Optimization of Changeovers
The process of optimizing changeovers with Lean Production tools

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Master of Science Thesis
KTH Industrial Engineering and Management ITM
June 2016, Stockholm, Sweden
Abstract

The production line at Mondelez International is heavily exposed to changeovers and is not originally designed to manage the vast amount- and frequency of the occurring changeovers. The aim is thus to decrease the total changeover time on the production line by applying several methods such as SMED and by reducing any wastes related to the changeover. The goal was furthermore to introduce the concept of Industry 4.0 to the company as a philosophy that will lead to automatic information gathering and correct performance analysis. These implementations, ideas, and key concepts could later on be implemented in other production lines in the factory both locally in the plant, but also globally in other factories.

The methods used to reduce the changeover time were based on random timings taken from the production line combined with interviews with operators and experts within respective fields. In order to optimize the problem areas that were found in the production line, it was necessary to find several solutions to each problem, as each solution had its own benefits. These solutions were then analyzed and compared to each other in order to find the best possible solution for each case.

The results of the project are that the total yearly changeover time of the production line could be reduced by a significant amount of time and this would reduce the costs of running the production line.

Industry 4.0 can be applied to the production line by adding sensors to some machines on the production line. These sensors will then report when the production line is undergoing a changeover and the information is stored in a database which can either automatically or manually be analyzed in order to find out where the main problems are occurring in the production line. This would decrease the time it takes in finding out where the problems are, and would also over all help in keeping track of the state of the production line in a more detailed and controlled way as compared to the current fully manual database system.

Keywords: SMED, Changeover time, 7 wastes, LEAN, Industry 4.0, Production line
Sammanfattning

Produktionslinjen som har undersöks i denna studie är mycket utsatt för omställningar. Målet har därför varit att reducera den totala omställningstiden för produktionslinjen genom att applicera metoder som exempelvis SMED och genom att reducera tids-slösande faktorer relaterade till omställningstiden. Målet var dessutom att introducera konceptet av Industri 4.0 till företaget och att använda produktionslinjen som en pilotlinje för att kunna visa hur Industri 4.0 kan appliceras. Dessa implementeringar, idéer, och nyckelkoncept ska senare kunna implementeras på andra produktionslinjer i fabriken både lokalt, men också globalt.

Metoderna som har använts för att reducera omställningstiden har varit baserade på godtyckliga tidtagningar från produktionslinjen kombinerat med intervjuer mer både operatörer och med experter inom respektive område. För att kunna lösa varje case som hittats på produktionslinjen, var det nödvändigt att kunna ta fram flera lösningar till varje problem, eftersom varje lösning hade sin egna fördel. Dessa lösningar analyserades sedan och jämfördes med varandra för att kunna hitta den bästa möjliga lösningen för varje case.

Resultatet av projektet blev att den totala årliga omställningstiden av produktionslinjen kunde reduceras med en viss tid som också innebar att kostnaderna för produktionen kunde minskas.

Industri 4.0 kan appliceras till produktionslinjen genom att lägga till sensorer till vissa maskiner. Dessa sensorer ska sedan kunna ge signaler om när produktionslinjen är utsatt för omställningar och informationen ska sparas i en databas som sedan kan antingen automatiskt eller manuellt analyseras för att kunna ta reda på var det största problemet hos produktionslinjen befinner sig. Detta skulle minska tiden det tar att hitta var problemen befinner sig och skulle också hjälpa med att hålla reda på vilket tillstånd produktionslinjen befinner sig i, i en mer detaljerad och ett mer kontrollerat sätt jämfört med sättet denna information hanteras just nu.

Nyckelord: SMED, Changeover time, 7 wastes, LEAN, Industry 4.0, Production line
Acknowledgements

This project would not have been possible without many people who have been an amazing support during this journey. We give our humble thanks to everyone at Mondelez International for greeting us with open arms – all of them are the reason to why this experience has been very pleasant and memorable.

We cannot thank the operators at Mondelez International enough for their support during this project. The operators at the production line greeted us with a smile every day and were very positive to share their knowledge and ideas. They listened to all our questions and ideas and always gave us a heads up when a changeover was happening. Without their brilliant ideas and their positive attitude, this project would not have been possible to execute.

We want to thank our supervisor at the Royal Institute of Technology, Mats Bejhem- his support and guidance have been great assets during the time of our project. Thank you for being so positive and supportive.

We also want to thank Peter Nylund, Anna Brorsdotter and Tommy Sundsvall for their feedback and guidance on our work at Mondelez International. They have helped us to get great insight on how to gather useful information and have taken their time to give us feedback every time we needed it.

Furthermore, we would also like to thank Anders Ferner, Line Manager at the production line, for introducing us to the friendly operators and taking your time to give us information about the production line. Thank you for believing in us and giving us a push in the right direction whenever we needed it.

Thank you Business Development Engineers Pierre Forsberg and Farhad Shiralipour, and Quality Engineers Urban Essing, Harry Sykes and Diana Alanie. You have all helped us a lot in our search to find a solution to clean the molding machines.

Thank you Maintenance Manager Tobias Bredenwall and Business Development for believing in continuous improvement and helping us develop our projects.

Thank you to Conversion Cost Analyst Patrik Aviander and CI Engineer Cedric Hanson for helping us analyze data and do calculations. We have learned a lot from you.

A big thanks to the Automation Engineer, Lars Lundström, for taking his time to help us test and develop our ideas. Your knowledge and enthusiasm is very appreciated. Thank you for being by our side on the production floor.

Thank you Manufacturing Planner Patricia for taking time for us and giving us information about how the Manufacturing Planning is done.

June, 2016

Stockholm, Sweden

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Table of Contents

1 Introduction .................................................................................................................. 1
  1.1 Background ............................................................................................................. 1
  1.2 Problem Definition and Purpose ........................................................................... 1
  1.3 Problem Statement and Project Deliverables ....................................................... 1
  1.4 Methodology .......................................................................................................... 2
  1.5 Delimitations .......................................................................................................... 2

2 Theoretical framework ................................................................................................. 4
  2.1 The 7+1 Wastes ..................................................................................................... 4
  2.2 Changeover Time and SMED ............................................................................... 5
  2.3 Frame of Mind when Optimizing Processes ......................................................... 6
  2.4 Ergonomic Work Environment ............................................................................. 6
  2.5 Poka Yoke ............................................................................................................... 6
  2.6 Industry 4.0............................................................................................................ 7
  2.7 The Payback Method ............................................................................................. 7
  2.8 Global Efficiency .................................................................................................... 7

3 The Production Line ...................................................................................................... 9

4 CASE 1: The Mold Changing Station ......................................................................... 12
  4.1 Light Barrier .......................................................................................................... 14
    4.1.1 Possible Solutions ............................................................................................ 14
    4.1.2 Analysis and Proposed Solution ....................................................................... 15
  4.2 Mold Racks ............................................................................................................. 16
    4.2.1 Possible Solutions ............................................................................................ 17
    4.2.2 Analysis and Proposed Solution ....................................................................... 20
  4.3 The Sensors ............................................................................................................ 21
    4.3.1 Possible Solutions ............................................................................................ 22
    4.3.2 Analysis and Proposed Solution ....................................................................... 22

5 CASE 2: Adjustments at the Packing Side .................................................................. 23
  5.1 The Handles ............................................................................................................ 23
  5.2 The Instructions ...................................................................................................... 25
    5.2.1 Possible Solutions ............................................................................................ 26
    5.2.2 Analysis and Proposed Solution ....................................................................... 29
6 CASE 3: The Washing of the Molding Machine ......................................................... 30
  6.1 Possible Solutions .......................................................................................... 31
    6.1.1 Analysis and Proposed Solution ................................................................. 32
7 Discussion and Conclusion .................................................................................. 34
  7.1 Action Plan ........................................................................................................ 34
  7.2 Issues Regarding Data ..................................................................................... 35
  7.3 The Next Step - Industry 4.0 .......................................................................... 36
  7.4 Zero Vision Concept ....................................................................................... 36
  7.5 Proposal for Further Studies ........................................................................... 36
  7.6 Reflection .......................................................................................................... 37
8 References ............................................................................................................ 38
1 Introduction

1.1 Background

It has increasingly gotten important for manufacturing companies to be able to produce a large variety of products. At the same time financial targets must be met and time must not be wasted on changing the settings of the machines in order to be able to produce different products. This makes it necessary to put focus on improving the time it takes to change to a new product.

The project was executed at a production line where Marabou chocolate bars are produced. Marabou is a part of the Mondelez International group which is the world’s largest chocolate producer. The brand Marabou was founded by a Norwegian man named Johan Thorne Holst in 1916. The company is named after the marabou stork [1].

Marabou was acquired by Mondelez International in 1993. Mondelez International was then called Kraft Foods. Kraft Foods split into two independent companies in 2012 which led to the founding of Mondelez International [2].

Mondelez International believes in continuous improvement and sets new goals every year to improve their work. The objective is to improve the safety, quality and efficiency within the enterprise.

The most occurring type of downtime at the production line is due to changeovers. This gives the area a high priority to be improved in order to increase the overall efficiency.

There are different tools that can be used in order to lower the changeover time. This report will present solutions based on lean production methods, in order to lower the changeover times at the production line at Mondelez International in Upplands Väsby.

1.2 Problem Definition and Purpose

The production line has changeovers as the main reason for downtime which is unusual compared to the other production lines that have speed loss as the main reason. This information suggests that the total efficiency of the production line can be increased if the changeover downtimes are lowered.

The purpose of this study is to investigate why the changeovers take a long time to execute and use lean production tools such as SMED and Toyota Principles to increase the productivity and lower the changeover times.

1.3 Problem Statement and Project Deliverables

With the previously described definition, the problem statement is:

“How can different lean methods be applied in order to reduce the overall time spent for changeovers at the production line?”
The project deliverables are to

- Propose various short- and long term solutions that will improve problem areas within the changeover processes at the production line in order to lower the changeover times
- Estimate quantity of economic resources and time that can be spared with the proposed solutions
- Consider how the solutions can be of benefit to other similar production lines within the enterprise
- Introduce and apply the concept of Industry 4.0 for performance measurement at the production line

1.4 Methodology

The case study started with observation of the changeover processes followed up by an open dialog and discussions with the employees of the factory. The aim was to find out what the bottlenecks are in the current changeover processes. The initial plan was to analyze what the bottlenecks were by looking into the existing data of the changeovers. Unfortunately, this data was faulty and insufficient for the purpose. Therefore, the main way of collecting data was by interviews and observations.

After the observation and information gathering stage, the concept generation for the solutions was started. The solutions were mainly based upon the information that was gathered from the operators. Their opinion is key since they are the ones with most hands on experience with the changeovers and it is important that the solutions will facilitate their job. The solutions were discussed with experts within the company and analyzed with knowledge from literature studies. Consultation has also been made with people in the industry in order to find the most suitable options for Mondelez International.

Sensitive data was chosen not to be presented in the report due to confidentiality agreement.

1.5 Delimitations

The following delimitations were made:

- This project is delimit to focus on the changeovers at the production line.
- It is not within the scope of the project to analyze how the production planning could be changed in order to lower the changeover times.
- The given solutions will not interfere with how the ingredients of the products or product specifications could be changed in order to lower changeover times.
- The only type of production processes that will be discussed are those that are directly connected to changeovers at the production line.
- This report will not present investment analysis of the proposed solutions. It will however contain rough approximations on the amount of economical resources that can be spared as a basis for future calculations regarding investment decisions within the company.
• The proposed solutions will not be tested regarding maintenance and sanitation during within the time frame of the project
• The proposed solutions will not be implemented during the time of project.
• It is not within the scope of the project to look at how the products are shipped away from the production line.
2 Theoretical framework

The section will explain lean manufacturing tools as well as other methods that are of relevance when optimizing changeover times. Lean Production is a philosophy that contains numerous tools for improvement of processes. This section will only mention a couple of these tools that are relevant for this particular project.

2.1 The 7+1 Wastes

When optimizing changeover times with lean philosophy, it is important to begin the improvement by observing the current situation and identifying different types of wastes which occur in the current manufacturing scenario. The Japanese word for waste is “Muda” and there are mainly seven forms of non-value adding activities, although there is also an eighth waste that is worth mentioning.

The different wastes are [3]:

1. **Overproduction**: Producing more than the demanded quantity in the production schedule. This means that even producing too early is considered to be an overproduction.
2. **Waiting**: Waiting for a certain process to finish before being able to continue adding value.
3. **Transport**: Moving a product between two locations.
4. **Over processing**: Adding too much value to a product which the customer is not willing to pay for.
5. **Inventory**: Keeping high work in process, buffers, and inventories between stations and at the start and end of the production system.
6. **Motion**: Moving too much in order to be able to add value. This for example includes walking to obtain tools and materials or having to bend down to reach for something.
7. **Defective products**: Producing products with a lower quality level than the customer is willing to pay for.
8. **Unused competence**: Not making sure that everyone has the possibility to voice their opinion in order to increase the possibility to find the best solution.
2.2 Changeover Time and SMED

Changeover time is the total time it takes to change from producing the last good unit of product A to producing the first quality approved unit of product B. A changeover is often segmented into two parts: the internal changeover time, and the external changeover time. The changeover time and its two components have been visualized in Figure 1.

![Figure 1](image.png)

*Figure 1. An overview of the definition of changeover time and its two different components. The production is stopped during the internal changeover time and is the critical time that should be reduced. Changeover operations that can be done during production time are external.*

Internal changeover time is the part of the total changeover time that is used for changing and configuring parts on the machine or production line while the system is *not running*. This means that the production is stopped during this step and it is thus the part that is of most importance to be reduced.

External changeover time is the part of the total changeover time that is used for changing and configuring parts on the machine or production line while the system is *running*. This part of the changeover can in other words be performed without affecting the production output of the production line. It is thus more favorable to have an external changeover time compared to an internal changeover time [3].

It is important to be able to reduce the total changeover time of a system since this will facilitate the ability of producing smaller batches and thereby cater the production to customer demand. Reducing the changeover time will also increase production time since it will increase the utilization of the machines.

One of the methods that can be used to reduce the changeover time between two products is Single Minute Exchange of Die – SMED. SMED is often performed step-wise and the first step is to separate the internal changeover time from the external changeover time [4].
SMED is often performed step-wise in the following steps [3]:

1. The first step is to separate the internal changeover time from the external changeover time. It is often recommended to videotape the changeover in order to easier be able to segment the two different changeover times.
2. The second step is to convert as much of internal changeover time as possible into external changeover time.
3. The third step is to reduce what is remaining of both the internal- and the external changeover time. Some examples of what can be done in order to streamline the changeover times is to keep a clean workplace, introduce parallel operations, use fixtures, and reduce the need for adjustments.

2.3 Frame of Mind when Optimizing Processes

“Genchi Genbutsu” is a part of the manufacturing philosophy the Toyota Way, which means to go see for yourself. This means that the way to really understand a problem, is to go where the problem is and observe it first hand [5]. This frame of mind can be linked to “Gemba”. “Gemba” means “real place” in Japanese and this will be where the value is added and where the problem is occurring. When working with manufacturing projects, Gemba is the production line [3].

I order to fully understand manufacturing related problems and solve them in the best way, it is of importance to talk to the operators since they are a core part of the “Gemba”. It is important to integrate the operators when working with improvement projects in order to make sure that the solution will facilitate their work and thereby increase productivity and solve the problem thoroughly.

2.4 Ergonomic Work Environment

To use as few resources as possible in the best way is a valid conclusion of the lean philosophy. Employees are a form of resources for a company. It is therefore important to utilize this resource in the best possible way. A safe and ergonomic work environment is key to preserve the health and positive attitude of employees. Improvements in the work environment should therefore be a weighted argument when making investment decisions [3].

2.5 Poka Yoke

Poka Yoke is the idea of designing a manufacturing process to eliminate risk of mistakes. It was first classified by Shigeo Shingo. Poka Yoke can for instance be applied by installing a device that will prevent that the operator can make a mistake or highlight a mistake so it can be corrected before it is passed to the following operation and create a defect [5]. Outlets are an example of Poka Yoke. The design makes it impossible for the user to plug in the inlet in the wrong way.
2.6 Industry 4.0

Industry 4.0 can be seen as the fourth industrial revolution and it’s about the disruption of manufacturing through digitalization. In conclusion, Industry 4.0 is promoting the importance of information gathering as a way of measuring and improving performance. Industry 4.0 was born when the manufacturers looked for new methods to improve their work. The first step when implementing Industry 4.0 into manufacturing processes is to change the way data is collected. The manufacturer should consider what factors are affecting their performance and then collect data in those fields in a digitalized, reliable way.

The next step is to use the data, sort it and use it to analyze performance. In order to this, sufficient tools in terms of stable data transmission and data storage must be implemented. There must also be a software that will analyze the data in a correct and reliable way.

When choosing what data to collect, the manufacturers can consider eight basic value drivers, service/aftersales, resource/process, asset utilization, labor, inventories, quality, supply/demand match, time to market. Within these value drivers are sub-categories called Industry 4.0 levers. For instance, if the manufacturer wants to increase asset utilization, a few of the levers he/she can consider are routing flexibility, machine flexibility, remote monitoring and control, see Figure 2 [6].

2.7 The Payback Method

The payback method is an investment method that is used to calculate the time it takes to get the money back of a certain investment. It is a basic tool for decision making regarding an investment. The time that is calculated is often compared to the policy of payback time that the company might have. This time can for instance be between 2-3 years and interest rates are usually not considered. An investment is considered to be profitable if the payback time is less than the payback time that has been set to be acceptable. For example, if the acceptable payback time is 5 years and the calculated payback of a project has a payback of 4 years, the project is considered to be profitable. If there are many options to choose from for a certain investment, the investment with the shortest payback should be chosen [7].

2.8 Global Efficiency

When it comes to keeping track of data and being able to know the current situation of different production lines, the term global efficiency – GE is used. GE is used to understand the losses occurring on a specific production line so that it is possible to prioritize and allocate relevant resources in order to increase the efficiency of the respective production line. A high GE factor means the production line is running smoothly, while a low GE factor means the production line is running with a lot of waste and errors. GE consists of circa 17 different waste-factors such as for example changeover time, planned maintenance, and sanitation. GE also includes the overall equipment efficiency – OEE. The goal is to continuously increase the GE factor by reducing the wastes described by the GE [8].
Figure 2. The eight value drivers and their levers that are being used for implementing Industry 4.0. The value drivers are the different areas that could be improved, and the levers are sub areas of the value drivers that must be improved in order for the respective value driver to be improved. E.g. in order to improve the asset utilization, the machine flexibility must first be improved. Figure reference: www.mckinsey.com

1Maintenance, repair, and operations.

McKinsey&Company
3 The Production Line

The production line is one of the production lines in the Upplands Väsby plant. It is considered one of the smaller production lines of the factory but its equipment is among the most modern. The line was initially built for production of pralines but was rebuilt for production of chocolate bars in 2009.

Roughly 2622 tons of chocolate bars were produced at the production line in 2015. Some of the different kinds of products that are produced at the line can be seen in Figure 3. There are 16 different products that are produced with different formats. This can be compared to the products at a very similar but larger production line at the plant that have 37 different products but only two different formats.

The challenge of production within the food industry is that the goods are perishable. The rapid changes in the forecast pushes the production planners to produce small batches of products with many changeovers. This to meet the requirements of selling products that will perish earliest one year after being sent to the vendors.

There are a number of different types of changeovers that are performed at the production line. Each product falls into an allergen group depending on the ingredients. The changeovers are divided into groups depending on the switch between the different allergens. The groups are:

- Blue: Scraping of the machines
- Green: No process
- Red: Scraping of the machines

![Changeover Matrix](image)

*Figure 3. The changeover matrix for the different allergens in the production. This matrix is used in order to know which allergen must be considered when the production is changed from producing different products. E.g. if product 2 is produced, and then product 3 should be produced, this means that a blue changeover should be performed.*
The operators have to carefully follow the given procedure of each changeover type to maintain the quality of the products. The production line is divided into two sections; the processing side and packaging side, see Figure 4.

![Diagram of the production line](image)

Figure 4. A visualization of the production line that shows both the packaging- and the processing side of the production line. It can be seen how some important features of the production line have been marked out in order to easier be able to understand the different cases.
The type of downtime that has the largest share of the total downtime on the studied production line, is changeovers. This can be seen in the pareto chart below in Figure 5. This is something the production line does not have in common with the other production line since the primary type of downtime is usually speed loss. The reason to this is that the production line has smaller batches with more varieties of formats compared to the other production lines.

Figure 5. A Pareto diagram taken from the company database showing the different GE factors for the production line. It can be seen how the changeover time is the biggest factor and that it is responsible for the biggest part of the GE loss as compared to other factors.
4 CASE 1: The Mold Changing Station

The changeovers that take the longest time are the ones that require change of molds. The molds need to be changed during yellow changeovers and between different formats of chocolate bars. 70% of the changeovers in 2015 where changeovers that required change of molds. After observation of the various changeovers, it was clear that the process of changing molds is the overall biggest bottle neck in the changeover processes. Changeovers between different formats without any stops should take a certain amount of time according to tests by the operators. The time depends on the speed settings of the changeover, which in this case is around 15 molds per minute. The mold changing process takes 50% more time than it should without any stops at the current state. The high frequency of occurrence and the large amount of external changeover time makes the mold changing station the case of highest priority. This chapter will present the different areas of improvement with proposed solutions within this case of the mold changing station.

The automatic mold change station consists of a conveyor belt where clean mold racks stacked with molds are being transported. The used molds are being transported out of the molding system and the new ones are being transported in the molding system.

This is a walkthrough of the mold changing process as illustrated in the squares in Figure 6:

1. A clean mold rack is placed at the out-feed position.
2. A full mold rack with clean molds is collected from storage and loaded on the conveyor belt.
3. The mold rack is transported on the conveyor belt and pushed into correct position by an actuator.
4. The mold rack is moved to the in-feed position.
5. The mold rack starts feeding in clean molds and the dirty molds being fed out from the production line into the empty mold rack. The mold racks change column when all of the molds have been emptied out / filled in.
6. When the respective mold racks are full/ emptied, they are moved as shown in the picture. Note that the empty mold rack is first transported to the elevator in the upper right corner before being transported further.
7. The mold racks are held in the following position and there is a need for both an empty mold rack and a full clean-mold rack.
8. A new full clean-mold rack is placed onto the mold changing station.
9. The forklift moves to pick up the full dirty-mold rack
10. The mold changing station is set to running again, and the full clean-mold rack again moves to in-feed position while the empty mold rack in the bottom right moves in to the out-feed position. The in-feed of new molds and the out-feed of dirty molds are then continued as previously described. (step 5 is repeated).
Figure 6. A step by step guide showing how the mold changing process works. It can here be seen how the mold racks with molds are being loaded onto the mold changing station and how the mold racks are being moved around on the station. It can further be seen how the molds are being fed into- and out of the production line and how the mold racks can get stuck while being transported on the conveyor belt of the mold changing station. It can also be seen how the light barrier will break when the truck is loading mold racks onto the mold changing station.
4.1 Light Barrier

The purpose of the light barrier is to screen off the walking lane and the automatic mold change station and provide safety, see Figure 7. When something breaks the light barrier, the automatic mold change station will stop moving immediately and the pneumatic system will release air pressure. The light barrier was installed in 2013 during an initiative to create a safer work environment. The light barrier is one of the reasons to why the changeovers between different formats take a long time. This, since the operators need to break the light barrier every time they load and unload mold racks on the conveyor belt. The changeover time could be shortened for changeover times between different formats if the loading and unloading of mold racks could be carried on without braking the light barrier.

Figure 7. A picture showing the current mold changing station and how the light barrier is present. Two mold racks have been visualized on top of the station with two and one molds respectively. The green lines are used for transporting molds while the grey lines are used for transporting mold racks.

4.1.1 Possible Solutions

The light barrier should be replaced with an arrangement that will provide safety without stopping the movement of the station during loading and unloading of mold racks. Figure 8 shows the proposed solution where the light barrier is replaced with safety fences. This solution was developed together with the operators, the line manager, the maintenance manager and a safety representative.

- The fences are 180 cm high according to safety standards of Mondelez International.
- The mold station can be entered through two doors in the fence. Breakers in the doors will stop the movement of the station when the doors are opened. The doors are wide enough for a mold rack to be transported though it in case this would be needed.
- Elevators will allow the operators to load and unload the mold racks over the fence.
4.1.2 Analysis and Proposed Solution

By implementing the proposed solution, the wastes motion and waiting will be avoided. The operators don’t have to go to the clearing-button by the fence and then go to the panel in order to start the movement of the mold changing station every time they break the light barrier for loading and unloading of mold racks. Waiting will also be avoided since the process of mold changing does not have to be stopped because of the loading and unloading operation. This solution would also ease the work of the operators and increase their motivation which will benefit the productivity. To ease the work of the operators and decrease their motion is a lean practice, since it is a smart and sparse way of using resources, which in this case are the operators.

After observing and timing a changeover where the mold changing station was used, it was stated that there are roughly 15% of the mold changing time could be spared if the loading and unloading could be carried out without stopping the mold changing station.

According to the Conversion Cost Analyst at Mondelez International, the amount of economical resources that can be spared if 15% of the mold changing time is reduced, can be calculated by multiplying the cost per working hour per operator times number of operators times the amount of time spared.
4.2 Mold Racks

The mold racks are used to stack the molds. They are stored in designated parts in the factory and transported with forklifts. The racks are designed with three slots for the molds and the molds are held in place with splines. The splines are located in diagonal of the slots, see Figure 9.

![Figure 9. CAD model of one of the mold rack models used at Mondelez International. It should be noted that also some other models are being used.](image)

There are several issues related to the molds racks. All of the observations, except the last one, contribute to the main problem with the mold racks which is that the molds occasionally get stuck when entering or exiting the mold rack. Some of the observed issues are:

1. The racks get easily damaged while being transported. Since the racks are sensitive to stress, they deform plastically. The crooked racks later cause trouble during the mold changing process since the molds can get stuck when the rack is being emptied.
2. The racks are not properly stabilized when they are being fixed for loading of molds by the outlet. The margins for the molds to fit into the mold rack are little, and small angles can cause problems, especially with chocolate covered molds.
3. The edges of the splines are sharp and the molds get stuck while being pushed up into the racks. Since the splines are only placed in diagonal edges, it can cause a momentum on the molds that are pushed up into the racks and twist them. The twisting motion can cause the mold to get stuck.
4. The actuator that pushes the molds up into the mold rack has a quick jerky motion which makes the molds bounce and thereby increase the risk of them getting stuck in the mold rack.
5. The empty mold rack which can be seen in Figure 6 square 6, is transported with a high speed and bounces against the fence to the right into an angular position. When the mold rack is tilted so the corner of it is closest to the sensor as in Figure 6 square 7b, the sensor will make the conveyor belt stop. When the tilted mold rack is further transported it can get stuck in the cylinders at the sides of the conveyor belt, causing the mold rack to get stuck, see Figure 10.

6. A crowbar is used in order to wrench loose the molds that are stuck. The crowbar is stored far from the mold changing station and the operator needs to spend time in order to search for and collect it.

![Image of mold rack stuck]

*Figure 10. The mold rack is stuck in the mold changing station when on the way to the out-feed position. It can be seen how the mold rack has been angled due to earlier faulty operations.*

4.2.1 Possible Solutions

The possible solutions are:

1. The current mold racks need to be reinforced by adding support or by hardening the material if possible. In the event of that new mold racks would have to be purchased in the future, it would be highly recommended to have a higher E-modulus on these and that they would be constructed with a higher safety factor against impacts.

2. The current actuators that are stabilizing the mold rack should be changed with a design that will make sure that the racks are stabilized in place.

3. The edges of the splines should be rounded to allow the mold to go up into the mold rack more smoothly. The splines should be placed in all four corners of each slot in order to prevent the momentum that gets them stuck, see Figure 11.
4. Slow down the speed of the vertical motion of the actuator so the molds are pushed up into the mold rack without bouncing.

5. There were multiple solutions for this problem and evaluations needed to be made. A table with the different solutions compared with each other has been created and presented below in Table 1.

![Figure 11. Box A shows the current condition of the edges of the guide ways in the mold racks and box B shows how the edges should be rounded in order to reduce the risk of molds getting stuck in the mold racks.](image)
Option 1: Reducing the speed of the upper conveyor belt so the mold rack will impact the fence with a lower speed. The main problem is that the system is not built for alternation of velocity. This makes it necessary to rebuild the system in order to implement this solution.

Option 2: Install a better fence with dampening to hinder the mold rack from bouncing upon collision. The main problem is that there is still a relatively high risk of the mold rack being angled after impact.

Option 3: Running conveyor belt during a longer time in in order to correct the angle of the mold rack. This solution caused bugs upon testing and the conveyor belt lost grip of the mold rack.

Option 4: Installing a second sensor that will detect that the mold rack is angled and adjust the movement of the conveyor belt to correct the position. This proved to be costly and hard to realize with the current systems architecture.

Option 5: Installing an actuator similar to the current one in position A in order to push the mold rack in the desired position.

Figure 12. The locations of the different possible solutions
Fixing the root problem is often the best option, but since there are many sequential operations in this process, the risk for an error occurring later on is increasing. The best and most preferred option is thus solution nr 5, to install an actuator that will position the mold rack and ensure that it is fully planar regardless of how angled it has become in the previous steps.

6. Locate a crowbar (or other relevant tool) near both the loading/unloading stations that can be used to unstuck molds in the mold racks. These tools should be easily accessible and not collected from somewhere else.

Table 1. An analysis of the problem with the mold rack being angled. The costs have been estimated in order to be able to compare the different solutions to each other. The expert’s view is referring to the automation staff. The numbers of the problems are taken from Figure 12.

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
<th>Operator view</th>
<th>Expert’s view</th>
<th>Risk for error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slow movement</td>
<td>High</td>
<td></td>
<td>Bad, requires rebuilding</td>
<td>High</td>
</tr>
<tr>
<td>Put a better impact fence</td>
<td>Medium-High</td>
<td></td>
<td>Bad, requires rebuilding</td>
<td>High</td>
</tr>
<tr>
<td>Run conveyor belt for longer</td>
<td>None</td>
<td></td>
<td>Bad, sensor will not always detect and allow this</td>
<td>High</td>
</tr>
<tr>
<td>Install a 2nd sensor</td>
<td>Medium</td>
<td></td>
<td>Difficult to program and maintain</td>
<td>Small</td>
</tr>
<tr>
<td>Install an actuator for planar positioning</td>
<td>Medium</td>
<td>Most preferred</td>
<td>Safest way, can use similar actuator as in position A</td>
<td>None</td>
</tr>
</tbody>
</table>

4.2.2 Analysis and Proposed Solution

Around 20% of the downtime during the mold changing process is due to molds getting stuck by the output, according to a time measurement test. The cost savings that will be gained through solving the problems with the mold racks can be calculated in the same way as in section 4.1.2. This suggests that some resources could righteously be allocated to reduce to problems stated in this section.
4.3 The Sensors

There are many sensors at the mold changing station in order to make the process possible. Two of these sensors have been noted to cause delay in the mold changing process.

- The first sensor, which can be seen at position A in Figure 13 below, is placed a bit too far away from the edge of the mold changing station. This causes the operator to drive back and lift the mold rack a second time in order to place it further in on the conveyor belt in order to activate the sensor.

- The second sensor, which can be seen at position B Figure 13 below, is counting the number of molds in the mold rack. Since one of the mold racks will not be full, this can cause problems. The sensor will not allow for the mold rack to be transported until the molds are emptied from the slot, which forces the operator to activate the sensor manually by moving their hands in front of the sensor until it has counted all the “molds”.

![Figure 13. A and B show the locations of the two concerned sensors. C shows the new location of the sensor that is currently in position A as explained in section 4.3.1.](image-url)
4.3.1 Possible Solutions

The possible solutions are:

- A solution for the problem with the first sensor is to move the sensor from position A closer to the fence at position C as proposed in Figure 13 above.
- A solution for the problem with the second sensor is to introduce a routine where the mold rack with less molds is the last one to be loaded onto the conveyor belt. This will eliminate the problem since the mold changing process will not be stopped when all the molds are changed.
- Another solution for the second sensor is to reprogram the sensor to count to end of column instead of counting total number of molds. This will allow the operator to place the not-full mold rack at any time and the system will manage it without the operating having to neither think nor interfere.

4.3.2 Analysis and Proposed Solution

The first solution regarding the first sensor is easy and cheap to implement, and can be implemented when rebuilding the mold changing station.

The first solution regarding the second sensor which includes implementing the routine where the mold rack that is half full is put last requires the operators to change their routine and to remember the new routine. The second solution regarding the second sensor which includes reprogramming the sensor to count the molds, has a lower risk of error but it requires more resources than the first solution. So in conclusion, even though the first solution has more room for error than the second one, it is the cheapest and quickest one to implement and is therefore recommended as the best solution for this case.
5 CASE 2: Adjustments at the Packing Side

Some adjustments on the packaging side of the production line need to be made during every changeover. The complexity of this process depends on the type of changeover. If there is a changeover between two products that have the same format, the parts that need to be changed are:

- The wrapping in the flow pack machine
- The amount of pockets in the SKU pack machine
- The settings of the product codes
- The box type
- The measurements in the CU pack machine

There are a lot more changes to do if the changeover is between products with different formats. This process can take up to two hours for an experienced operator to execute alone. Since there are many steps in the process which have little margin for error, mistakes can happen which will lead to defects.

5.1 The Handles

The measurements are changed in different ways depending on the type of handle. Three main types of handles were observed. The three types of handles or fixtures are:

1. Nuts (see Figure 14)

The measurements with nuts need to be adjusted with a wrench. The metal wrench sometimes hinders the adjustments to be made when the line is working since they activate the metal sensor. There are also nuts that are placed in order to fix covers on the flow pack machine. These covers need to be removed during changeovers between different formats. The solutions with nuts are time consuming since they are not ergonomic, especially if the nut was excessively tightened in the previous changeover and since they need a tool to be adjusted.

Figure 14. The nut must be loosened in order to be able to adjust the measurement and must then be retightened in order to lock the adjusted measurement.
2. Lock levers (see Figure 15)

The lock lever is basically a handle with a spring. When the spring is pushed down by pressing down the black button, the movement of the handle gets unlocked. When the wanted setting is achieved, the handle is let down and the position is locked. This handle is causing the operators a lot of time loss. The operator can spend up to 30 seconds to adjust a handle since the spring in the lock lever often causes problems.

![Figure 15. The lock lever is rotated in order to unlock the clamping force and is then rotated back to clamp again after changing the measurements. Figure reference: www.wiberger.se](image)

3. Mechanical position indicators (see Figure 16)

The mechanical position indicator is a device that shows accurate position value. The setting is made manually with a detachable lever. The operators prefer this tackle since it is easy to adjust and easy to see the value. The adjustment takes 5-10 seconds per tackle.

![Figure 16. Mechanical position indicator with lever. The current measurement is visualized on the small screen on top of the device as the lever is rotated. Figure reference: www.acumo.se](image)

The possible solutions and the analysis and proposed solution for this area of improvement will be explained in section 5.2.1 and 5.2.2.
5.2 The Instructions

There are some areas of improvement regarding the instructions for the changeovers. Here are some:

- The current way for the operators to keep track of the setting values for the different machines is to look in a binder that has pictures for where the changes should be made and what the standard setting values are. Having instructions far from where the changes are made causes waste in terms of motion. The operator has to walk back and forth to the binder when executing the changeover or hold it in their hand if they are working alone. Even if they move the binder with them and put it on the floor they still have to look up and down while working.

- There is a risk for an experienced operator to skip the instruction manual. This has previously caused mistakes since some of the steps in the changeover process have been forgotten or been executed incorrectly. On some areas of the packaging side, the operators have already tried to facilitate the process by putting marks and stickers with information about the wanted values for the different format adjustments, see Figure 17. This shows that there is a need for quick access of correct information during the changeovers.

Figure 17. Position indicators with stickers for wanted values that should be set for each of the changeover types on the packaging side.
5.2.1 Possible Solutions

The quality of the changeover on the packaging side is crucial for the overall performance of the following production time. Most of the stops after the changeovers are caused by complications on the packaging side. Since the outcome of the changeovers are dependent on how well the changeover has been made, it is important to remove the risk of making mistakes. There are several actions that can be taken in order to minimize, and finally, eliminate the risk of making mistakes and thereby creating defects. Here are some solutions to this problem with increasing level of automation:

1. **Implement snap on functions for the detachable parts**

According to tests, the nuts take 5-10 seconds each to remove. When this time is multiplied with all the nuts that need to be adjusted on the packaging side it adds up to minutes. The nuts can easily be lost and are overall not a SMED solution. A better solution would be to implement snap on functions for as many parts as possible for faster setup.

2. **Implement tackles that are ergonomic and easy to adjust**

As stated in section 5.1, there are several different handles with varying level of ergonomics. The handles that are the easiest to work with should be implemented on as many places as possible on the machine. The mechanical position indicator is believed to be the most efficient of the current tackles, see Table 2. It does require a tool but the lever is ergonomic. The counter shows the exact measurement and makes it easier for the operator to clearly see the setting. Since there is a motion waste in getting the lever, the control knob would provide the benefits of the position indicator without the drawback of requiring an additional tool, see Figure 18. These type of tackles are around 500 SEK each according to the company Acumo.

![Figure 18. Control knob with analog counter. Current measurement is visualized on the screen in the middle as the device is rotated. Figure reference: www.acumo.se](image-url)
Table 2. Comparison of handles based on operator's experience

<table>
<thead>
<tr>
<th>Tackle</th>
<th>Ergonomics</th>
<th>Need for tool</th>
<th>Operator view</th>
<th>Risk for error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuts</td>
<td>Low</td>
<td>Yes</td>
<td>Dislike</td>
<td>High</td>
</tr>
<tr>
<td>Lock Levers</td>
<td>Medium</td>
<td>No</td>
<td>Spring can cause problems</td>
<td>Medium</td>
</tr>
<tr>
<td>Mechanical Position Indicator</td>
<td>High</td>
<td>Yes</td>
<td>Favorable</td>
<td>Low</td>
</tr>
<tr>
<td>Control Knob</td>
<td>High</td>
<td>No</td>
<td>Favorable</td>
<td>Low</td>
</tr>
</tbody>
</table>

3. Implement monitored format adjustment

The next step of optimizing the changeover on the packaging side is to implement electronic tackles, see Figure 19. The electronic position indicator and the control knob are able to show the target value for the format, as well as the current value. The LED light on the position indicator blinks green when the target value is reached.

![Electronic position indicator and control knob](Figure reference: www.acumo.se)

The most important benefit of having electronic position indicators is that they are bus-compatible which means that they can be integrated into a fieldbus system which allows communication between the tackles and the computer, see Figure 20, where it is visualized with a purple cable. The indicators are connected via the fieldbus system to a computer where the values for all the indicators are controlled before starting the changeover. This gives the operators more control of the changeover and prohibits mistakes. These tackles are around 3500 SEK each together with the supportive system according to the company Acumo.
Figure 20. Position indicators in a fieldbus system. The indicators are receiving information from the field bus in order to know what the “should” value should be, and sends the current value back to the computer via the field bus. Figure reference: www.acumo.se

4. Implement automated format adjustment

The final step in optimizing the changeover time and quality on the packaging side is to implement automated solutions, see Figure 21. The electronic position indicators have built in motors and locks that will adjust the settings to the desired value. This system is built on the previous system of monitored format adjustment which means that the changeover can be monitored from a computer. These tackles are around 6000 SEK each together with the supportive system according to the company Acumo.

Figure 21. Position indicators with motors for automated solution. Figure reference: www.acumo.se
5.2.2 Analysis and Proposed Solution

The proposed solutions are an example of SMED implementation. The goal is to make the changeover process as easy and fast as possible. To make the handles easy to use and to make the removal and attachment of parts as fast and smooth as possible will lower the changeover time and minimize errors, i.e. make the process Poka Yoke.

The automated solution is the most favorable one since it will lower the changeover times the most and reduce errors the most. The changes towards a faster changeover time can however be made in steps. The first step is to change the non ergonomic tackles to ergonomic options. These will be easier to handle by the operators and will therefore lower the changeover times. It will also create a better work environment through lowering the waste of motion of the workers.

The automated solutions can be considered costly but will implement Poka Yoke to the packaging side. The production will run much better since the speed loss due to mistakes during changeovers will be eliminated. This will mean that the overall performance of the production line will be improved and the income will increase.

The automated solution will also lower the internal changeover times drastically since all the adjustments can be made at the same time. This improvement will still be of benefit even tough the adjustments on the packaging side are not the bottle neck of the overall changeover time. This since the required number of operators will be lower and the operators can cater to the other operations during the changeover.
6 CASE 3: The Washing of the Molding Machine

The molding machines need to be washed or scraped during changeovers depending on the color of the changeover. It has to be washed during yellow changeovers and scraped during the others except for the green one. At the current state, this procedure is done manually. If the cleaning step is done faster, the operators can use their time to finish another task during the changeover and thereby finish quicker.

*Figure 22. View of inside of MM3 that is to be cleaned*

*Figure 23. MM 2 with safety grid*

There are two molding machines in the production line that are to be cleaned this way. MM 3 has a reed switch and MM 2 has a contact sensor in order to provide safety. The switches are located on different sides of the rectangular hole depending on the machine, although the measurements of the holes are the same for both of them. There are safety grids on top of the
machines that activate the switches and thereby the movement of the molding machines, see Figure 23. When the grids are off, the machines will not move because of safety reasons. The contact sensor is the more favorable switch according to the operators since there is a higher risk for the reed switch to break or malfunction.

### 6.1 Possible Solutions

Applying a device that will wash the molding machines would eliminate the problem of having the operator work from a non-ergonomic position. The scraping and washing of the molding machine takes around 12-15 minutes and this time could be used to do other internal changeover operations and lower the changeover time. The suggested washing lid, see Figure 24, will be connected to the water hose and have a contact sensor that will allow movement of the machine for better results. Since the molding machines have different kinds of switches, MM 3 needs to be adjusted to have a contact sensor at the same position as MM 2. The objective is to have one washing lid that is applicable for both machines, see

![Figure 24. Schematic model of the proposed washing lid. The washing lid includes a spray ball and a hole where the hose can be attached. The middle area below consists of water pipes which the hose is then connected to via the hole.](image)
The selection of the spray ball for the washing lid has been consulted with the company Sveflow. A consultant from the company recommended the spray ball S30 that has more than enough capacity to clean the inside of the washing machine. The price of the spray ball is around 3000 SEK. Sveflow did however mention that the temperature of the water is crucial in order to get wanted results. The water temperature should be sufficiently warm to melt the chocolate since it is around 45-50 degrees warm.

6.1.1 Analysis and Proposed Solution

The washing lid is a very favorable concept to the problem of washing the molding machine, but it should be noted that the washing lid can be built in different ways and that the quality of its cleaning cannot be measured until a prototype is created and tested. It should thus be noted that this solution needs to be tested in order to be optimized and wash the machines in the best way possible.

The current temperature and pressure of the water that will be used is adequate for the stated solution. The pressure of the water is between 6, 5 to 7 bar which is enough pressure for the spray ball.

A way of improving the solution is to implement blow drying, unless the molding machine can be heated and air-dried naturally in case the molding machines are rebuilt. The operators today are using manual blow drying after washing and the current outlet for air could be attached to the washing lid. A further improvement could be to automate the washing lid so it can switch
from washing to drying by itself when the washing is done. There could also be a signal that notifies the operator that the process is done.

It should be noted that it is of most importance that there is under no circumstances any water left in the molding machine when it is filled with chocolate. The water causes bacterial growth in the chocolate. Since it is of doubt whether the automatic blow drying will ensure a completely dry machine, other solutions should be considered.

The two molding machines are not equally built which means that only one machine is suitable for certain products. This means that the machine has to be washed and dried quickly in order to lower the internal changeover time. If one of the molding machines is rebuilt so that they will become similar, it would be possible to let one of the machines air-dry after washing and continue the production with the other machine. It would also mean that the cleaning of the molding machine would no longer be an internal changeover time. The time it takes to clean for the washing lid would thus not be significant.

An important aspect is however that the washing lid helps in reducing the manpower needed for the production line, and is estimated to also give a better and more even quality on the cleaning. At the same time, it is also a process that is more related to the concept of Poka Yoke. Also, the solution means that the working environment will be significantly improved. The rebuilding of one of the molding machines is already in discussion in the company. The weight of the washing lid is estimated to be circa 6 kg, which is below the weight of 15kg which is the recommended limit to carry the device without any lifting aid [9].

The total internal changeover time saved is difficult to calculate since if the two molding machines are made similar, the washing of one molding machine will more or less no longer affect the internal changeover time. It should however be mentioned once again that his solution greatly improved the working environment for the workers while also improving the quality and allowing the operators to spend time on other tasks. The washing or scraping of the machine takes around 12 minutes. The washing lid will allow the operator to proceed with other operations within the changeover process and might thereby reduce the changeover time. It may also contribute to the reduction of number of operators needed on the production line.
7 Discussion and Conclusion

The several different proposed solutions in this report should be implemented in a certain way and at a certain time, since some of these take relatively long to implement. For example, replacing the light barrier and similar time consuming projects should at first hand be considered to be implemented during times when the production output will not suffer from the installation itself. The best such time is during the days where the entire production line is subject to being stopped completely due to planned stops.

Furthermore, as will be explained later on in this chapter, it should be noted that the internal changeover time could be greatly reduced to as little as zero minutes if enough investments are made and if the state of the production line can be kept track of in a more detailed and better way.

7.1 Action Plan

The procedures and recommended solutions could be implemented in the following order:

1. **Create a routine where operators must place the half full mold rack lastly**, as this requires little effort, is free, and is quick to implement.
2. **Replacing the light barrier with a fence**, as this is the most critical and time consuming process related to the bottle neck of the mold changing station. The installation is recommended to be made during a period where no changeovers are made, alternatively during a maintenance week. This also requires the installation of the elevators.
3. **Install an actuator to prevent angling of incoming mold rack**, as this will further reduce the time consumed by the bottle neck of the mold changing station.
4. **Implement the dish washing lid to clean the foundries**, as this will allow operators on the processing side to have more time to do other things in order to reduce the internal changeover time. This will also improve the working environment.
5. **Install better handles on the packaging side**, as this will reduce the number of adjustments and improve the working environment. This project is further considered to mostly only be necessary once the processing side has been optimized, as the current bottle neck is not in the packaging side, and of course the bottle neck should always firstly be focused on.
7.2 Issues Regarding Data

Several problems were discovered with the data that was at first used to analyze the current situation. This data introduced an uncertainty in the calculations made of how much the GE could in fact be improved once the changeover improvements will be implemented. The main problems that were found with the company database “DTA” were that the resolution and accuracy of the data were very poor. The reasons behind this are that:

- The changeover times reported are not 100% accurate – only a circa time is taken.
- Only very few eventual problems occurring during the changeover are reported.
- The time of each sub process in the changeover is not reported.
- No adequate additional comments or data is reported.
- The information is mainly gathered manually from the computers located next to the production line. It was found that it is easy to accidentally make a report for the wrong area, and that it is easy to accidentally report that a stop for a changeover was made when in fact it was a stop for cleaning, i.e. the computer interface does not allow for Poka Yoke.

The data that was collected from DTA was not usable other than to identify how many changeovers were made the previous year and how many of these were mold changes for the processing side. The reason behind this is that a changeover of molds on the processing side can currently technically not take less than a certain amount of minutes, but the data collected from DTA shows that circa 35% of the changeovers in fact took less than this amount, making the data not reliable. Furthermore, there is a need to start running the production line after the mold change, which also requires some extra time. A histogram with the changeovers made during 2015 has been presented in Figure 26. The data to the left of the dashed line are changeovers with unrealistic changeover times. The x-axis is changeover time and the y-axis is frequency.

![Figure 26. Histogram for data from DTA-analysis from 2015 for the processing side](image)

After analyzing the data from DTA it is easy to understand that it is important to have correct data reporting from the manufacturing processes in order to be able to accurately and precisely keep track of the current state so that also the future state can be modelled accordingly.
The lack of Poka Yoke in the reporting process leads to mistakes. This is a problem since the development of Mondelez International is based on GE and OEE numbers and these numbers have to be correct in order to follow the development of the production.

7.3 The Next Step - Industry 4.0

In order to make the system work better with the philosophy of Poka Yoke, it is thus recommended that the machines are themselves creating reports of their current state and when they are undergoing a changeover or another form of operation or stop. It would be necessary to create a system that can store the data in a cloud database and analyze it through basic statistic modeling. The previously described errors related to the reporting of data to DTA would thus be minimized as operators would also no longer have to create the reports themselves.

This leads us to realize that a need of Industry 4.0 is necessary in order to be able to run the production under full control. Currently, there is little or no implementation of Industry 4.0 in the production line, but with the data collecting system previously described, a step towards Industry 4.0 would be made. The production line is suitable as a pilot project for the implementation of such a system since it has automated production processes.

7.4 Zero Vision Concept

It can be worth considering spending even more money and resources on making the mold changing station run 100% perfectly. If there were no stops in the mold changing process, the molding machine could technically start molding right away once the molding machine and mixers have been cleaned and once new ingredients are prepared and the packaging side is ready. This leads us to imagine the possibility of reducing the changeover time to a number that is very close to 0 minutes – a zero vision. Bars with a filling are more sensitive to stops due to the design of the casting process. This, however, requires a bigger commitment to reduce the changeover time and requires a lot more resources and an implementation of Industry 4.0 with the mindset of Poka Yoke and reducing all wastes related to the internal changeover time.

7.5 Proposal for Further Studies

One of the most important outcomes with this projects has been the realization of the lack of correct performance measurement. A proposal for further studies is therefore to do further research in how to introduce Industry 4.0 applications to the production line.

A basic pre-study for this area was made in order to gain more knowledge about possible solutions for the future. A company named Axxos was contacted. Axxos is a company that provides solutions for production monitoring and has other clients within the food industry such as Cloetta and Göteborgs Kex. Cloetta claims that they have saved 50% of their production costs since they have started their Lean project which includes products for automatic production performance measurement. [10].

The procedure for implementation is that representatives from the company will visit their client in order to make a pre-study of the current system and what the needs of the client are. When the pre-study is done, a system will be installed that automatically gathers data from the
machines with PLC and OPC connections. The data will be stored in a cloud database and can be visualized in a software. It is possible to customize the system so that it can register the reasons behind the downtime. This way, it is possible to get accurate overview of the performance and find bottlenecks faster.

7.6 Reflection

The solutions and knowledge in this report are mainly based on the data that was collected through interviews and measurements, since the existing data was insufficient. The data that is based upon time measurements for Case 1, was collected at a single occurrence of mold changing. It would have been better to measure the time during multiple mold changings and calculate the average times. The reason to why there was only one session of time measurement is because it was difficult to be present and predict the time of mold changing since this was either very early in the morning or late in the evening.

The interviews could have been made more structured in certain scenarios in order to be able to compare the viewpoints of different people on a certain case. This could have helped in finding the best solution as opposed to asking about the solutions openly. Even though several possible solutions were created for most of the cases, having even more solutions could have been beneficial, as this would ensure that the best solution could be found.

Even though time measurements were made according to the philosophy of “Genchi Genbutsu”, i.e. to see for yourself, the data that these times were measured towards where not reliable enough in order to be able to give a clear answer in exactly how much time could be saved with the proposed solutions for each case.

Furthermore, the changeover time that is saved is sometimes external, and sometimes internal, since in certain combinations of allergens, there are no changing of molds. This leads another part of the production line to be the bottle neck, and because of this complexity, it is difficult to say exactly how much the GE factor could be improved due to these implementations. It should however be noted that the total changeover time will significantly be lowered, and that even more time can be saved in the future once the state of the production line can be controlled more efficiently and in a more detailed way as explained by the concept of zero vision.

Also, it is difficult to measure how much time the proposed solutions would save, since only concepts for them have been created. The total saved time cannot be measured until these projects have been implemented and running for a while. It is however possible to give an estimate of how much time these solutions would save.
8 References


