---|---|---|---|
| 1 | Gå till Bipack matare 1 | 18.6 | |
| 2 | Töm bipackmatare | 77 | |
| 3 | Jämför PIL mot order | 15 | |
| 4 | Fyll bipackmatare | 143 | |
| 5 | Flytta den blåa lådan (QA) | 9.6 | 18.6 |
| 6 | Byt formverktyg | 59.4 | |
| 7 | Ställ räcke buren | 14.4 | 9 |
| 8 | Ställ räcke 6 & 7 | 16.8 | |
| 9 | Ställ kartongresare 1 | 485 | |
| 10 | | | |
| 11 | | | |
| 12 | | | |
| 13 | | | |
| 14 | | | |
| 15 | | | |
| 16 | | | |
| 17 | | | |
| 18 | | | |
| 19 | | | |
| 20 | | | |
| 21 | | | |
| | total | 839 | 27.6 |




* Behov av hjälp från kollega.

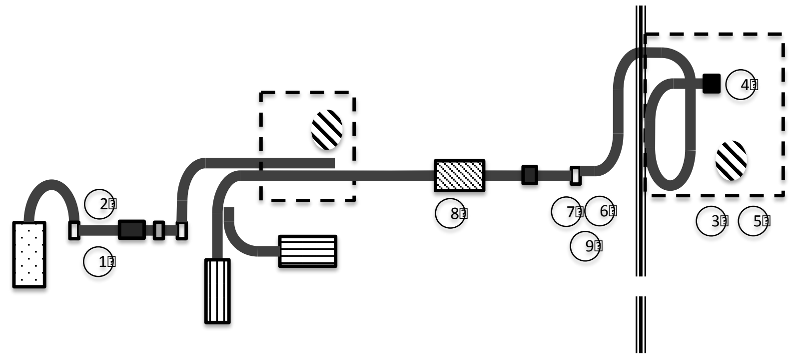
**Figure 53: Standardised work sheet for Main server during setup.**

## Inspector

Standardised work sheet - Formatomställning (organisation+metod+Line Clearance)

Linje: Våta | Datum 10/5/14
Titel: Avsynare | Issued by: Josefsson&Ödebrink
Tid(s): 454.4

| # | Operation | Work | Walk |
|---|---|---|---|
| 1 | Avslutande dokumentering | 29.6 | 28.8 |
| 2 | Ställ räcke 1-4 & Data matrix | 115 | 34.2 |
| 3 | Begär & invänta tillträde robotcell (lager) | 7.2 | |
| 4 | Ställ robotcell (lager) | 31.2 | 10.2 |
| 5 | Kvittera formatomställ robotcell | 15 | 21 |
| 6 | Granska mått trp. Panel | 9.6 | |
| 7 | Ställ aktivsorteringsbox | 21 | 3 |
| 8 | Ställ kartongförslutare | 40.8 | |
| 9 | Kvittera formatomställ. Kartongförslutare | 12 | 3 |
| 10 | Kvittera omställn för aktivsortering?????? | 12 | |
| 11 | Kvitera format buren | 60.6 | |
| 12 | | | |
| 13 | | | |
| 14 | | | |
| 15 | | | |
| 16 | | | |
| 17 | | | |
| 18 | | | |
| 19 | | | |
| 20 | | | |
| 21 | | | |
| | total | 354 | 100 |




* Behov av hjälp från kollega.

**Figure 54: Standardised work sheet for Inspector during setup.**

## Material planer

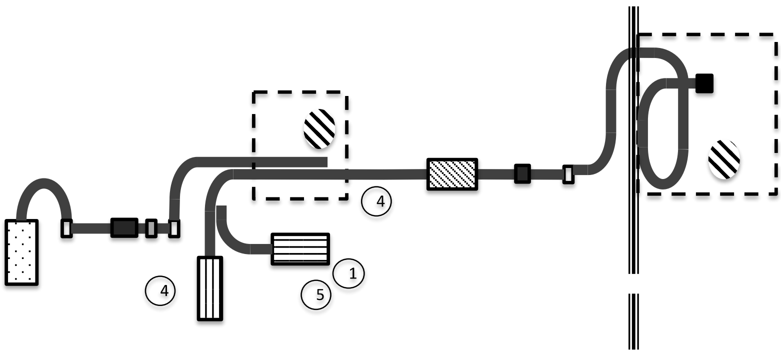
Standardised work sheet - Formatomställning (organisation+metod+Line Clearance)

Linje: Våta — Datum 10/5/14

Titel: Materialplanerare — Issued by: Josefsson&Ödebrink

Tid(s): 560.6 — Total tid:

| # | Operation | Work | Walk |
|---|---|---|---|
| 1 | Kör kartong från kartongresare 2 | 22.2 | |
| 2 | Kör kartong till kartongresare 2 | 22.2 | 20 |
| 3 | Ställ kartongresare 2 | 357 | |
| 4 | Läs av etikett mot medarbetare | 27.6 | |
| 5 | Inkörning av kartongresare | 67.2 | 19.8 |
| 6 | Töm och stäng av trp.bipack | 24.6 | |
| 7 | | | |
| 8 | | | |
| 9 | | | |
| 10 | | | |
| 11 | | | |
| 12 | | | |
| 13 | | | |
| 14 | | | |
| 15 | | | |
| 16 | | | |
| 17 | | | |
| 18 | | | |
| 19 | | | |
| 20 | | | |
| 21 | | | |
| | total | 521 | 39.8 |




* Behov av hjälp från kollega.

**Figure 55: Standardised work sheet for Material planer during setup.**

## Order change:

## Administrator

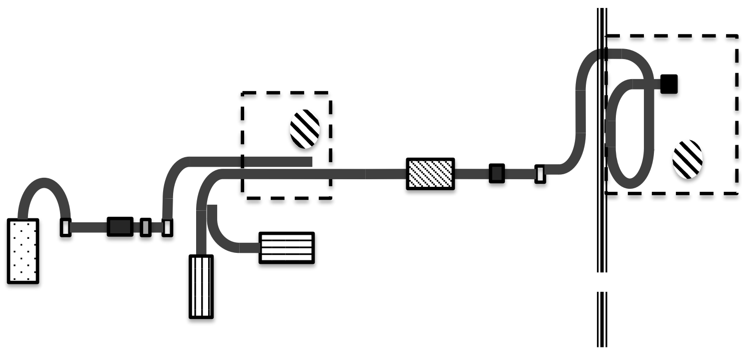
Standardised work sheet  Orderbyte (organisation+metod+Line Clearance)

Linje: Våta — Datum 10/5/14

Titel: Orderhanterare — Issued by: Josefsson&Ödebrink

Tid(s) 348.8

| # | Operation | Work | Walk |
|---|---|---|---|
| 1 | Förbered nytt orderblad (start 120s innan) | 18.6 | 0 |
| 2 | Signera orderstart | 14.4 | 0 |
| 3 | Ta fram etiketter, adm. dator | 69 | 0 |
| 4 | Logga in på huvudpanel | 17 | 0 |
| 5 | Avsluta order, dokument | 75 | 0 |
| 6 | Avsluta order, huvudpanel | 7.2 | 0 |
| 7 | Mata in orderdata | 3 | 4.8 |
| 8 | Skriv ut avd. etikett | 9.6 | 0 |
| 9 | Skriv ut topp. etikett | 9.6 | 0 |
| 10 | Klistra avd. & topp. Etikett på orderblad | 12 | 0 |
| 11 | Klistra transp.etikett* | 9.6 | 0 |
| 12 | Läsa av etiketter mot medarbetare* | 27.6 | 0 |
| 13 | Kontrollera och kvittera etiketter | 40.2 | 0 |
| 14 | Kvittera bipacksedelmatare | 16.2 | 0 |
| 15 | Stänga av/på bipacksedelmatare | 10.2 | 0 |
| 16 | Kvittera ny orderdata (onställning) | 8.4 | 0 |
| 17 | Starta line | 1.2 | 0 |
| 18 | | | 0 |
| 19 | | | 0 |
| 20 | | | 0 |
| 21 | | | 0 |
| 22 | Starta line | | |
| | total | 349 | 4.8 |



* Behov av hjälp från kollega.

**Figure 56: Standardised work sheet for Administrator during order change.**

## Main server

| | | | |
|---|---|---|---|
| Standardised work sheet - orderbyte (organisation+metod+Line Clearance) | | | |
| Linje: Våta | | | Datum 10/5/14 |
| Titel: Huvudservare | | | Issued by: Josefsson&Ödebrink |
| Tid(s): 64.2 | | | |
| # | Operation | Work | Walk |
| 1 | Ladda depaliterare | 21 | 32 |
| 2 | Skriv ut trp. Etikett | 15.6 | 17.4 |
| 3 | Läs av etikett mot medarbetare | 27.6 | |
| 4 | | | |
| 5 | | | |
| 6 | | | |
| 7 | | | |
| 8 | | | |
| 9 | | | |
| 10 | | | |
| 11 | | | |
| 12 | | | |
| 13 | | | |
| 14 | | | |
| 15 | | | |
| 16 | | | |
| 17 | | | |
| 18 | | | |
| 19 | | | |
| 20 | | | |
| 21 | | | |
| | total | 64.2 | 49.4 |
| * | Behov av hjälp från kollega. | | |

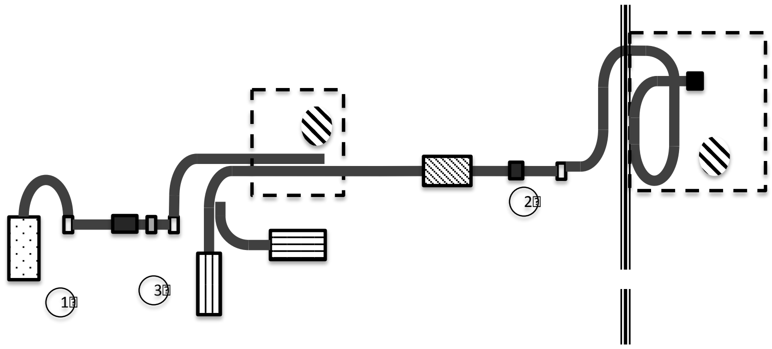
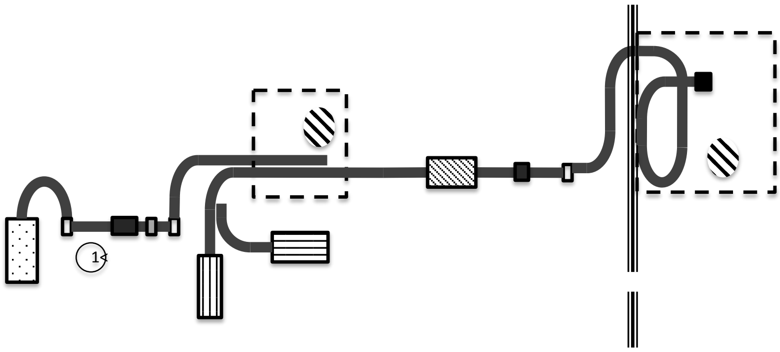



**Figure 57: Standardised work sheet for Main server during order change.**

## Inspector

| Standardised work sheet X Orderbyte (organisation+metod+Line Clearance) | | | |
|---|---|---|---|
| Linje: Våta | | Datum | 10/5/14 |
| Titel: Avsynare | | Issued by: | Josefsson&Ödebrink |
| Tid(s): 29.6 | | | |

| # | Operation | Work | Walk |
|---|---|---|---|
| 1 | Avslutande dokumentering | 29.6 | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| 6 | | | |
| 7 | | | |
| 8 | | | |
| 9 | | | |
| 10 | | | |
| 11 | | | |
| 12 | | | |
| 13 | | | |
| 14 | | | |
| 15 | | | |
| 16 | | | |
| 17 | | | |
| 18 | | | |
| 19 | | | |
| 20 | | | |
| 21 | | | |
| | total | 29.6 | 0 |




* Behov av hjälp från kollega.

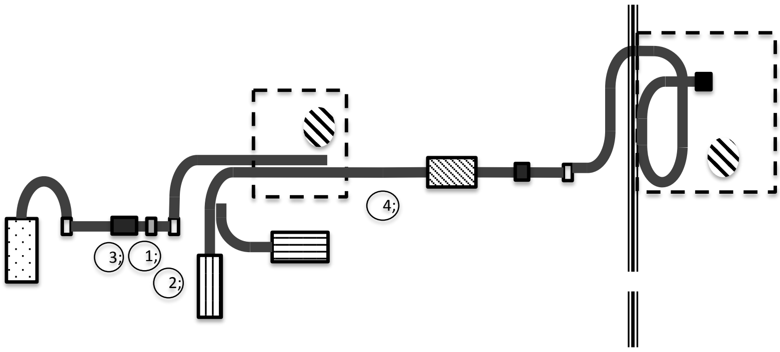
**Figure 58: Standardised work sheet for Inspector during order change.**

## Material planer

Standardised;work;sheet;\;Orderbyte;(Organisation+metod+Line;Clearance)

| | | | | |
|---|---|---|---|---|
| Linje: | Våta | | Datum | 10/5/14 |
| Titel: | Materialplanerare | | Issued;by: | Josefsson&Ödebrink |
| Tid(s): | 259.8 | | Total;tid: | |

| # | Operation | Work | Walk |
|---|---|---|---|
| 1 | Töm;bipackmatare | 76.8 | |
| 2 | Jämför;PIL;med;order | 15 | 20 |
| 3 | Fyll;bipackmatare | 143 | 19.8 |
| 4 | Töm;och;stäng;av;trp.;Bipack | 24.6 | |
| 5 | | | |
| 6 | | | |
| 7 | | | |
| 8 | | | |
| 9 | | | |
| 10 | | | |
| 11 | | | |
| 12 | | | |
| 13 | | | |
| 14 | | | |
| 15 | | | |
| 16 | | | |
| 17 | | | |
| 18 | | | |
| 19 | | | |
| 20 | | | |
| 21 | | | |
| | total | 260 | 39.8 |




* Behov;av;hjälp;från;kollega.

**Figure 59: Standardised work sheet for Material planer during order change**

# APPENDIX 12

Standardised work combination table for setup and order change with organisational , method and technical improvements

**Format change**

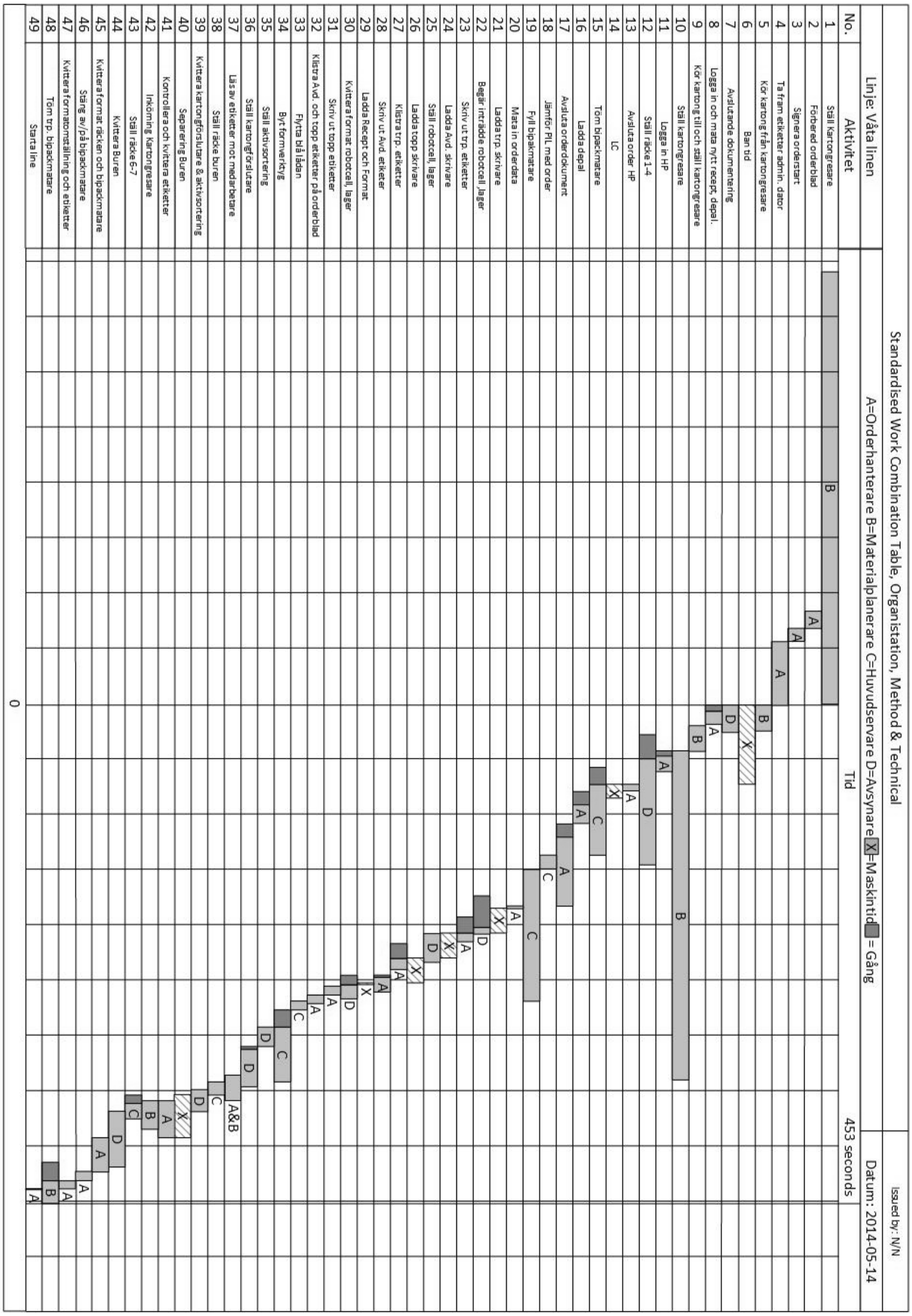



**Figure 60: Standardised Work Combination Table for the format change with organisational, method and technological improvements.**

## Order change

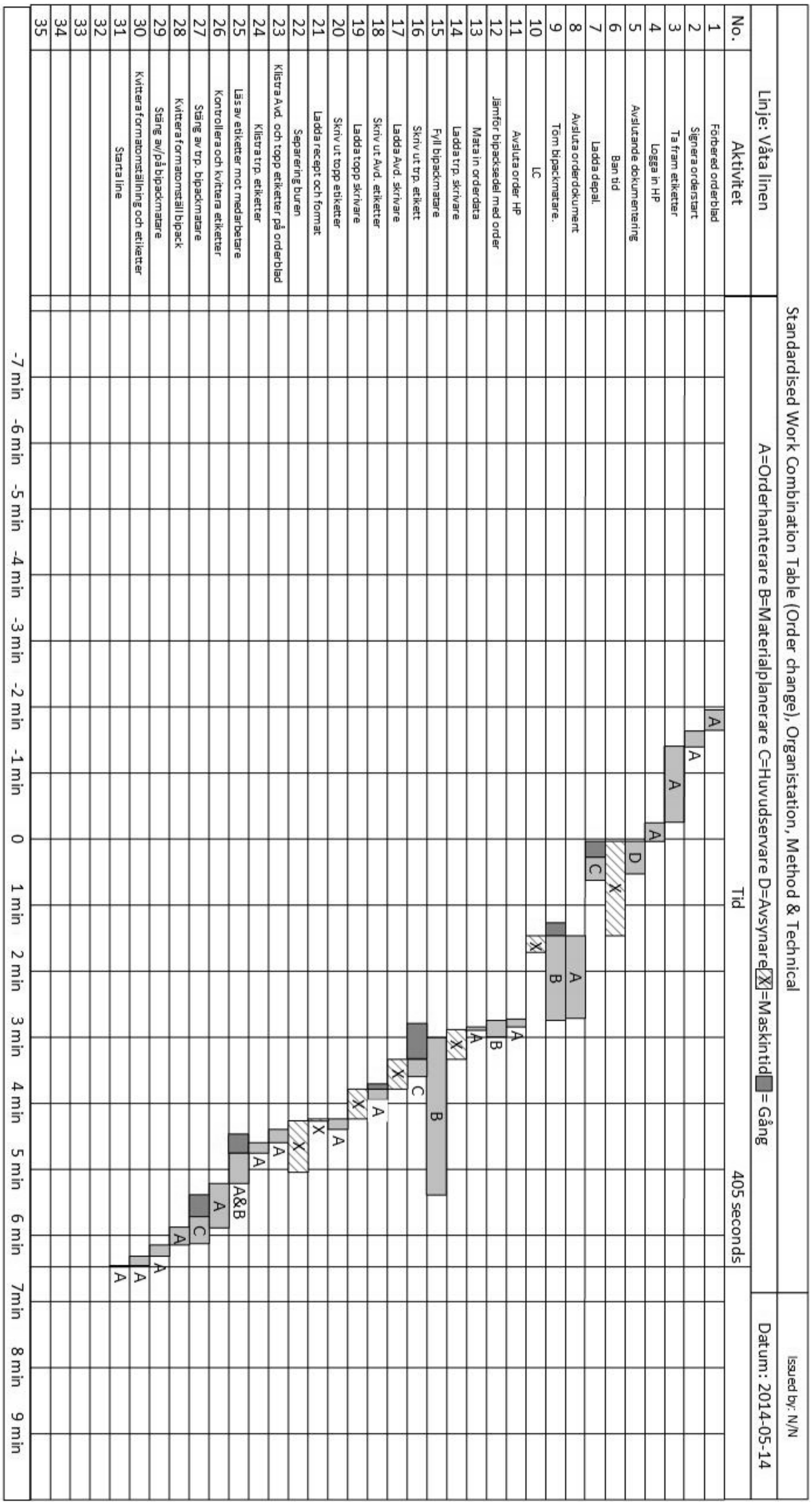



**Figure 61: Standardised Work Combination Table for the order change with organisational, method and technological improvements.**