UNIVERSITY OF TWENTE.

vitalo global. thermoforming.

6/4/2020

Production line efficiency improvement

Thesis bachelor Sc.

Quentin Cheret
BMS DEPARTMENT: BACHELOR INDUSTRIAL ENGINEERING AND MANAGEMENT

I Table of Contents

II List of figures

III List of tables

IV Reading guide

This research is composed out of two main parts. The first one is the introduction of the research. The second part is the research with all the measurements, calculations and analysis.

Chapter 1

This chapter introduces the company broadly. Moreover, the research will as well be introduced. Next, the code of conduct of the company will be presented. This chapter also includes an introduction to the production line. It gives a complete overview of the research. It will introduce the research design and philosophy, the research goal, the research limitations and the solving approach. Finally, it will also give an overview of my personal code of conduct.

Chapter2

The second chapter is the theoretical framework. This chapter consists of three core concepts. These concepts are lean manufacturing, 5s theory and visual management. To conclude, these core concept are put together to retrieve the basis theory for my research.

Chapter 3

The third chapter is presenting the production flow. All the productions steps will be explained in detail.

Chapter 4

This chapter will present the core problem of the research namely the die-cutting machine. Moreover, a pareto analysis will be conducted and presented to limit the research.

Chapter 5

Chapter five exposes the measurements of the current production line. This chapter will be about data gathering. Multiple measurements will be taken and these measurements will serve as a basis for a comparison at the end of the research.

Chapter 6

The analysis of the measurements retrieved in chapter 5 will be presented in chapter 6. These analysis will give a broad insight in the current production line. Moreover, it will provide a guideline for future research. It will guide the research in the most effective direction to improve the production rate.

Chapter7

This chapter will explain the possible improvement actions. These action will be ranked in function of criteria. A weighted decision matrix will be used for the ranking and the implementations will be selected.

Chapter 8

Chapter 8 is about the implementation of the improvement actions. The implementation steps are presented one after one.

Chapter 9

This chapter is presenting the analysis of the die cutting machine after improvements. The same analysis as in chapter 6 are presented in this chapter. A broad analysis of the production line after the improvements is exposed. To conclude, a final comparison of the yield/hour for the production line is provided.

Chapter 10

The chapter 10 is presenting the conclusion of the research. All the results are presented and summarized in this chapter.

Chapter 11

This chapter is presenting the discussion and future work opportunities.

Chapter 12

This chapter contains all sources that are used for the research.

Chapter 13

Chapter 13 contains the appendices.

V Preface

This thesis is the last step of my 3-year long journey in The Netherlands. I came to The Netherlands to discover the culture, the way of teaching but certainly as well to get to know new people. It is with high pleasure that I can finalise this piece of work symbolising the final point of my learning journey in The Netherlands.

After the opportunity I get to make my first semester of 2019 at the university of Madrid, I would have loved to conduct my research in a company in Spain where I should have done it in first intention. However, everything doesn’t always go as planned. With the corona virus getting spread, borders getting closed and companies which close, there was no other possibility than to put an end to this option. But anyway, I want to thank Ignacio Lopez Ibañez for defining an interesting subject to work on, for all his efforts and the support he put in place in trying everything he could to welcome me in these circumstances. Ignacio, I will remember and the world is short anyway !

After all constrains of the corona virus, I had to be flexible, creative and move forward fast. I went back to look for a new company and a new subject. Finally I could find a company in Belgium which was having an interesting problem to be solved and where I could also be of added value.

The company is one of the world’s leading manufacturers of thermoformed plastic parts. I would like to thank this company and his management to allow me to conduct this research during these uncertain times. Also, I would like to thank all the management team for their important support during my research.

Finally, I would like to thank my supervisor at the university of Twente, Devrim Yazan, who guided me during the whole project. Moreover, I would like to thank Luca Fraccascia for his help during the project. They were the perfect type of support I was needed and expecting: clear advice with a certain degree of delegation: real sparring partners.

Thanks to my parents for their support and help whenever needed.

I hope you`ll enjoy reading this research. Keep safe.

Regards,

Quentin Cheret

PART1: Thesis introduction

1. Introduction

The introduction of the present research consists of two main parts being first the introduction to the company and secondly the research introduction. I will introduce the company focussing on the sectors it is operating. Afterwards, I will introduce my research in 5 steps. The first step will be about the problem description. The next steps will be the discussion of the objective of the research, research limitations and research questions. Finally, I will introduce the deliverables of this research.

1.1 Company introduction

The company where my research is taking place is named Vitalo. It was established in 1936 and has up to now 450 employees around the world with over 50 Mio turnover. It is one of the world's leading manufacturers of thermoformed plastic parts. The company is making short and medium series – so that typically they are not active in the automotive sector, but at the agricultural sector for instance - as well as complete systems for different industry sectors. (Vitalo group "Vitalo home" 2010).

Building on more than 80 years of experience, the company has developed a wide range of expertise in plastics processing technologies, including thin and thick gauge thermoforming, insulation materials processing and thermo- compression of natural and synthetic fibres.

This enables the company to service and focus on various markets including electronics, medical and industrial applications as well as home comfort and mass transport.

It has production plants in China, Slovakia and in Belgium. The company is one of the world's leading manufacturers of plastic parts. The plant I will do my research at is located in Meulebeke in Belgium, near Kortrijk. It is the company's biggest production plant. (*Vitalo home,* 2010).

The company is most active in the thermoforming sector. It has two main core products categories.

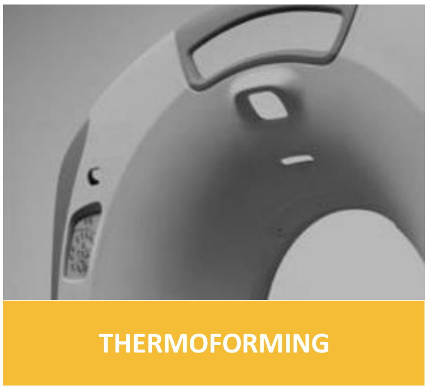

Figure 1: Thermoforming product

The first division is thermoforming plastic parts. Figure 1 is showing a picture of a thermoformed part. In thermoforming you start from an extruded thermoplastic sheet. The sheet will be heated so it becomes flexible and stretchable but retains sufficient strength to withstand gravitational force. Finally, you put a pressure on it or bring vacuum to make the soft plate fitting a mould to give it a dedicated form. The last step is to die cast the product (after cooling) for retrieving a complete finished product. (Schwarzmann, 2019). The company is using two technologies for thermoforming. These technologies are thin gauge thermoforming and thick gauge thermoforming.

Figure 2: Insulation product

The second category produced is insulation. Figure 2 is representing an insulation part. It is producing products used for the acoustic and/or thermal insulation. This is made by compression moulding or foam processing. The company is as well using two technologies for insulation products. These technologies are compression forming and 2d foam processing. These technologies are used for noise insulation as well as heat insulation. My research will be conducted more specifically at one of these lines for the production of insulation products.

The company has a variety of customers from the car industry till the medical sector. All together they generate a turnover of over 50Mio euro with a very stable shareholding. . (*Vitalo home,* 2010)

To conclude, Vitalo is a leading manufacturer of thermoformed plastic parts with over 50Mio of turnover and over 450 employees based in China, Slovakia and Belgium. It has 2 core products categories including thermofoming and insulation. (*Vitalo home,* 2010)

1.1.1 Codes of Conduct of the company

In this part I will specifically present the codes of conduct of the company .

Historically, codes of conducts were implemented as an internal monitor system to ensure internal consistency (Mamic, 2006). I will of course work according to the values of the company.

The value of data-intensive research is highly variable (Mackie & Bradburn, 2000). After discussion about confidentiality with the plant manager, we decided which data could be valuable for competitors. We decided that all data can be published with the exception of some limited points: the mentioning of the exact name of the product and line researched cannot be published.

Firstly, I should work with total integrity and transparency. This means I will work in close relation to people. I will have a weekly meeting with the plant manager. By the way, I intend also to have a weekly update also with my supervisor, by sending him a weekly update on what I did during the week and what I intend to do in the next week. In the weekly planning with the production manager I will present my findings and speak with him about it. If he thinks I should ask someone for validity reason, I will do. In this way I will be in total transparency and communicate with all other people who ask me. This was also approved by the plant manager. I can communicate and ask all information to all the management team.

With the operators on the work floor I will have limited contact and preferably will not communicate too much information or results unless indicated or asked by the management.

Secondly, teamwork is an important value of the company. It is more difficult to work in team in time of corona crisis. However, I will have a weekly meeting with the plant manager and I will get the email of all management team members. This means that I can send emails to the other team members of the management team if I need some info. Therefore, according to me, I can conclude I work in team with them, certainly respecting the necessary safety rules.

Thirdly, agility is one of their values. I will as well include ownership in this part. I will conduct my internship in the time laps of 10 weeks, which is a short time to retrieve data, analyse it, implement it and report it, especially in corona times when all is made more complex and takes more time. The at least weekly contact with the plant manager and my supervisor will certainly make new decisions and/or orientations every week, requiring certainly for flexibility. Therefore, these two values of the company will surely be part of my research and code of conduct.

1.2 Research introduction

In this part I will introduce the research, being the main subject of this thesis. I will introduce the problem, the objective of the research, the research limitations, the research questions and the deliverables of the research. By the end of these chapters, you will have a broad overview of all the different aspects of the research.

1.2.1 Problem description

The present research will be conducted at the biggest production plant of the company located in Meulebeke in Belgium. More specifically, the research will be conducted on one of their production lines dedicated to insulation products.

The actual problem of the production line is the production capacity. The machines can produce, in terms of norm values, significantly more items per hour than what the real output is today. In other words, there is a significant difference - evaluated at roughly 20% - between the theoretical norm values and real production output (reality measurements). This means that the company produces 20% less products than the machines could deliver if they were efficiently used. Therefore, my research consists of finding the core problem of this difference between norm and reality and improving it.

To get an overview of all the possible problems I have made a problem cluster. I made this cluster based on methods described in the book Data Clustering: Algorithms and Applications (Aggarwal & Reddy, 2018). There are a couple of potential core problems which I have identified at the beginning of my research. After my research, first visits and discussions with the plant manager, I have found a couple of expected core problems which are indicated in the picture below and highlighted in different colours. The expected core problems were: the localization of the raw materials, lost time of people, transportation of people and settings of machines.

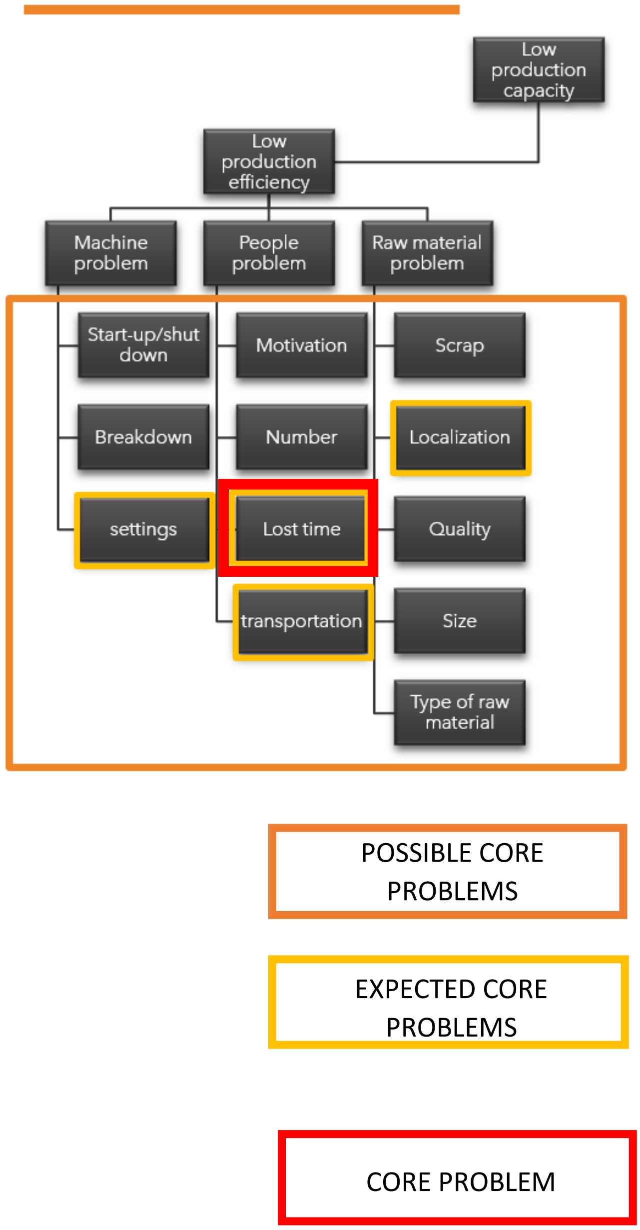

Figure 3: Problem cluster

1.2.2 Core problem identification

In this part I will explain the core problem and explain the actual situation.

Figure 3 shows the problem cluster of the company. After 1 week on the work floor, the core problem was clear. The core problem of the company is the time lost by the workers at the die cutting machine, which was clearly seen as a bottleneck and known from workers and management team. However, neither workers or management team had taken the time to think about a possible improvement the throughput of the die-cutting machine. Therefore, the improvement of the machine was a perfect research subject for my thesis.

The die-cutting machine is slowing down the production flow and increasing the WIP. The machine is a necessary step for almost all products. But, the machine is not always used as it needs an operator to work. However, the operators as well need to do other things like going to take the mould, getting the raw material and delivering the WIP. Therefore, the throughput rate [1]is not as high as the norm value for the machine.

My research will have as goal to increasing the throughput rate of the die cutting machine and thereby increase the overall production rate.

To conclude, the time people are operating at the die cutting machine has to be optimized. The die cutting machine is a key step in production and has to be as efficient as possible to remove the bottleneck. The research will be about the minimization of the time lost at the die cutting machine the optimization of the utilization rate.

1.2.3 Personal code of conduct

In this part I will present my personal code of conduct for conducting my research in an appropriate and safe way. Especially during these times with the corona crisis, it is important for myself but also for others to apply a strict and safe code of conduct.

The world is currently facing a difficult time. With the corona virus active in many countries, people start to think about other things than work. People are worried about their well-being which is a normal reaction to a crisis. (Doherty, 2010).

My personal code of conduct will be fully in line with the values of the company as this is mandatory to be accepted in the management team. I will add some other codes of conduct for myself as I want to retrieve the maximum of experience of this opportunity which is given to me and show the maximum respect to the workers in times of uncertainty.

Firstly, I will add the fact I will deliver work on time as asked by my supervisor from the UT. Moreover, I will as well deliver the same quick and appropriate response to the plant manager who will be my single point of contact at the company. Therefore, I intend to react quickly and be flexible, adapt myself to the wishes of both my supervisor and plant manager.

Secondly, I know from myself sometimes I may be less aware of safety rules. However, this is very important in a production site. I already have had the explanations about the security rules at the company. Thus, I will add to my code of conduct that I will always follow the safety rules and be an example in that kind of case.

Finally, I will dress adequately to follow the un-written company codes. I will adapt myself to the company. I will also adapt myself to the way of working of the company, for example in the way they are classifying everything in excel or in local server. I will try to follow the same kind of reporting so they can easily integrate it in their way of reporting/working.

All in all the important factor is that I will adapt myself to the company and follow their code of conduct completed with my own codes to be able to deliver a qualitative work for the UT and Vitalo.

[1] The throughput rate is an indicator based on the number of products produced divided by the time needed to produce them.

1.2.4 Research design and philosophy of science

In this part I will introduce the research design which is based on a philosophy of science. This part is constructed in two parts. The first part is about the research design and the second part is about the link between my research design and philosophy of science.

There are three possible forms of research design: exploratory, descriptive and explanatory. I will conduct an explanatory research. Explanatory research is conducted in order to identify the extent and nature of cause-and-effect relationships (Cooper & Schindler, 2019).

My research will be an explanatory research. This research method is effective when investigators test an intervention in an already applied setting (Creswell & Creswell 2018). The methods which will be use will be fully based on the lean methodology. I will analyse the research production based on empirical studies and data gathering I will make on the work floor. I will calculate the efficiency of machines on the production line. I will use some key variables to measure the efficiency.
Moreover, the key variables will be calculated in the same way before and after the implementations to highlight the differences and confirm the improvement. The key variable will be

- the production overall efficiency index,
- the time at machine,
- the difference between norm and reality (effective hours versus available hours.),
- the start time, stop time, lost time,
- and the machine operating time.

Afterwards, the flow will be analysed based on lean methodology. After the analysis, I will try to improve the production site with 5s theory and visual management.

Finally, after all the analysis, I will implement the changes into the production line. One week after the implementation I will measure the efficiency of the production line in the same way as I did the first weeks of my research. In this way I will have empirical data supporting my research and improvements (if any). I will base my whole research starting from a theoretical analysis, followed and applied by an analysis based on empirical data and calculations which means I will mostly use quantitative sources to do my research.
However, I will not conduct interviews, neither personal questioning. Moreover, with the current situation of corona, the company advises me to work alone (and certainly keep social distances) and conduct my research in a way to limit contacts with the operators. Therefore, I will not have any subjective sources and will personally measure everything related to my research. Collected data will not be person-related, but process and organisation-related.

My research design is linked to a specific philosophy of science, namely logical positivism. Logical positivism is a philosophical perspective that is committed to the principle of verification, which holds that the meaning and truth of all nontautological statements are dependent on empirical observation ("APA Dictionary of Psychology"). “Logical positivism believes in a “scientific” enterprise in which continuous and cooperative improvements could be made solving fundamental technical problems” (Friedman, 2007).
Therefore, this theory is perfectly in line with the lean approach which will be used during the research. Firstly, I will base my research on data retrieved from calculations and observations held by me. Afterwards I will analyse this data. When the analysis will be done, I will implement improvement actions. Finally, I will measure the improvements on the empirical data which will be retrieved after

the implementation of the improvement actions. I will retrieve the same data form from the same observations before and after the improvement actions.

As a conclusion, the whole research will be based on data and empirical evidence. Therefore, my research design fits in the logical positivism mentality.

1.2.5 Research goal

In this section I will explain the goal of my research. This goal is made to help the company which wants to increase the production rate at the insulation production line.

At this moment, the company has never implemented any form of lean in its production process/sites and is aware of clear potential points of improvement. Still, they are profitable. Therefore, there is a big improvement possible and a possibility to increase the production rate. The company doesn't have a clear and smooth production flow and a lot of time is currently lost by the workers.

The goal of the research is to eliminate the loss of time by operators. I will first measure the time lost and find the main bottleneck. Afterwards, I will look for potential improvements so that the bottleneck can be eliminated or at least reduced and an improvement action plan will be made. Finally, the improvement actions will be implemented and the operating efficiency will be measured again to check/verify the impact of the implemented actions.

All in all, the overall goal of the project is to help the company increase its production rate for the insulation product line. The initial question to support the research goal was:

> *How can the company adapt the operations at the production line to increase the overall production rate?*

This initial question has been roughly discussed with the production manager as well as my supervisor, and I started to study on my own more on lean manufacturing among others. As a result, the main subject of the research has been slightly adapted to the following one:

> *How can the company adapt the operations of the production line to increase the overall production rate while keeping quality high and respecting it's people?*

1.2.6 Research questions

The objective of this part is to introduce the research question for the thesis research. Providing an answer to these questions will be necessary to be able to answer main subject. The different questions are:

1) Which method to increase the overall production rate has been used in the past?
2) How is the plant organized nowadays?
3) What kind of methods or theories are there to help increase overall production rate?
4) How do you implement methods to increase overall production rate??

5) What recommendations can the company be given based on the results of the analysis?

1.2.7 Research limitations

My research will have multiple limitations to keep it feasible and to assure a qualitative thesis.

Firstly, I will have a limitation regarding the production line. I will only focus on one production line regardless of the other ones. Moreover, I will focus my research on insulation products. All in all, I will conduct my research at one production line of insulation products.

Secondly, the data gathering phase will be conducted within a time frame of (only) 2 weeks. Because the available timeframe for conducting my research is 10 weeks, the data gathering has to be done maximum in 2 weeks-time. Consequently, we will consider that these 2 weeks may be taken as representative for normal operating circumstances.

Thirdly, I will limit myself in the type of problems I will deal with to keep the research feasible and qualitative. I will for instance not look at possible improvements when switching from type of raw material, or looking at the setting of machines. Moreover, I will not investigate the level of scrap production or rejected products, even if this aspect may be very relevant to improve again the total output. Additionally, maintenance problems neither the training and/or managing of people will be analysed.

To conclude, my research will focus on one production line in the acoustic department and will specifically and only focus on the efficiency in the time operators are effectively operating the machine, and consequently generating outputs.

1.2.8 Problem solving approach

The problem-solving approach will be based on different phases (Koffman, 1985).
The phases will be organised as follow:

Phases of research

Phase 1	Understand production flow (one week on work floor)
Phase 2	Find core problem
Phase 3	Data gathering regarding core problem
Phase 4	Analysis of data
Phase 5	Improvement proposals
Phase 6	Implementation
Phase 7	Measurement after improvement actions

Table 1: Phases of research

The first phase will be used as a kind of introduction to the company and understanding of processes and products I will gather qualitative sources during my first phase with observations. One mayor feature of qualitative data is that they focus on naturally occurring, ordinary events in natural settings, so that they have a strong view on reality. I will use observation as data gathering method. I will be a participant of the experiment.(Cohen et al., 2018). I will be working with day workers on the work floor to “feel the real life” and way of working. I will follow the production process from raw material to finished products. In this phase I will analyse the production flow and working process. I will consider this phase as an indicator for identifying the core problem. After phase one I will decide about the core problem I will focus on to improve the efficiency of the production line.

The second phase will be the analysis of the data I will collect on the work floor during my first week. After several exchanges and brainstorming sessions with the plant manager and my supervisor I will select one of the possible core problems to focus on: this will become my core problem to be solved.

The third phase will be gathering the data with a single focus on the core problem (for instance, it may be that we focus on one machine, if this machine will be identified as being a bottleneck). I will analyse the core problems in terms of numerical data. I will ask data at the management team of the company (theory) and will combine this data with own measurements on the work floor (practice). Finally, I will put all data together in an excel file and sort them accordingly.

The fourth phase will be the analysis of the data received and collected. This phase will be conducted in excel with calculation, analysis and pivot tables.

The fifth phase will be the reflexion to understand the root causes and define potential improvement actions. These improvements will be based on two theories: 5S and visual management. These are theories the plant manager wants to implement in his factory. My research will be the first project at the company using these theories. I will include the data analysis and based on the analysis I will propose some improvements.

The sixth phase will be the implementation of the improvement actions of at least some of them, to be defined together with the plant manager and my supervisor. I will go again on the work floor and implement the changes proposed.

The seventh and last phase will be the control that proposed actions effectively delivered improvement to the initial problem. This phase will be similar to the third one, with the gathering of the same data on the work floor. By this way, I will be able to measure the possible improvements comparing the operation efficiency before and after actions.

2 Theoretical framework

In this part of the research I will introduce the theory which will be used for my research. There are a lot of lean manufacturing tools to improve production sites (McArdle, n.d.). My research will be an explanation of the base theories of my research being: lean manufacturing, 5s theory and visual management. All three of them will be introduced and explained to an extend it is interesting and applicable in my research.

2.1Concept of Lean manufacturing

In this part of the thesis I will introduce and explain lean manufacturing. I will focus on the parts of the theory which are important for my research.

One thing is for sure. manufacturing has no shortage of buzzwords, catchphrases, homilies, platitudes, advice or New Age dogma. The terminology can be overwhelming. (Hobbs, 2004). Because of there are so many terms to describe lean manufacturing, I will explain clearly and concisely the basic concept and the applicability for my thesis.

In today's business environment enterprises have to face changed conditions such as higher requirements concerning quality, shorter product-life-cycles and costumer demands for shorter delivery times, and the need to reduce continuously manufacturing-costs (Intra & Zahn, 2014).

The benefits of lean manufacturing are evident in factories across the world. Companies have adopted a wide variety of lean tools and techniques and gained many performance improvements. (Ferdousi, 2009). Companies may bet on continuous improvement of the quality of their products / services, to retain customers and gain market share (Roriz, Nunes, & Sousa, 2017).

Lean is a comprehensive set of techniques that, when combined and matured, will allow a company to reduce and then eliminate the Seven wastes (Wilson, 2015). Lean will remove or reduce waste (time, energy, material, etc.) or non-value adding steps in our processes (Womack & Jones,2003).

This system not only will make your company leaner, but subsequently more flexible and more responsive by reducing waste. it is called lean because in the end the process can run:

- using less material
- requiring less investment
- using less inventories
- consuming less space and
- using less people

Even more importantly a lean process Is characterized by flow and predictability that's severely reduces the uncertainties and chaos of typical manufacturing plants (Wilson, 2015).

Many lean tools are available to assist companies in their lean manufacturing journey. These tools constitute a toolbox that helps to eliminate waste in every area of production including customer relations, product design, supplier networks, and factory management. This toolbox enables companies to incorporate less human effort, less inventory, less time to develop products, and less space to become highly responsive to customer demand while producing top-quality products in the most efficient and economical manner possible. (Wang, 2019). Some of these tools are 5s and visual management. I will explain them later on.

It is important to note that lean is focused on improving the customer satisfaction, by improving the quality of products as well as stability of processes. It is not just about churning things out more quickly, but about looking for ways to improve both the product and the system wherever this is possible.

The true spirit of lean is to work with slow, steady purpose, making incremental advancements at a consistent and level pace. This idea leads to lasting improvements. Solutions to problems in a lean company lead to permanent improvements, and this is reflected in the quality of the products and services provided (Reidenbach & Goeke, 2006).

In the lean production context, employees have to accustom to a wide range of new principles, methods, and behavioral routines that radically reshape the way tasks are carried out (Wickramasinghe & Wickramasinghe, 2016).

In my research, the goal is to adapt the production line to increase the production rate. However, as described before, by using the lean toolbox I will eliminate wastes but always keeping the quality high. The social part of the change will not be part of the research. All in all, the goal of my research changed towards:

How can the company adapt the production line to increase the overall production rate of the line while keeping quality high?

There is one final element which is critical for successfully implementing lean methodologies. Many companies overlook arguably the most important aspect, respect for people. Companies should always strive to eliminate waste, but don' t lose sight of most important assets (Reidenbach & Goeke, 2006). Thus, my research goal will also include the people aspect and will become as followed:

How can the company adapt the production line to increase the overall production rate of the line while keeping quality high and respecting it's people?

All in all, I will focus on two tools from the lean toolbox to eliminate waste while keeping quality high and respecting people. I will use 5s theory and visual management. Both will be implemented to reduce waste at the die cutting machine to increase the overall production rate. Lean manufacturing toolbox will remain the basement of my research and will be used to answer my research questions.

2.2 Concept of 5s theory

In this part I will introduce one of the tools of lean that I will implement. 5s theory is as the name indicates, composed out of 5 phases. I will explain the 5 phases shortly.

Factories are living organisms. Organisms move and change in a flexible relationship with their environment (Cao, 2016).

5s theory is a methodology for organizing, cleaning, developing, and sustaining a productive work environment. Improved safety, ownership of workspace, improved productivity, and improved maintenance are some of the benefits of the 5s program (WANG, 2019).

5s is the name of a workplace organization methodology that uses a list of five Japanese words which are seiri, seiton, seiso, seiketsu and shitsuke. Translated into English they all start with the letter s, therefore the name 5s theory. The decision-making process usually comes from a dialogue about standardization which builds a clear understanding among employees of how work should be done (Asefeso , 2011).

There are 5 traditional phases of 5s: sorting, straightening, systematic cleaining, standardizing and sustaining. Lately, there are two other phases which are sometimes included, safety & security. Because of the corona virus, I will also include these additional phases as it is essential to ensure safety and security for the employees. In the following part of the theoretical perspective I will explain each phase briefly.

1. Sorting:
   Eliminate all unnecessary tools, parts, and instructions. Go through all tools, materials, and so forth in the plant and work area. Keep only essential items and eliminated what is not required, prioritizing things as per requirement and keeping them in easy accessible places. Everything else is stored and discarded.

2. Straightening or setting in order/stabilize
   There should be a place for everything and everything should be in its place. The place for each item should be clearly labelled or demarcated. Items should be arranged in a manner that promotes efficient work flow. Each tool, part, supply, or piece of equipment should be kept close to where it will be used in other words, straightening the flow path.

3. Systematic cleaning
   Keep the workplace tidy and organized. At the end of each shift, clean the work area and be sure everything is restored to its place. A key point is that maintaining cleanliness should be part of the daily work not an occasional activity initiated when things get too messy.

4. Standardizing
   Work practices should be consistent and standardized, All work stations should be identical. All employees should be able to work in any station doing the same job with the same tools that are in the same location in every station.

5. Sustaining the discipline or self- discipline
   Maintain and review standards. Maintain focus on this new way of working and do not allow a gradual decline back to the old way.

6. safety
   Safety is key in a successful company. By stating this value explicitly in the 5s theory it promotes the value.

7. Security

In order to leverage security as an investment rather than an expense security is added to the 5s theory. It addresses the risks to key business categories.

To conclude all 7s phases are important. However, due to time limitations I will establish a short term plan with the most obvious improvement actions possible at first look. The theory of 7s will be used as a basement for the improvement actions.

2.3 Concept of Visual management

In this part of the thesis I will explain visual management. Visual management can be seen as part of the 5s theory. I will focus on visual management theory for the improvement actions.

Visual communication is performing a critical role in today's fast paced society. Even though visual communication systems are abundant elsewhere in our lives, however, the benefits of effective visual communication methods are not yet commonly realized in manufacturing organizations around the world (Ortiz & Park, 2018).

The 5s system is designed to create a visual workplace. That is a work environment that is self-explaining, self-ordering and self-improving. In a visual workplace, the out-of-standard situation is immediately obvious and employees can easily correct it (Dennis, 2017).

Visual management creates a standard which allows 'abnormality', in whatever form, to e detected quickly and frees the worker from thinking about the basics of goods management in favour of applying thought processes to more important matters of improvement (Rich, 2012).

I will use visual management to improve the production process. I will reduce the non-machining time by implementing actions which will be based on the visual management theory. This theory will together with 5s theory and lean management be the basis of the improvement actions.

2.4 Conclusion of core concepts

In this part I will link the three concepts to form the theoretical perspective for my research.

All in all, the research will combine three theoretical concepts being: lean manufacturing, 5s theory and visual management. All three of them are correlated and have common points. The core concept which will be used in my research is the elimination of wastes through straightening, standardizing and using visual processes. These improvement actions will be based on the theory but adapted to the company culture and necessities. To conclude, the improvement actions will be based on three theories, lean manufacturing, 5s theory and visual management, and will be adapted to the culture and production line as goal to adapt the production line to increase the overall production rate of the line while keeping quality high and respecting it's people.

PART 2 : RESEARCH

This part will consist of all the phases I did in my research. All phases will be introduced and explained more in detail. Finally, a conclusion has been formed based on all the phases of the research.

3 Understand production flow

In this chapter I will present the production line as it is nowadays. The production will be presented based on the different steps a product has to pass to become a final product. The explanation is based on my personal experience on the work floor.

Figure 4: Raw material blocks

The production line is organised in three steps. The first step is to cut the insulation block into layers of several centimetres. Figure 4 is representing raw material blocks which are the main raw material used in production. The sawing has to be done vertically as well as horizontally. The second step is to die-cut the layers into the wished formats. This is done by a machine but needs a human next to it to operate successfully. The third and last step is the finishing step. In this step all the little parts are put together and some parts are adapted to the wishes of clients if needed.

Figure 5: Layers of raw material

The first step is the sawing of the raw material insulation blocks. The sawing machine is represented in figure 5. The raw material for the production of insulation products is sourced in the form of big cubes of foam of +/- 5 m^3. So they have to be cut into the right format (being the weight as well as the length of the final desired product) to be able to be processed by the die-casting machines later on. This step is fully automated, after the block of foam has been placed in the sawing table. Big stocks of cut insulation layers are available on the production floor, as Work In Progress (WIP) materials.

The second step is the die cutting machine. These central machines in the production flow are simple but require a continuous presence of an operator as they are not automatic. Without operator, these machines are not producing any output.

The last step is the finishing step. After die-cutting, products still need to be fine-tuned to fit with the customer expectations. This results in many potential manipulations and adding parts, such as but not limited to laming some extra parts together, making a hole, adding a sticky part, add needle, …. This last step is a quite complex and very diverse one, as each article/customer has its own expectations. The company produces extremely high quantity of references, which may just differ from each other by a very short detail which has been added/removed during this last step. It is a very human intensive operation, but not crowded. This means that they are not considered as being a bottleneck in the complete production facility.

Finally, the desired article is put into boxes in the warehouse before finally being transported to the client via trucks.

4 Understand core problem: Die cutting machine description

In this part the core problem will be explained. As the core problem is the die cutting machine, the machine will be explained more in detail.

There are a couple of steps which are needed to produce a product with a die-cutting machine. The steps which have to be implemented to form a product (foam) into the desired shape are represented graphically in figure 6 and are the following:

1. The operator of the die-cutting machine has to look for sheets of foams previously cut into the expected dimensions which are located in next to another machine.
2. The operator has to look for a cutting tool in the warehouse were all the knives are classified.
3. The operator puts installs the tool inside the machine.
4. The foam sheet is introduced between the two jaws.
5. The machine cuts the layer into the desired format (the machine is operating by one operator).
6. The shaped product is retrieved and put into a box ready to transport to the finishing step.
7. The operator prepares again from step number 3 for the next production run

These steps are all simple steps. However, the operator has to be present all the time. This means that any time an operator is not present at the machine, the die cutting machine does not operate, and there is no production.

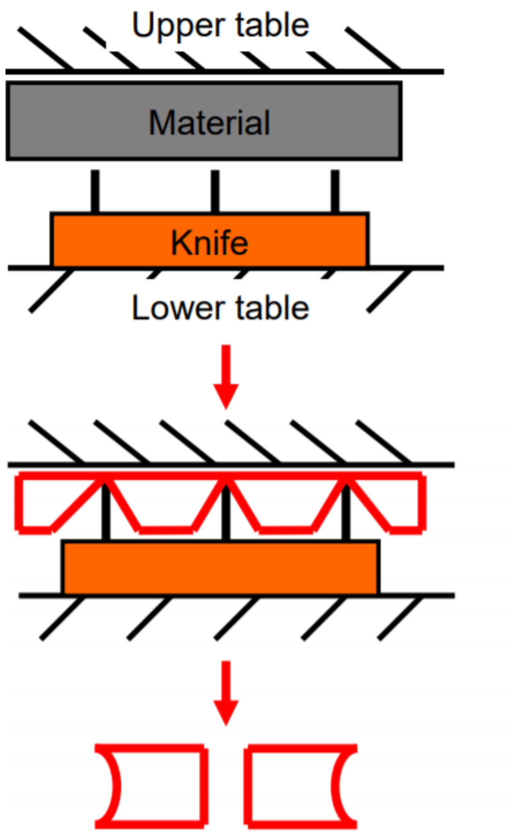

Figure 6: Die cutting steps

4.1 Pareto analysis

In this part I will conduct a pareto analysis.

The pareto analysis is used to classify problems or products based on the cummulative percentage. It followes a 80/20 percentage prinsiple. To make things simple, the products which represent 80% of the cummulative percentage produced goods will be considered important. I will use this tool to limit my research due to time constraints.

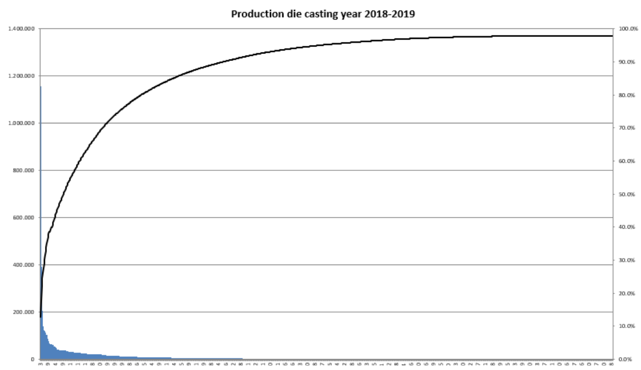

Figure 7: Pareto analysis graph

The pareto analysis was conducted on data from last year. By this way, I had retrieved a representative presentation of the production. Table 2 represents the numbers retreived after the pareto analysis has been conducted. At first sight, the excel file already represents a lot of rows. Each row representing one product. Thus, it is sure that I cannot conduct my research for all products. Moreover, I will have to measure, analyse and imrpove a number of products in a timeframe of 10 weeks only.

I conducted a pareto analysis for all products which were produced during the year 2019. The excel files presents multiple informations. The first thing which is documented in the excel file in the first colllumn is the product-id. This product-id is unique for each product and comes from the ERP system. All data which will be discussed later on will always use the product-id as base reference. Secondly, it shows the number of total pieces produced per product-id. Lastly, it is showimg the cummulative number. This number is composed by summing all previous products and adding the number pieces for the actual products. By the end you retreive the grand total of produced goods. Lastly, the cummulative percentage is represented. This percentage is calculated by deviding the cummulative number with the grand total cummulative number for all products.

The pareto analysis was conducted in order to limit my research to the products which represents 80% cummulitative percentage of all produced products. But, 80% of the cummulative percentage is representing 732 products. After discussion with the management team and the production planner, I decided to limit my research to the ten most produced products. This is due to two factors. The first factor is of course the time limitation. Analysing all products would result in a lot of work. Because the company wants a solution as soon as possible, the focus will be on finding a solution as soon as possible, preferring incremental improvement after that a first, suboptimal, The second factor is the production planning. Because not all products are produced constantly. This means that I wouldn't be able to measure progress on all products. The ten most produced goods will be produced in the two weeks were produced during the two weeks I was on the workfloor. Therefore, it was an obvious decision to limit my research to these products.

The ten most produced products are still representing 32.7% of the total produced products. This percentage can be considered sufficient for representing the other products. Consequently, my research will focus on these top10 products which will serve as reference for the whole production line. All measurements and analysis will be conducted on these ten products.

Production die casting 2018-2019

Product	number of pieces	Cum number	Cum %	10 most produced products
525EL0903	1.156.770	1.156.770	12.9%	1
525EL1057	443.761	1.600.531	17.8%	2
525EL0898	391.140	1.991.671	22.2%	3
525EL0358	206.802	2.198.473	24.5%	4
525EL2704	139.860	2.338.333	26.0%	5
525EL0897	128.239	2.466.572	27.5%	6
525EL2640	124.300	2.590.872	28.8%	7
525EL0896	120.973	2.711.845	30.2%	8
525EL2487	114.850	2.826.695	31.5%	9
525EL2596	114.248	2.940.943	32.7%	10
525EL2463	103.500	3.044.443	33.9%	
525EL2946	103.180	3.147.623	35.0%	
525EL2731	86.760	3.234.383	36.0%	
525EL2979	81.493	3.315.876	36.9%	
525EU0046	77.886	3.393.762	37.8%	
525EL2642	67.983	3.461.745	38.5%	
525EL2823	65.816	3.459.578	38.5%	
525EL2823	65.816	3.527.561	39.3%	
525EL2822	63.209	3.522.787	39.2%	
525EL2822	63.209	3.590.770	40.0%	
525EL2763	60.821	3.583.608	39.9%	
525EL2763	60.821	3.651.591	40.7%	
525EL2641	60.623	3.712.214	41.3%	
525EL2582	53.478	3.765.692	41.9%	
525EL2412	53.377	3.819.069	42.5%	
525EL2947	53.010	3.872.079	43.1%	
525EL2804	50.015	3.922.094	43.7%	
525EL1855	48.485	3.970.579	44.2%	
525EL1839	43.378	4.013.957	44.7%	
525EL2980	42.789	4.056.746	45.2%	
525EL2132	41.700	4.098.446	45.6%	
525EL2390	39.957	4.138.403	46.1%	
525EL0818	39.600	4.178.003	46.5%	
525EL2810	39.600	4.217.603	47.0%	
525EL2446	39.576	4.257.179	47.4%	
525EL2801	39.360	4.296.539	47.8%	
525EL2802	39.000	4.335.539	48.3%	
525EL2803	39.000	4.374.539	48.7%	
525DZ0023	38.874	4.413.413	49.1%	
525EL2799	38.400	4.451.813	49.6%	
525EL2800	38.000	4.489.813	50.0%	
525EL2794	37.320	4.527.133	50.4%	
525EL2811	37.200	4.564.333	50.8%	
525EL2812	37.031	4.601.364	51.2%	
525EL2423	36.793	4.638.157	51.6%	
525EL1672	36.000	4.674.157	52.0%	
525EL2728	35.910	4.710.067	52.4%	
525EL2443	35.117	4.745.184	52.8%	
525EL2809	34.000	4.779.184	53.2%	
525EL2807	33.032	4.812.216	53.6%	
525EL1671	32.950	4.845.166	53.9%	
525EL2730	31.950	4.877.116	54.3%	
525EL2691	31.860	4.908.976	54.6%	
525EL2690	31.765	4.940.741	55.0%	
525EL2574	30.600	4.971.341	55.3%	
525EL2764	30.020	5.001.361	55.7%	
525FR0141	30.000	5.031.361	56.0%	
525EL2162	29.825	5.061.186	56.3%	
525EL2732	29.652	5.090.838	56.7%	
525EL2760	29.402	5.120.240	57.0%	
525EL2761	29.276	5.149.516	57.3%	
525EL2762	29.110	5.178.626	57.7%	
525EL0901	28.718	5.207.344	58.0%	
525EL2373	28.371	5.235.715	58.3%	
525EL0904	28.250	5.263.965	58.6%	
525EL2411	28.008	5.291.973	58.9%	
525EL2549	27.857	5.319.830	59.2%	
525EL2420	27.575	5.347.405	59.5%	
501DB0123	27.530	5.374.935	59.8%	
525EL2376	27.460	5.402.395	60.1%	
525DN0258	26.063	5.428.458	60.4%	
525EL2561	25.663	5.454.121	60.7%	
525EL2796	25.366	5.479.487	61.0%	
525DN0280	25.202	5.504.689	61.3%	
525EL2805	25.128	5.529.817	61.6%	
501BN0588	24.860	5.554.677	61.8%	
525EL2806	24.300	5.578.977	62.1%	

Table 2: Pareto analysis

5 Data gathering

In this part I will gather data on the work floor.

I will conduct the measurements for 10 products as decided in the previous chapter.

5.1 Limitations of measurements

In this part I will list the limitations of the measurements. These limitations are set to keep the research feasible in a time frame of 10 weeks.

There are a couple of limitations to this measurements due to the 10 weeks' time constrain. The main one is the number of measurements. This was already mentioned previously and is the main limitation of the research.

Secondly, the operators are not taken into account in the measurements. Note that the information of the operator is not represented in the measurements. In a time frame of ten weeks, it is impossible to measure ten products with the identical operator.

Thirdly, the measurements will be taken at different moments of the day. This can cause a difference due to fatigue of the operators.

Fourthly, due to the fact the measurements are taken at different time moments, the production team as a whole will be different as well. This means that the transportation routines or the working routines could be different from team to team and change the results of the measurements.

Lastly, the measurements are not taken at the same machine. This is purely due to the fact that each product is not produced or planned at the same machine. Therefore, it is impossible to conduct the measurements at the same machine. However, all machines are identical, so normally the time difference of operating should be minimal.

All in all, these limitations will not be taken into account and I assume that these limitations do not influence the results significantly.

5.2 Measurements of products

In this part I will conduct an interval study for the ten most produced products.

Today, the die cutting machine is limiting the production throughput and causing a bottleneck. This is mainly because it is human powered in comparison with the other machines which are automated. Consequently, it is clear that to increase the production output, the operating time of this machine should be optimized to boost production rate. Therefore, I have conducted a precise interval analysis for each of the 10 most produced products. Figure 10 is an example of the lay-out used to conduct an interval study.

date	07-May	Machine	Red
		cavity	5
		product-id	525EL2596

activity	Starttime	Stoptime	lost time to produce	used time	number of plates / layer	number of die casting movements / plate	number of pieces	yield/hour
getting mould	13:30	13:31		00:01				
getting raw material	13:32	13:36		00:04				
die casting	13:37	13:40		00:03	4	1	20	400
deliviring WIP	13:41	13:45		00:04				
		TOTAAL	**00:09**	**00:03**			**20**	**20**

Figure 8: Interval analysis example

Firstly, for each product info is classified to ensure the correctness and traceability of the measurements. Therefore, the date, machine, cavity and product-id are stated for each measurements. The machines are classified in colours. The cavity represents the number of pieces which can be made out of one movement on one raw material sheet. In this example, it means that the operator can make five pieces with one movement out of one piece of raw material. There are four activities which are needed to make a product which are named in the first column. For each activity, the start and stop time was retrieved and the total used time to the activity has been easily calculated by subtracting the end time by the start time. The die casting line is more detailed as it is the centre of operation. Firstly, the number of plates per layer is representing the layers of raw material which can be die-cut simultaneously. Secondly, the number of die cutting movements represent the movements needed to die-cut the layers. Thirdly, the number of pieces which are produced are retrieved. Finally, the yield per hour is calculated by dividing the number of pieces by the used time * 24. To conclude a total representation is calculated on the bottom of the table. The total yield per hour regardless off the cavity is calculated.

The cavity is important to be able to calculate the total yield per hour regardless of the cavity.

$$total\ yield\ per\ hour\ regardless\ of\ cavity = \frac{number\ of\ pieces}{(lost\ time\ + used\ time) * 24 * cavity}$$

By using this formula, I retrieve the yield per hour regardless of the cavity. This information will be used to analyse the variance of the yields for the different products.

6 Analysis of data :

In this part I will present the findings of the measurements. These findings will serve as basement to compare after the improvements will be conducted.

6.1 Time-frame analysis

In this part I will present the findings of my own measurements on the work floor.

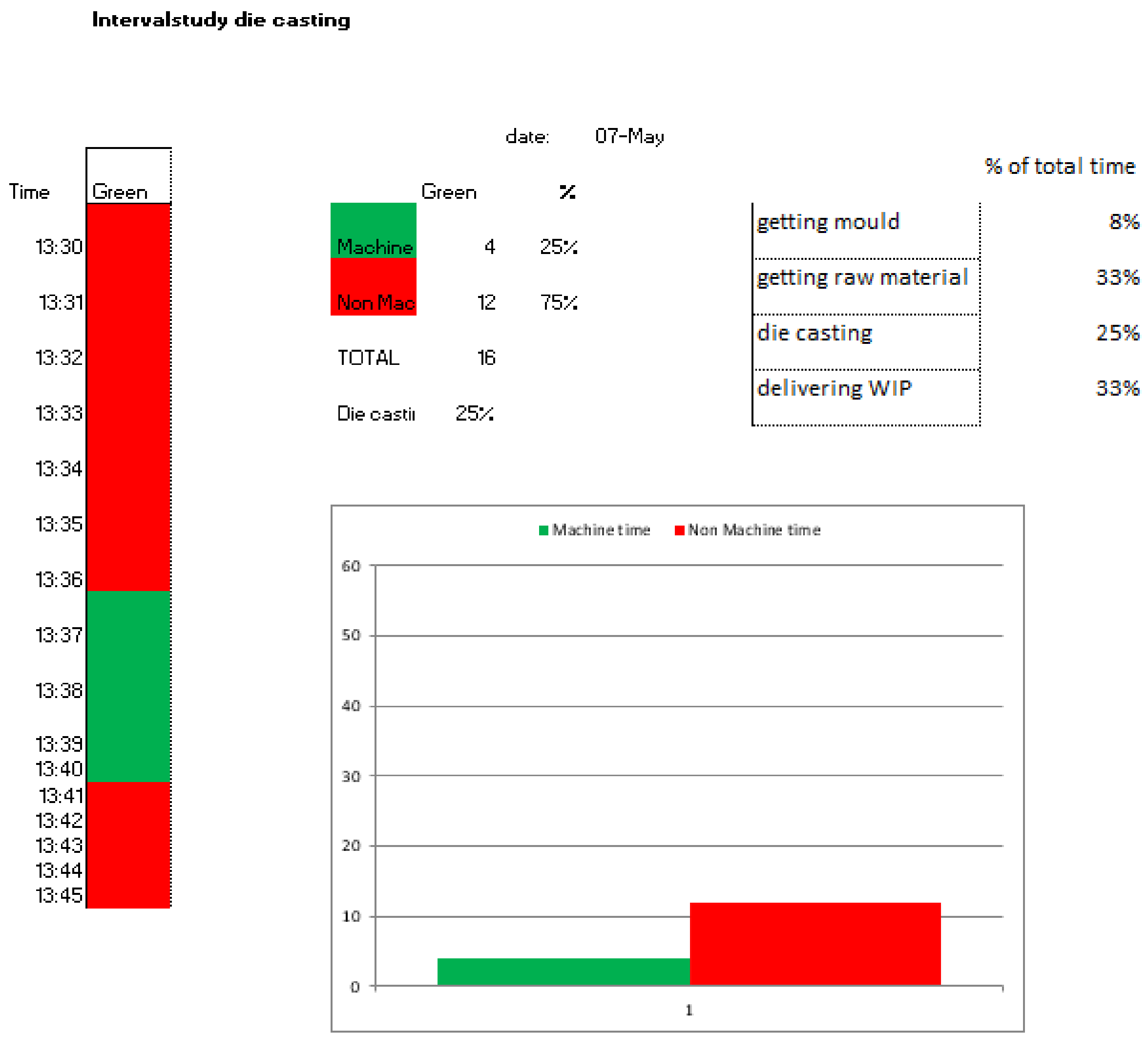

Figure 9: Time frame analysis example

The above figure is the representation of the analysis of the measurements made for each product. The die casting activity is marked as the machining time. The other three activities are counted in the non-machining time. The interval study is started from the time the operator is getting the raw material. Furthermore, all of the activities are represented in percentage of the total time needed for the production. The non-machining time is lost time for the company and therefore should be minimized. Finally, all these individual analysis have been put together to retrieve the following chart:

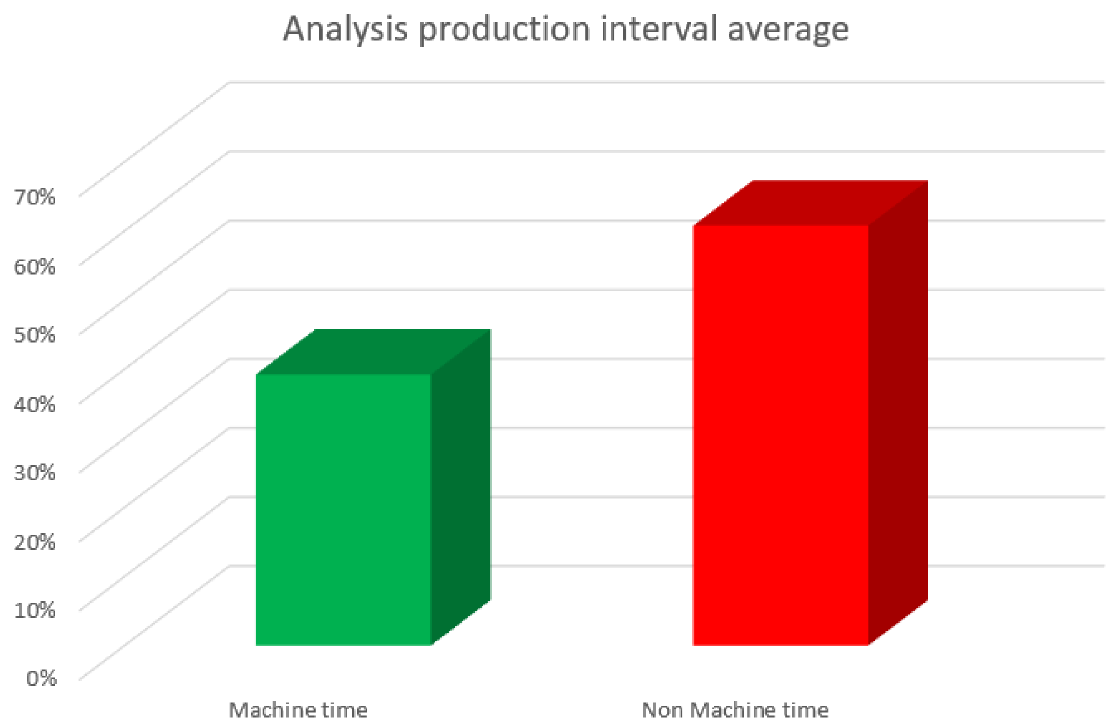

Figure 10: Interval analysis before improvement

The charts represent the % of total time the machining time and non-machining time consist of. It is clear that the non-machining time represents the biggest part of the production time. Moreover, the die-cutting machine is human powered. Therefore, the non-machining time should be highly minimized as the operator is not at the machine during this time which means the machine is simply not working. To get a better overview of the non-machining time, a deeper analysis will be made in the following section.

6.2 Analysis non-machining time

In this part the non-machining part will be analysed more in detail.

The non-machining part is composed out three activities. Therefore, the same graph as in the previous chapter has been changed with the representation of the three activities.

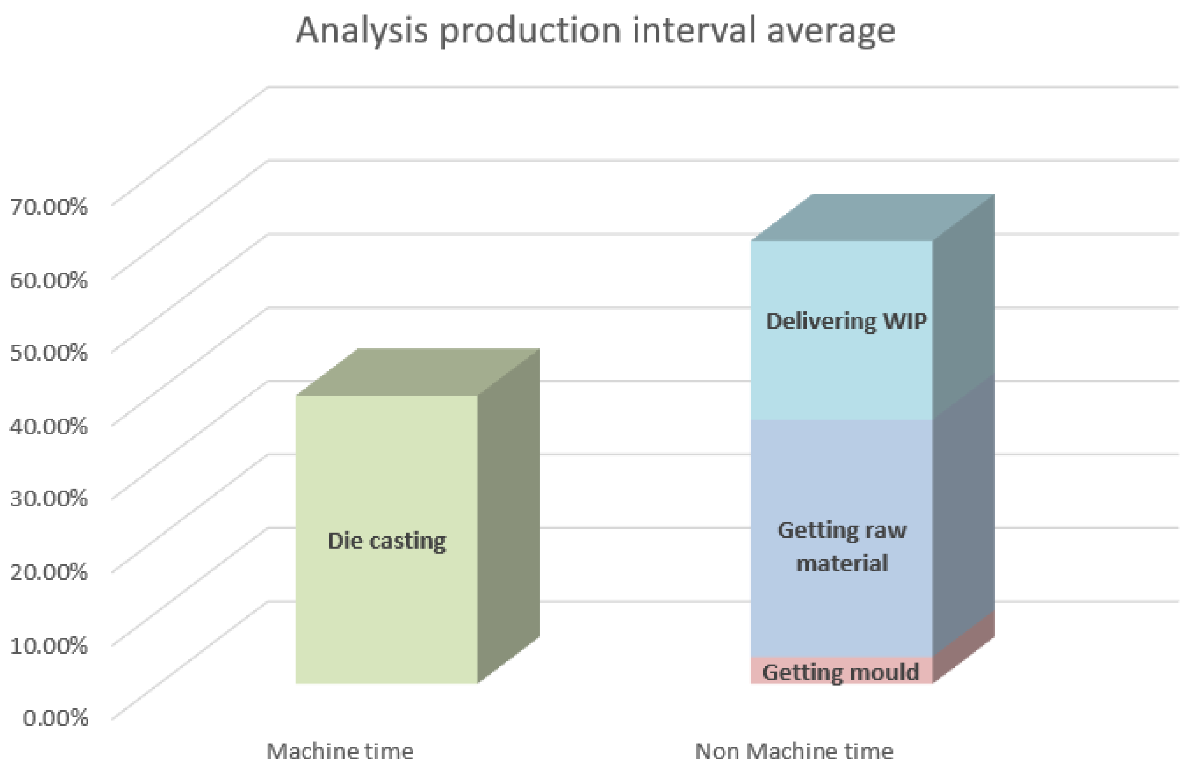

Figure 11: Non-machining time analysis before improvement

It is clear that the activity of getting the mould for the die-cutting machine represents a negligible part of the non-machining time. However, the delivering of the WIP and the activity of getting the raw materials represents together most of the non-machining time. These two activities represent more than 55% of the total time of production.

6.3 Variance non-machining time

In this part a calculation table for the variance of the non-machining time(in %) will be presented.

The non-machining time is clearly the most important part of the production time. To get a better view on the variation of the non-machining time, the following table was conducted. The formula for calculating the variance is:

variation non-machining time

product-id	non-machinig time (x)	average x	(x-average)	(x-average)^2
525EL2596	75	64.3	10.7	114.49
525EL2487	81	64.3	16.7	278.89
525EL0896	80	64.3	15.7	246.49
525EL2640	40	64.3	-24.3	590.49
255EL0897	78	64.3	13.7	187.69
52EL2704	51	64.3	-13.3	176.89
525EL0358	77	64.3	12.7	161.29
525EL0898	51	64.3	-13.3	176.89
525EL1057	54	64.3	-10.3	106.09
525EL0903	56	64.3	-8.3	68.89
total	**643**			**2108.1**

Standard deviation	14.5
average	**64.3**

Table 3: Variation non-machining time before improvement

As shown above, the variance is of 14.5 % . The smallest non-machining time percentage of the total time is 40 %. This is still a significant percentage of the time which is not useful for the production. Because the variance of the non-machining time is high, the uncertainty of production is high as well. This means that the production manager is always counting more time to be able to plan the production correctly. One of the goals of the improvement actions will be to decrease this variance. Consequently, the production planner will be able to plan more effectively with more certainty about production times for these products.

To conclude, the variance of the non-machining time is of 14.5%. This variance is extremely high and prevents the production planner to plan tight and diminish the buffer time for each product. By decreasing this variance and thus decreasing uncertainty, the production planner will be able to plan more effectively and thereby increase production significantly.

6.4 Interval study non-machining time

In this part of the thesis an interval study for the non-machining time will be presented.

The variance of the non- machining percentages has been calculated in the previous chapter. With this variance, an interval study of the non-machining can be made. By conducting an interval study of the non-machining time, a clearer overview of the spread of the data will be represented. The interval analysis table is retrieved as follows:

interval of non-machinig time data			
		left bound	right bound
68% interval	*(x-average) - variance <X< (x-average) + variance*	49.8	78.8
95% interval	*(x-average) - 2*variance <X< (x-average) + 2*variance*	35.3	93.3
99% interval	*(x-average) - 3*variance <X< (x-average) + 3*variance*	20.8	107.8

Table 4: Interval of non-machining time data

It is remarkable that the 68% interval has a left bound of 49.8%. This means that 68% of data is minimum 49.8. Which means that on average 68% of the time, the smallest non-machining time will be of 49.8%.

The 95% interval is already much broader. The left and right bound are more than 55% out of each other. This shows ones again the huge spread of the data. This means there is an uncertainty around the non-machining time. This makes it difficult to plan the production effectively.

To conclude, the left bound of the 68% interval is 49.8%. Which means that 68% of the time the lowest non-machining time will be of almost 50%. However, the 95%, has a left bound of 35.3%, which is still high. But the spread of this 95% interval is of more than 55%, which means there is a huge uncertainty about the non-machining time. To ensure an effective planning of the production, this uncertainty and spread of interval has to be decreased.

6.5 Conclusion current production measurements

In this part the conclusion for the work floor measurements will be given.

To conclude, the production line was analysed using a pareto analysis to limit the research. However, 80 % of the most produced products still represented more than 100 products. Due to time limitations of the research, ten most produced products, which are representing 32% of production will be used for the research. All the measurements were conducted for these products.

A time frame analysis has been conducted. The non-machining time of a production represents on average 64.3% of the time an operator is working at the die cutting machine. More specifically. the time lost for getting the raw material and delivering the WIP is representing on average 57% of the time an operator is working at the die cutting machine.

The variance of the non-machining time is of 14.5%. This variance is significant and is creating uncertainty in the production.

The interval study shows a that 68% of the results for the non-machining time lays between 49.5% and 78.8%. This means the left bound is almost 50%. Which means that 68% of the time, the minimum non-machining time will be of almost 50%. Moreover, the spread of the different intervals are significant, which means the production uncertainty is high.

Therefore, I have decided to focus my research on the optimization of the non-machining tasks, and more specifically the time “lost” in looking for raw materials and in delivering the WIP, with as objective to reduce uncertainty and thereby reduce the variance and the spread of the intervals. This lost time will be referred as logistic time. The final objective will be to increase the throughput rate and thereby the overall production rate.

7 Improvement options

In this part of the thesis I will present the possible improvement actions and finally describe the theoretical improvement possible by executing the chosen improvement action.

7.1 Explanation of possible improvements

In this part an explanation of possible improvement action will be given.

After having analysed the current production line, the conclusion was that the non-machining time of the die casting machine should be minimized as this is the part of the production which takes the most time. It was also clear that by far the most important time lost was due to logistic activities.

Therefore, the management team of the company organised a brainstorming event around the subject, with as main question "how to avoid the operator to be disturbed by logistic tasks?"

A couple of improvements were named in line with lean management, visual management and 5s theory. Here is the list of the different ideas:

- Change the localization of raw material
- Change the localization of finished goods delivery
- Rearrange the placement of die cutting tool in warehouse
- Explanatory screens above die cutting machine
- Colour code for most produced products
- Visual representation of inventory level
- Change the flow and responsibilities: give the responsibility of bringing raw materials to a logistic team

7.2 Weighted decision matrix

In this part I will compare the different improvement actions by the use of weighted decision matrix. Based on this classification I will chose the improvement action I will conduct for my research.

All the improvement actions will probably have a positive effect on the production rate, and will probably best be implemented sooner or later on the work floor. However, due to time constrain I will not be able to implement all of them. On top of that, when changing things in operation floor you have to take into account the change aspect for the operators and all the workers. Changing is not easy, especially if you do things the same way already for years. For these reasons, I decided to be selective and focus on just a few improvements.

Therefore, I have analysed the theoretical improvement together with the management team. First of all, criteria were made. Based on these criteria the improvement options will be ranked. All of the criteria are linked to a specific weight, based on the positive effect it will have on the production site. Finally, the total score is calculated by multiplying the score with the specific weight of the criteria for each options.

Weighted decision matrix

		OPTIONS											
criteria	weighting (1-5)	Option 1		Option 2		Option 3		Option 4		Option 5		Option 6	
		score	total	score	total	score	total	score	total	score	total	score	total
easy to implement	**1**	2	2	5	5	5	5	4	4	1	1	1	1
decrease action time of getting raw material	**5**	1	5	1	5	1	5	3	15	5	25	1	5
decreasae action time of getting mould	**2**	5	10	3	6	1	2	1	2	1	2	1	2
decrease delivery time of Wip	**4**	1	4	1	4	3	12	1	4	1	4	5	20
increase knowledge of procees for operator	**1**	1	1	5	5	5	5	1	1	4	4	4	4
increase visibility of warehouse	**2**	1	2	1	2	1	2	5	10	4	8	4	8
	TOTAL		24		27		31		36		44		40
	RANKING		6		5		4		3		**1**		**2**

option 1	Rearrange the placement of die cutting tool in warehouse
option 2	Explanatory screens above die cutting machine
option 3	Colour code for most produced products
option 4	Visual representation of inventory level
option 5	Change the localization of raw material
option 6	Change the localization of finished goods delivery

Table 5: Weighted decision matrix

The final ranking is as follows:

1) Option 5
2) Option 6
3) Option 4
4) Option 3
5) Option 2
6) Option 1

Due to time constraints, only two of the following options will be implemented. Thus, option 5 and 6 will be implemented and analysed in this research.

These options are the change of localisation of raw material and of the finished goods. The other improvement actions will be discussed in the recommendation section of the thesis. By this way, I give the information and possibility to the management team to implement these changes as well in the future.

Practically, this newly-created section would be located just in front of the die cutting machines which means that the operator will just have to take the raw material there and place it under the die- cutting machine. The same was done for the finished goods section we located on the other side of the machine. Doing so, the raw material section and finished goods section are placed next to each other in front of the die-cutting machines. Consequently, the operator "just" has to get the raw material behind him/her, place it into the machine and put the die-cut insulation layer in the section for finished goods. The operators will be much more focused on the die-cutting machine as he

- Doesn't have to go physically in another location (warehouse) to get the raw materials and bring back the end product
- Remains much more focused on his main task, being operating the die-cutting machine

This would enable him/her to win a significant amount of time which was spent previously for finding the raw material and delivering the die-cut product at the perfection line.

To get an idea before implementing this action, I have made an estimation on the time it would take to get the raw material and deliver the finished goods after the change of location of the raw material and finished products section. As these sections are in front of the die-cut machine, the time to get raw material is of +/- 2 minutes, the same applies for the delivery of the finished products. Therefore, these improvement actions are significantly beneficial for the production rate. Thus, I have got the green light from the site manager to implement these changes and change a part of the production line.

8 Implementation of actions

In this part of the thesis the implementation steps will be explained.

Two improvement actions have been chosen to improve the production rate. The first improvement action was to change the localization of raw material. The second improvement action was to change the localization of finished goods delivery.

Both of them have been implemented simultaneously on the work floor. The first step was to free some space for the raw material and finished goods. This step consisted of eliminating the work in progress which was stocked there as well as some tools which were rarely used but still located next to the die-cutting machines. I calculated that there was a need of minimum 20 m2 to be available to store sufficient quantity for one or maximum 2 batches of raw material layers. The second step was to design a delimited space. To design and free some space, a new material flow has to be drawn, discussed with the management, before being presented and explained to the operators, and finally being implemented. After all these materials and products were cleaned up and transported to the place where they had to be, the delimitation of the sections had to be made.

As safety is also a key concept of my research, I did this with the help of the safety advisor to ensure the safety of the operators and of the operations. The delimitation of the zone was measured and painted on the floor to make it clear and follow the principals of visual management.

The third step was the teaching of the workers who are transporting the raw material as the finished goods. These workers had to change their normal way of working, their routine. As explained previously, a change in a routine is never easy. Therefore, I made a presentation with the explanation of the change and the benefits for the company. At first, the logistic workers reacted negatively as this would mean more and different work for them. However, after having discussed with the production manager and presented the benefits for the company and the potential gain of production rate, they were favourable for the change. Of course a lot of on-the-floor coaching was required, certainly during the first shifts, to make them understand what we were expecting from them and why. Finally, the workers adapted themselves to the change. After two weeks of changing their routines, all were favourable to the change of location as it was significantly more efficient for the production. Thus, the production manager adopted the change and the localization for the raw material and finished good has been definitely changed.

9 Analysis of improvement actions

In this section I will report the measurements after the improvement actions were implemented. The same analysis will be conducted

9.1 Time frame analysis after improvement

In this part I will present the results of the time frame analysis after the improvement actions have been installed.

A time frame analysis has been conducted for the ten most produced products. As explained in the chapter from the time frame analysis before improvement, this time frame analysis gives a broad view on the time an operator spends on each task in order to make a product. The goal of the improvements were to decrease the non-machining time. Especially, decrease the action of getting the raw material and delivering the WIP. These two actions have been tackled by making an area in front of the die cutting machine for raw material and WIP. The wished outcome of the improvement actions is to decrease the non-machining time so the operator can focus on his main task being operating the machine.

A time frame analysis was made and the average outcomes for the ten products after improvement results in the following chart:

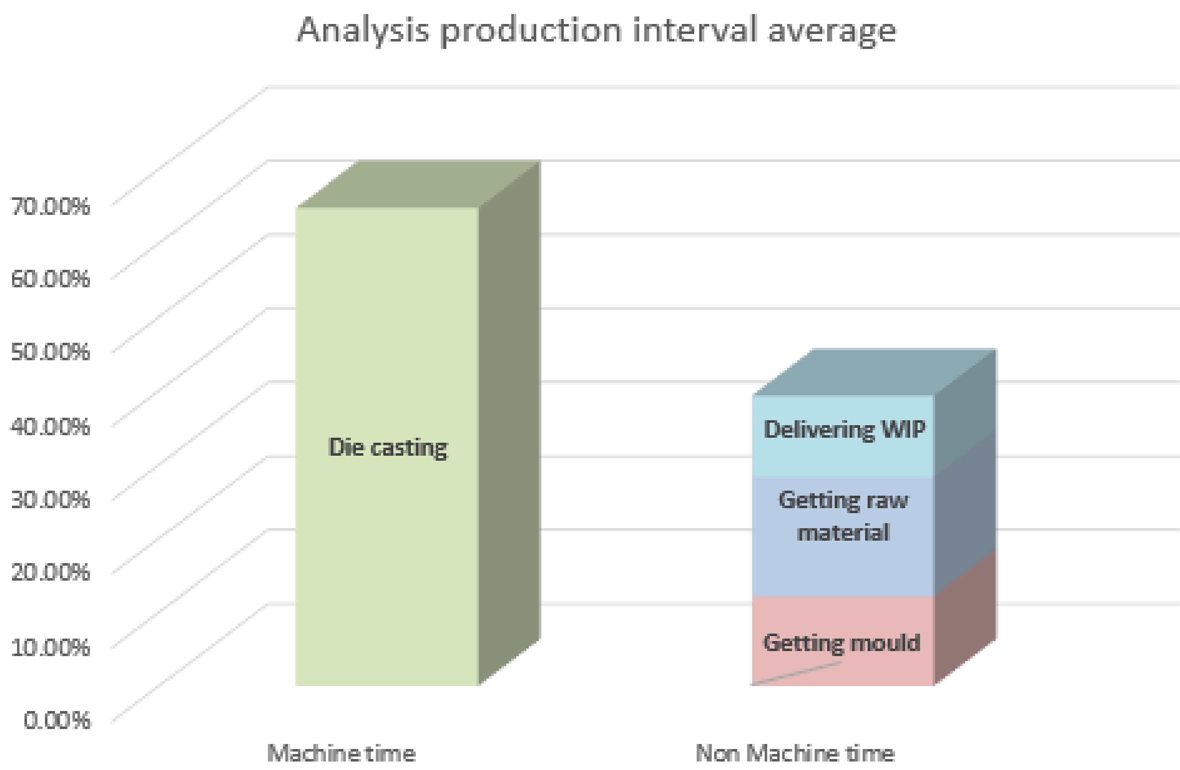

Figure 12: Analysis production interval after improvement

It is clear the die casting is taking the most % of total time which is a positive result. Moreover, the % of time of the action of delivering WIP and getting raw material relative to getting mould is more equilibrated. The getting mould action represents 12.16% of the total production time. Whereas the action of getting raw material and delivering WIP represents together 27% of the time. Moreover, the die casting action which is clearly the most % of the time, represents after improvement 64.78% of the time. All in all, one can clearly see the die casting action is taking the % of the total time of production. However, the goal was to increase the yield and diminish the variation of the non-machining time. Therefore, in the following chapters I will present the findings of the time analysis and the variation and interval study of non-machining time.

9.2 Variation analysis non-machining time after improvement

In this part I will present the findings of the variation analysis of the non-machining time after improvement.

One of the goals of the research has been to decrease the variation and the average time of non-machining activities. The results of the change in variation and the change of average yield/hour are extremely positive.

variation non-machining time after improvement

product-id	non-machinig time (x)	average x	(x-average)	(x-average)^2
525EL2596	50	41.4	8.6	73.96
525EL2487	48	41.4	6.6	43.56
525EL0896	51	41.4	9.6	92.16
525EL2640	35	41.4	-6.4	40.96
255EL0897	47	41.4	5.6	31.36
52EL2704	26	41.4	-15.4	237.16
525EL0358	44	41.4	2.6	6.76
525EL0898	45	41.4	3.6	12.96
525EL1057	32	41.4	-9.4	88.36
525EL0903	36	41.4	-5.4	29.16
total	**414**			**656.4**

variance	**8.1**
average	**41.4**

Table 6:Variation non-machining time after improvement

The variance of the non-machining time is only of 8%. This number is extremely positive and useful for the production planner. Another factor which is positive is the average of all the non-machining task together. The average is of 41.4% of the total time. Thus, the die cutting action, which should be the main focus of the operator, is now representing approximately 60% of the total production time.

All in all, the variance is of only 8% and the average non-machining time is of 41.4%. This means at first sight that the improvement actions had a positive impact on the non-machining time.

9.3 Interval study non-machining time after improvement

In this part of the research an interval study for the non-machining time will be presented.

One of the goals of the improvement actions has been to decrease the spread of the interval of the non-machining time. Meaning that the production planner would be able to plan with more certainty the production and thereby increase the productivity of the plant. The interval study of the non-machining time after improvement looks as follows:

interval of non-machinig time data			
		left bound	**right bound**
68% interval	*(x-average) - variance <X< (x-average) + variance*	33.3	49.5
95% interval	*(x-average) - 2*variance <X< (x-average) + 2*variance*	25.2	57.6
99% interval	*(x-average) - 3*variance <X< (x-average) + 3*variance*	17.1	65.7

Table 7: interval of non-machining after improvement

It is very positive to see that the spread of the 68% interval is of only approximately 15%. Moreover, the right bound which represent the highest number, is 49.5%. This means that on average 68% of time the non-machining time will be between 33.3% and 49.5%. Thus, 68% of the time the die cutting action will be the action which will take the most time of the productions. This was one of the goals of the improvements as this should be the main operator task. However, the overall goal of the research was to increase the production rate. Therefore, I will present an analysis of the yield/hour regardless of the cavity to have a complete view of the production site.

To conclude, the interval study of the non-machining time data shows a 68% interval which has a left bound of 33.3% and a right bound of 49.5%. This means the spread of the interval is about 15%, with 68% of the time having the non-machining time that represents between 33.3% and 49.5% of the total production time.

9.4 Comparison yield/ hour before/after improvements

In this part I will compare the yield per hour for the ten most produced products.

The variation of the non-machining time diminished, the average nonmachining time dimisnished, the interval spread diminished, but the overall wished outcome was to increas ethe througput rate or in other words, to increase the yield/hour. Therefore, an analysis has been made before and after the improvement actions.

analysis before	yield/hour

product-id	yield/hour (x)	average x	(x-average)	(x-average)^2
525EL2596	20	24.1	-4.1	16.81
525EL2487	24	24.1	-0.1	0.01
525EL0896	34	24.1	9.9	98.01
525EL2640	15	24.1	-9.1	82.81
255EL0897	21	24.1	-3.1	9.61
52EL2704	17	24.1	-7.1	50.41
525EL0358	28	24.1	3.9	15.21
525EL0898	32	24.1	7.9	62.41
525EL1057	32	24.1	7.9	62.41
525EL0903	18	24.1	-6.1	37.21
total	**241**			**434.9**

variance	**6.6**
average	**24.1**

Table 8: Analysis yield/hour before

The avergae yield per hour before the improvement actions is of 24.1 pieces per hour with a variance of 6.6 pieces. This yield/hour has been calculated for the ten most produced products. The yield/ hous has been calculated with taking into account the cavity of th different parts. Therefore, this is a realistic representation of the production rate of the production site.

The same analysis has been conducted after the improvement. The following chart represents the outcomes:

analysis after	yield/hour

product-id	yield/hour (x)	average x	(x-average)	(x-average)^2
525EL2596	24	32	-8	64
525EL2487	29	32	-3	9
525EL0896	37	32	5	25
525EL2640	24	32	-8	64
255EL0897	40	32	8	64
52EL2704	43	32	11	121
525EL0358	30	32	-2	4
525EL0898	41	32	9	81
525EL1057	28	32	-4	16
525EL0903	24	32	-8	64
total	**320**			**512**

variance	**7.2**

average	**32**

Table 9: Analysis yield/hour after

The avergae yield/hour for the ten most produced goods is of 32 parts per hour with a variance of 7.2 pieces.

In comparison with the previous yield/hour analysis, the yield significantly increased. Thus, the production rate increased. However, the variance also increased by aproximately 1 piece/hour. This can be seen as a bad sign. However, the average yield increased by approximately 6 pieces which means that the overall benefits from the improvement actions are significant positive for the production rate of the company.

To conclude, the yield/hour increased by 6 pieces with an avergae total of 32 pieces. The variance increase by 1 piece. All in all, the production rate increased signifiantly after the improvement actions were implemented.

10 Conclusion

In this part I will discuss the conclusion and findings of my research. The conclusion will consist of the results of the research as well as the different steps token to come to this result.

Initially, I expected to perform my research study in Spain in the company URSA in Tarragona. However, whereas everything was settled and agreed with the company – subject, conditions, as well as all practical aspects - the unexpected arrived: the Corona pandemic.

Of course, it was not a nice thing and I was definitely not happy with. But I always do my best to turn negative impacts into positive opportunities. This is what I did here and I went immediately again to look for another solution in my mother country (Belgium). My search brought me to this plastic company having a recurring problem in its production efficiency and wanted to solve it.

This is how I defined the project I worked for, resulting in the research question:

How can the company adapt the operations of the production line to increase the overall production rate while keeping quality high?

I started this research by understanding the company and its products, before talking about the problem. I spend 2 weeks on the floor next to workers and operators in order to familiarise myself with the products (raw materials, work in progress and end products) the processes, and the flow of materials. It was a real opportunity for me to discover a new environment and a real production facility.

The several discussions with the production manager, the management team and my supervisor at the university enabled me to better fine-tuned the subject. Fine tuning means certainly to better understand the question, define and study the tools and process I will have to apply to provide solutions to it, but also – and this is an important learning point for me also – to eliminate to aspects I would not tackle, and doing this from the beginning. This really enabled me to remain focused on the core problem I had to solve, and on the core potential root causes I had to analyse.

Very early, the operations representing the bottleneck in the throughput has been identified as being the die-cutting machine. I spent 2 weeks on the floor again to focus on this machine, and analyse the operating efficiency of the top ten most produced articles. As these machines are manually operated and cannot produce without having constantly an operator in front of them, each time the operators were leaving their position operating the machine, was a lost time for production. Out of my observations, the lost time could reach more than 65%. In other words, the effective operating/producing time was lower than 40%...for a machine which is already the bottleneck of the production floor.

Even if the management and the management team were not completely surprised by my findings, they were quite shocked by the values as they didn't expect to lose so much time. The brainstorming session organised generated many ideas, and the most significant and easy-to-apply ones have been listed and ranked in according to multiple criteria. I selected two actions which were ranked as the two most valuable ones based on the weighted decision matrix. These improvement actions were chosen because:

1) implementable by an external person

2) feasible within a timeframe of 10 weeks

3) involving a limited amount of human and organisation changes on the work floor

These 2 improvement points were both linked to logistics aspects, one being the location of the raw material, needed to start operations, and the second one to the location of Work in Progress products, after being die-cut. Making space free in a crowded production area is never a piece of cake. It took me hours and hours to think, discuss, understand and finally reach a consensus on where we could put these 2 products, and how to implement the changes. These discussions took place with many different people from various departments. Finally the following decision was taken:

- Where: just in front on the die-cutting machine to avoid any time to be lost by the operator
- How: making the area free, explaining to operators and logistic workers, marking that clearly on the floor and on the wall using visual management principles, and finally following up every hours and every day

I learned a lot in how to implement things which seems very obvious to me, but really not as obvious at it seems to implement.

Finally, after the change being implemented, I took again 2 weeks to perform exactly the same measurements as the one I did at the beginning for the top 10 references. As we saw in the beginning, there is important discrepancies between the products we measure, and the measurement time is limited. So all necessary cautions being taken, the conclusions were very significant and positive: we could prove that, by changing the location of the raw materials and finished goods, the production yield/ hour increase by approximately 6 pieces to a total of 32 pieces on average per hour. Knowing that the die cutting machine is very directly linked to the overall production efficiency (output), these changes have had a huge impact on the overall production line.

As a conclusion, this last part of my 3-years journey at Bachelor enabled me to learn an enormous amount of things. Next to the fact that I have been forced to be very resilient, flexible and creative in the choice of my research company, I have been confronted with a real acute problem which I had to solve by applying theories to practice, partly as self-study and analysis and partly in team, and finally apply actions on the work-floor, which was new to me.

All in all, and cherry on the cake for me, is that the implemented actions really generated very significant improvements on the work floor, so that the company also was extremely happy with the outcome and the way we could steer and conduct this research during these uncertain and strange times of Corona.

11 Discussion and future work

In this part of the research, several discussion points will be discussed in the following paragraph. Moreover, orientation for future work will be provided.

The research had a final goal of improving the production rate of the production line. Two improvement actions were implemented to increase this rate. The results after implementation were rather positive. The production rate increase and the non-machining time decreased. Although the results of the implementation can be seen as rather positive, there are doubts that the results are applicable to other production lines. This has not been tested and therefore it is uncertain that the same methodology for improvement will work on other production lines.

To decide which implementation will be applied to improve the production line, a decision had to be taken. This decision was taken by attributing weight to different criteria using a weighted decision matrix. Finally, the score has been decided by a few members of the management team. It would be better to let the criteria and weight be decided and assessed by more members of the management team or even the whole management team. However, even if the weights were interchanged, the methodology would be the same.

The analysis of data has been done using statistical methods. However, not all statistical analysis methods have been used to get a broader overview on the situation. Other statistical test could be beneficial to get a better understanding of the situation and improvements.

Another discussion point is the implementation of other improvement actions discussed in the research. This research is conducted as a bachelor's assignment. This has the consequence of having a time limitation of 10 weeks to conduct the research. Therefore, a selection on the improvement actions had to be taken and all statistical analysis couldn't be conducted due to time constraints.

Finally, a lot of social aspects regarding change of an organisation have been left aside. This is due to the sudden corona virus. Change management is often linked with lean production or 5s theory. However, all social contact has been forbidden during the 10 weeks of the research. One of the most important factors during these ten weeks was safety, safety for other but also safety for myself.

Therefore, a future oriented work topic could be about analysing the mentality of the people and the reaction to this change. A lot of studies have been made on change management and could surely be used in this context. For future work, this research could be implemented in another company and be finalized with a change management inside. This aspect was done by the management of the company and has been out of scope for me due to tine limitations and safety reasons.

Furthermore, an analysis could be made about the effect of each of the improvement actions. By this way a clear view can be made of the efficiency of each improvement action separately.

12 Bibliography

Aggarwal, C. C., & Reddy, C. K. (2018). Data Clustering: Algorithms and Applications. Boca Raton, FL: Chapman and Hall/CRC.

Asefeso, A. (2011). 5s lean manufacturing (key to improving net profit). Place of publication not identified: Lulu Com.

Cao, Y. (2016). Zuo ye yuan 5S huo dong: Ke shi hua che jian deu shi wu da zhi zhu = 5S for operators: 5pillars of the visual workplace. Bei jing: Ji xie gong ye chu ban she.

Cohen, L., Manion, L., & Morrison, K. (2018). Research methods in education. London: Routledge.

Creswell, J. W., & Creswell, J. D. (2018). Research design: Qualitative, quantitative, and mixed methods approaches. Los Angeles: Sage Publications.

Dennis, P. (2017). Lean production simplified: A plain-language guide to the world's most powerful production system. Boca Raton: CRC Press, Taylor & Francis Group.

Doherty, G. W. (2010). From crisis to recovery: Strategic planning for response, resilience, and recovery. Ann Arbor, MI: Rocky Mountain Region Disaster Mental Health Institute Press.

Ferdousi, F. (2009). An Investigation of Manufacturing Performance Improvement through Lean Production: A Study on Bangladeshi Garment Firms. International Journal of Business and Management, 4(9). doi:10.5539/ijbm.v4n9p106

Friedman, M. (2007). Reconsidering logical positivism. Cambridge: Cambridge University Press.

Hobbs, D. P. (2004). Lean manufacturing implementation: A complete execution manual for any size manufacturer. Boca Raton, FL: J. Ross Pub.

Home. (2018, April 06). Retrieved May 12, 2020, from https://www.vitalo.net/

Intra, C., & Zahn, T. (2014). Transformation-waves – A Brick for a Powerful and Holistic Continuous Improvement Process of a Lean Production System. Procedia CIRP, 17, 582-587. doi:10.1016/j.procir.2014.01.097

Koffman, E. B. (1985). A problem solving approach. Reading, MA: Addison-Wesley.

Logical Positivism | Definition of Logical Positivism by ... (n.d.). Retrieved June 12, 2020, from https://www.merriam-webster.com/dictionary/logical%20positivism

Mackie, C. D., & Bradburn, N. M. (2000). Improving access to and confidentiality of research data: Report of a workshop. Washington, DC: National Academy Press.

Mamic, I. (2006). Implementing codes of conduct: How businesses manage social performance in global supply chains. Geneva, Switzerland: ILO.

McArdle, Colin. “14 Of the Best Lean Manufacturing Tools for Improving Productivity .” Kaizen Kulture, www.kaizenkulture.com/blog/14-of-the-best-lean-manufacturing-tools-for-improving-productivity.

Ortiz, C. A., & Park, M. (2018). Visual controls: Applying visual management to the factory. Place of publication not identified: Productivity Press.

Reidenbach, R. E., & Goeke, R. W. (2006). Value-driven channel strategy: Extending the lean approach. Milwaukee, WI: ASQ Quality Press.

Rich, N. (2012). Lean evolution: Lessons from the workplace. Cambridge: Cambridge Univ. Press.

Roriz, C., Nunes, E., & Sousa, S. (2017). Application of Lean Production Principles and Tools for Quality Improvement of Production Processes in a Carton Company. Procedia Manufacturing, 11, 1069-1076. doi:10.1016/j.promfg.2017.07.218

Schindler, P. S., & Cooper, D. R. (2019). Business research methods. New York, NY: McGraw-Hill Education.

Schwarzmann, P. (2019). Thermoforming: A practical guide. Cincinnati, OH: Hanser Publications.

WANG, J. X. (2019). LEAN MANUFACTURING: Business bottom-line based. S.l.: CRC PRESS.

Wickramasinghe, G., & Wickramasinghe, V. (2016). Effects of continuous improvement on shop-floor employees' job performance in Lean production. Research Journal of Textile and Apparel, 20(4), 182-194. doi:10.1108/rjta-07-2016-0014

Wilson, L. (2015). How to implement lean manufacturing. New York: McGraw-Hill.

Womack, J. P., & Jones, D. T. (2010). Lean Thinking: Banish Waste and Create Wealth in Your Corporation. Riverside: Free Press.

13 appendix

13.1 Systematic literature review

Search string	scope	date	# of entries
Search protocol for google scholar			
“lean production improvement”	“title, abstract, keywords”	04/05/2020	85
“lean production methods”	“title, abstract, keywords”	04/05/2020	43
Total endnote			**6**
Selecting based on criteria			-78 -41
Remove after complete reading			-3

Nr.	Criteria	Reason for exclusion
1	Pre 2007 articles	The topic of lean production is rapidly changing, so articles before 2007 are not relevant.
2	Articles not in English	These are not readable for the researcher.
3	Topics which is not related to process improvement	These do not relate to the research.
4	Editorials, newspaper articles and other forms of popular media will be excluded.	These cannot be a considered a source for my research.
5	Cited by minimum 10 people	This criteria sorts out non-relevant sources.

Nr.	Title	Author	subject
1	An Investigation of Manufacturing Performance Improvement through Lean Production: A Study on Bangladeshi Garment Firms	F. Ferdousi	Impact of lean production
2	Application of Lean Production Principles and Tools for Quality Improvement of Production Processes in a Carton Company	C Roriz, E Nunes, S Sousa	Applications of lean production
3	Transformation-Waves – A Brick for a Powerful and Holistic Continuous Improvement Process of a Lean Production System	C Intra, T Zahn	Continuous improvement
4	Application of information technologies and principles of lean production for efficiency improvement of machine building enterprises	M. Razzhivina	Lean production and information technologies

5	Effects of continuous improvement on shop-floor employees' job performance in Lean production	G.L.D. Wickramasinghe	Impact of lean production
6	The application of lean production control methods within a process-type industry: the case of hydro automotive structures	D Powell, E Alfnes, M Semini	Lean production control methods

13.2 Full pareto analysis table

Production die casting 2018-2019	

Product	**number of pieces**	**Cum number**	**Cum %**	**10 most produced products**
525EL0903	1.156.770	1.156.770	12.9%	1
525EL1057	443.761	1.600.531	17.8%	2
525EL0898	391.140	1.991.671	22.2%	3
525EL0358	206.802	2.198.473	24.5%	4
525EL2704	139.860	2.338.333	26.0%	5
525EL0897	128.239	2.466.572	27.5%	6
525EL2640	124.300	2.590.872	28.8%	7
525EL0896	120.973	2.711.845	30.2%	8
525EL2487	114.850	2.826.695	31.5%	9
525EL2596	114.248	2.940.943	32.7%	10
525EL2463	103.500	3.044.443	33.9%	
525EL2946	103.180	3.147.623	35.0%	
525EL2731	86.760	3.234.383	36.0%	
525EL2979	81.493	3.315.876	36.9%	
525EU0046	77.886	3.393.762	37.8%	
525EL2642	67.983	3.461.745	38.5%	
525EL2823	65.816	3.459.578	38.5%	
525EL2823	65.816	3.527.561	39.3%	
525EL2822	63.209	3.522.787	39.2%	
525EL2822	63.209	3.590.770	40.0%	
525EL2763	60.821	3.583.608	39.9%	
525EL2763	60.821	3.651.591	40.7%	
525EL2641	60.623	3.712.214	41.3%	
525EL2582	53.478	3.765.692	41.9%	
525EL2412	53.377	3.819.069	42.5%	
525EL2947	53.010	3.872.079	43.1%	
525EL2804	50.015	3.922.094	43.7%	

525EL1855	48.485	3.970.579	44.2%
525EL1839	43.378	4.013.957	44.7%
525EL2980	42.789	4.056.746	45.2%
525EL2132	41.700	4.098.446	45.6%
525EL2390	39.957	4.138.403	46.1%
525EL0818	39.600	4.178.003	46.5%
525EL2810	39.600	4.217.603	47.0%
525EL2446	39.576	4.257.179	47.4%
525EL2801	39.360	4.296.539	47.8%
525EL2802	39.000	4.335.539	48.3%
525EL2803	39.000	4.374.539	48.7%
525DZ0023	38.874	4.413.413	49.1%
525EL2799	38.400	4.451.813	49.6%
525EL2800	38.000	4.489.813	50.0%
525EL2794	37.320	4.527.133	50.4%
525EL2811	37.200	4.564.333	50.8%
525EL2812	37.031	4.601.364	51.2%
525EL2423	36.793	4.638.157	51.6%
525EL1672	36.000	4.674.157	52.0%
525EL2728	35.910	4.710.067	52.4%
525EL2443	35.117	4.745.184	52.8%
525EL2809	34.000	4.779.184	53.2%
525EL2807	33.032	4.812.216	53.6%
525EL1671	32.950	4.845.166	53.9%
525EL2730	31.950	4.877.116	54.3%
525EL2691	31.860	4.908.976	54.6%
525EL2690	31.765	4.940.741	55.0%
525EL2574	30.600	4.971.341	55.3%
525EL2764	30.020	5.001.361	55.7%
525FR0141	30.000	5.031.361	56.0%
525EL2162	29.825	5.061.186	56.3%
525EL2732	29.652	5.090.838	56.7%
525EL2760	29.402	5.120.240	57.0%
525EL2761	29.276	5.149.516	57.3%
525EL2762	29.110	5.178.626	57.7%
525EL0901	28.718	5.207.344	58.0%
525EL2373	28.371	5.235.715	58.3%
525EL0904	28.250	5.263.965	58.6%
525EL2411	28.008	5.291.973	58.9%
525EL2549	27.857	5.319.830	59.2%
525EL2420	27.575	5.347.405	59.5%
501DB0123	27.530	5.374.935	59.8%
525EL2376	27.460	5.402.395	60.1%
525DN0258	26.063	5.428.458	60.4%
525EL2561	25.663	5.454.121	60.7%
525EL2796	25.366	5.479.487	61.0%
525DN0280	25.202	5.504.689	61.3%
525EL2805	25.128	5.529.817	61.6%

501BN0588	24.860	5.554.677	61.8%
525EL2806	24.300	5.578.977	62.1%
525EL1854	24.138	5.603.115	62.4%
525EL1771	24.091	5.627.206	62.6%
525EL1770	24.026	5.651.232	62.9%
525DO0638	24.000	5.675.232	63.2%
525EL1966	23.686	5.698.918	63.4%
525EL2808	23.040	5.721.958	63.7%
525EL2458	22.862	5.744.820	64.0%
525EL2981	22.757	5.767.577	64.2%
525EL2435	22.396	5.789.973	64.5%
525EL2074	22.345	5.812.318	64.7%
525EL1983	22.280	5.834.598	65.0%
525DZ0019	22.232	5.856.830	65.2%
525EL1984	22.123	5.878.953	65.4%
525EL2285	21.840	5.900.793	65.7%
525DN0268	21.794	5.922.587	65.9%
525EL1768	21.662	5.944.249	66.2%
525EL1968	21.612	5.965.861	66.4%
525EL2643	21.554	5.987.415	66.7%
525EL2286	21.510	6.008.925	66.9%
501DB0126	21.367	6.030.292	67.1%
525EL1967	21.363	6.051.655	67.4%
525EL2789	20.919	6.072.574	67.6%
525EL1969	20.880	6.093.454	67.8%
525EL2644	20.850	6.114.304	68.1%
525EL2570	20.728	6.135.032	68.3%
525EL2291	20.700	6.155.732	68.5%
525EU1237	20.582	6.176.314	68.8%
525EL2790	20.502	6.196.816	69.0%
525EL2860	20.200	6.217.016	69.2%
525EL1926	20.000	6.237.016	69.4%
525EU1236	19.090	6.256.106	69.6%
525EL2727	19.058	6.275.164	69.9%
525EL2814	19.000	6.294.164	70.1%
525EL1676	18.525	6.312.689	70.3%
525EL2271	18.511	6.331.200	70.5%
525EL2813	18.400	6.349.600	70.7%
525EL1928	18.018	6.367.618	70.9%
525EL2795	17.101	6.384.719	71.1%
525EL2733	16.650	6.401.369	71.3%
525DZ0025	16.208	6.417.577	71.4%
525EL2659	16.200	6.433.777	71.6%
525EL2756	16.128	6.449.905	71.8%
525EL2378	16.037	6.465.942	72.0%
525EL2792	16.007	6.481.949	72.2%
525EL2283	15.840	6.497.789	72.3%
525EL2612	15.590	6.513.379	72.5%

525EL2962	15.420	6.528.799	72.7%
525EL0912	15.201	6.544.000	72.9%
525EL2965	15.115	6.559.115	73.0%
525EL1929	15.100	6.574.215	73.2%
525ET0066	15.000	6.589.215	73.4%
525EL0905	14.916	6.604.131	73.5%
501BN0500	14.542	6.618.673	73.7%
525EL2559	14.040	6.632.713	73.8%
525EL2783	14.000	6.646.713	74.0%
525EL1838	13.746	6.660.459	74.1%
501BN0376	13.685	6.674.144	74.3%
525EL2966	13.532	6.687.676	74.5%
501BN0590	13.500	6.701.176	74.6%
525EL2488	13.500	6.714.676	74.8%
525EL2698	13.444	6.728.120	74.9%
525EL2391	13.281	6.741.401	75.0%
525EL2937	13.210	6.754.611	75.2%
525EL2371	13.119	6.767.730	75.3%
525EL2963	13.104	6.780.834	75.5%
525EL2785	12.969	6.793.803	75.6%
525EL2699	12.960	6.806.763	75.8%
525EL3007	12.768	6.819.531	75.9%
525EL2964	12.627	6.832.158	76.1%
525EL2564	12.623	6.844.781	76.2%
525EL2560	12.600	6.857.381	76.3%
525EL0906	12.555	6.869.936	76.5%
525EL2457	12.511	6.882.447	76.6%
525EL0913	12.245	6.894.692	76.8%
525EL2125	12.104	6.906.796	76.9%
525EL2581	12.100	6.918.896	77.0%
525EL2918	11.976	6.930.872	77.2%
525EL1831	11.910	6.942.782	77.3%
525EL2470	11.794	6.954.576	77.4%
525EL2388	11.600	6.966.176	77.6%
525EL2863	11.521	6.977.697	77.7%
525EL2859	11.520	6.989.217	77.8%
525EL2844	11.509	7.000.726	77.9%
525EL2853	11.500	7.012.226	78.1%
525EL2984	11.323	7.023.549	78.2%
525EL2855	11.250	7.034.799	78.3%
525EL2387	11.160	7.045.959	78.4%
525EL2857	11.040	7.056.999	78.6%
525EL2861	11.040	7.068.039	78.7%
525EL2854	10.800	7.078.839	78.8%
525EL2856	10.800	7.089.639	78.9%
525EL2465	10.786	7.100.425	79.0%
525EL2986	10.465	7.110.890	79.2%
501DB0172	10.040	7.120.930	79.3%

501DB0124	10.020	7.130.950	79.4%
501DB0175	10.020	7.140.970	79.5%
501DB0125	10.008	7.150.978	79.6%
525EL2793	10.007	7.160.985	79.7%
525DY0107	9.991	7.170.976	79.8%
501BN0511	9.800	7.180.776	79.9%
525EL2788	9.613	7.190.389	80.0%
525EL1987	9.383	7.199.772	80.2%
525EL2338	9.249	7.209.021	80.3%
501BN0586	9.244	7.218.265	80.4%
525EL2569	9.188	7.227.453	80.5%
525EL2985	9.177	7.236.630	80.6%
525EL2205	9.088	7.245.718	80.7%
525EL2339	9.040	7.254.758	80.8%
525EL1989	9.012	7.263.770	80.9%
525EL2275	9.000	7.272.770	81.0%
525EL2931	8.970	7.281.740	81.1%
525EL2453	8.959	7.290.699	81.2%
525EL2595	8.903	7.299.602	81.3%
525EL2977	8.716	7.308.318	81.4%
525EL1864	8.640	7.316.958	81.5%
525EL2842	8.640	7.325.598	81.6%
525EL2848	8.640	7.334.238	81.6%
222GE0213	8.638	7.342.876	81.7%
525EL2754	8.628	7.351.504	81.8%
525EU1140	8.549	7.360.053	81.9%
525EL2394	8.500	7.368.553	82.0%
525EL2755	8.500	7.377.053	82.1%
222GE0214	8.358	7.385.411	82.2%
525EL2440	8.256	7.393.667	82.3%
501BN0371	8.232	7.401.899	82.4%
525EL2439	8.221	7.410.120	82.5%
525EL2716	8.100	7.418.220	82.6%
525EL2657	8.015	7.426.235	82.7%
525EL2932	8.006	7.434.241	82.8%
525EL2384	8.003	7.442.244	82.9%
525EL2426	8.000	7.450.244	82.9%
525EU1139	8.000	7.458.244	83.0%
525EL2983	7.980	7.466.224	83.1%
525EL2176	7.800	7.474.024	83.2%
525EL2324	7.790	7.481.814	83.3%
525EL2989	7.683	7.489.497	83.4%
525EL2709	7.655	7.497.152	83.5%
525EL2916	7.650	7.504.802	83.5%
525EL2752	7.555	7.512.357	83.6%
525EL2746	7.480	7.519.837	83.7%
525EB0155	7.400	7.527.237	83.8%
525EL2179	7.400	7.534.637	83.9%

525EL1675	7.390	7.542.027	84.0%
525EL1927	7.354	7.549.381	84.0%
525EL2571	7.271	7.556.652	84.1%
525EL2273	7.270	7.563.922	84.2%
525EL3017	7.221	7.571.143	84.3%
525EL2867	7.200	7.578.343	84.4%
525EL3016	7.105	7.585.448	84.4%
525EL2772	7.081	7.592.529	84.5%
525EL2797	7.004	7.599.533	84.6%
525EL2798	7.000	7.606.533	84.7%
525EL0871	6.948	7.613.481	84.8%
525EL2374	6.800	7.620.281	84.8%
525EL2468	6.755	7.627.036	84.9%
525EL2372	6.745	7.633.781	85.0%
525EL2987	6.720	7.640.501	85.1%
525EL2484	6.718	7.647.219	85.1%
525DN0368	6.713	7.653.932	85.2%
525DZ0027	6.698	7.660.630	85.3%
525EL3006	6.650	7.667.280	85.4%
501DB0130	6.554	7.673.834	85.4%
525EL2552	6.510	7.680.344	85.5%
525EL1566	6.444	7.686.788	85.6%
526DS0063	6.440	7.693.228	85.6%
525DV0017	6.300	7.699.528	85.7%
525EL2933	6.290	7.705.818	85.8%
525EL2432	6.103	7.711.921	85.9%
525EL2467	6.025	7.717.946	85.9%
525DN0383	6.020	7.723.966	86.0%
525EL0875	6.008	7.729.974	86.1%
525EL2466	6.000	7.735.974	86.1%
525EL2482	5.964	7.741.938	86.2%
525EL1824	5.940	7.747.878	86.3%
525EL1825	5.940	7.753.818	86.3%
525EL0894	5.934	7.759.752	86.4%
525EL3066	5.840	7.765.592	86.5%
525DN0257	5.800	7.771.392	86.5%
525EL2845	5.795	7.777.187	86.6%
525EL2851	5.769	7.782.956	86.6%
525EL2841	5.760	7.788.716	86.7%
525EL2866	5.760	7.794.476	86.8%
525EU1252	5.760	7.800.236	86.8%
525EL2849	5.608	7.805.844	86.9%
525EU1162	5.596	7.811.440	87.0%
525EU1152	5.500	7.816.940	87.0%
525EL2865	5.460	7.822.400	87.1%
525EL2620	5.450	7.827.850	87.1%
525EL2274	5.400	7.833.250	87.2%
525EL2469	5.400	7.838.650	87.3%

525EL2594	5.400	7.844.050	87.3%
525EL2621	5.400	7.849.450	87.4%
525EL2975	5.390	7.854.840	87.4%
525EL2429	5.370	7.860.210	87.5%
501BN0589	5.124	7.865.334	87.6%
525EL2663	5.120	7.870.454	87.6%
222GE0211	5.109	7.875.563	87.7%
525EL2982	5.025	7.880.588	87.7%
525EU1158	5.000	7.885.588	87.8%
525EU1159	5.000	7.890.588	87.8%
525EU1163	5.000	7.895.588	87.9%
222GE0333	4.942	7.900.530	88.0%
525EL2385	4.914	7.905.444	88.0%
525EL2606	4.843	7.910.287	88.1%
525DN0366	4.800	7.915.087	88.1%
525EL2424	4.782	7.919.869	88.2%
525EL2943	4.771	7.924.640	88.2%
525EL1670	4.745	7.929.385	88.3%
222GE0210	4.688	7.934.073	88.3%
222GE0239	4.637	7.938.710	88.4%
525ET0070	4.630	7.943.340	88.4%
222GE0240	4.618	7.947.958	88.5%
525EL2169	4.600	7.952.558	88.5%
525EL2701	4.560	7.957.118	88.6%
525EL0816	4.524	7.961.642	88.6%
525EL2430	4.522	7.966.164	88.7%
525EL2343	4.500	7.970.664	88.7%
525EU1138	4.500	7.975.164	88.8%
525EU1151	4.500	7.979.664	88.8%
525EL2425	4.485	7.984.149	88.9%
525EL2710	4.470	7.988.619	88.9%
502BT0067	4.420	7.993.039	89.0%
525EL2858	4.400	7.997.439	89.0%
525EL3032	4.382	8.001.821	89.1%
525EL2003	4.356	8.006.177	89.1%
525EL2778	4.338	8.010.515	89.2%
525EL2577	4.320	8.014.835	89.2%
525EL1991	4.284	8.019.119	89.3%
525EL2938	4.206	8.023.325	89.3%
525EL2649	4.200	8.027.525	89.4%
525EL2123	4.186	8.031.711	89.4%
525EL2501	4.112	8.035.823	89.5%
525EL2881	4.062	8.039.885	89.5%
525DN0347	4.055	8.043.940	89.5%
525EL2658	4.050	8.047.990	89.6%
525DN0274	4.036	8.052.026	89.6%
525EL2656	4.030	8.056.056	89.7%
525DZ0028	4.024	8.060.080	89.7%

525EL1863	4.007	8.064.087	89.8%
525EL0814	4.000	8.068.087	89.8%
525EL1813	4.000	8.072.087	89.9%
525EL2647	4.000	8.076.087	89.9%
525EL2651	4.000	8.080.087	90.0%
525EB0159	3.980	8.084.067	90.0%
525EL2696	3.930	8.087.997	90.0%
525EL2654	3.912	8.091.909	90.1%
525DN0345	3.856	8.095.765	90.1%
525EL2974	3.844	8.099.609	90.2%
525EL2766	3.840	8.103.449	90.2%
525EL2864	3.840	8.107.289	90.3%
501BN0755	3.837	8.111.126	90.3%
525EL2880	3.825	8.114.951	90.3%
525EL2973	3.820	8.118.771	90.4%
525EL2652	3.804	8.122.575	90.4%
525EL2174	3.800	8.126.375	90.5%
525DN0346	3.795	8.130.170	90.5%
525EL2748	3.780	8.133.950	90.6%
525DN0378	3.778	8.137.728	90.6%
525EL2646	3.774	8.141.502	90.6%
525EL2655	3.750	8.145.252	90.7%
525EL1871	3.738	8.148.990	90.7%
525EL2542	3.680	8.152.670	90.8%
525EL2874	3.669	8.156.339	90.8%
525EL2624	3.660	8.159.999	90.8%
525EL2991	3.653	8.163.652	90.9%
525EL2337	3.636	8.167.288	90.9%
525EL2993	3.624	8.170.912	91.0%
525EL2999	3.622	8.174.534	91.0%
525EL2650	3.608	8.178.142	91.0%
525EL2653	3.607	8.181.749	91.1%
525EL2952	3.604	8.185.353	91.1%
525EL2175	3.600	8.188.953	91.2%
525EL2180	3.600	8.192.553	91.2%
525EL2181	3.600	8.196.153	91.2%
525EL2648	3.600	8.199.753	91.3%
525EL2753	3.600	8.203.353	91.3%
501BN0754	3.590	8.206.943	91.4%
525EL2014	3.538	8.210.481	91.4%
525EL2012	3.524	8.214.005	91.4%
525EL2182	3.504	8.217.509	91.5%
525EL2483	3.500	8.221.009	91.5%
525EL2586	3.500	8.224.509	91.6%
525EL3000	3.490	8.227.999	91.6%
525EL3003	3.490	8.231.489	91.6%
525EL2015	3.489	8.234.978	91.7%
525EL2994	3.466	8.238.444	91.7%

525EL2995	3.440	8.241.884	91.8%
525EL3011	3.436	8.245.320	91.8%
525EL3012	3.432	8.248.752	91.8%
525EL2178	3.400	8.252.152	91.9%
525EL2608	3.394	8.255.546	91.9%
525EL3001	3.380	8.258.926	91.9%
525EL3002	3.380	8.262.306	92.0%
525EL1996	3.377	8.265.683	92.0%
525EL2017	3.345	8.269.028	92.1%
525DZ0022	3.300	8.272.328	92.1%
525EL2177	3.210	8.275.538	92.1%
525EL1850	3.204	8.278.742	92.2%
525EL2625	3.200	8.281.942	92.2%
525EL2016	3.133	8.285.075	92.2%
525EL2942	3.113	8.288.188	92.3%
501BN0608	3.100	8.291.288	92.3%
525EE0042	3.004	8.294.292	92.3%
525DZ0032	2.996	8.297.288	92.4%
525EL2998	2.970	8.300.258	92.4%
525DN0361	2.947	8.303.205	92.4%
525EL2819	2.901	8.306.106	92.5%
501DB0156	2.840	8.308.946	92.5%
525EL2660	2.820	8.311.766	92.5%
525DN0371	2.808	8.314.574	92.6%
525DN0370	2.750	8.317.324	92.6%
525DN0313	2.710	8.320.034	92.6%
525EL2828	2.704	8.322.738	92.7%
525EL2751	2.700	8.325.438	92.7%
525EU1268	2.661	8.328.099	92.7%
525EL2603	2.641	8.330.740	92.7%
525EL0872	2.621	8.333.361	92.8%
525EL2313	2.611	8.335.972	92.8%
525EL2161	2.604	8.338.576	92.8%
525EL2315	2.600	8.341.176	92.9%
525EL1988	2.598	8.343.774	92.9%
525EL0874	2.590	8.346.364	92.9%
525EL2303	2.588	8.348.952	92.9%
525DN0367	2.556	8.351.508	93.0%
525DN0203	2.544	8.354.052	93.0%
525DN0369	2.530	8.356.582	93.0%
525EL3030	2.526	8.359.108	93.1%
525EL2334	2.500	8.361.608	93.1%
525EL2572	2.487	8.364.095	93.1%
525EL2555	2.413	8.366.508	93.1%
501DB0140	2.407	8.368.915	93.2%
501BN0587	2.406	8.371.321	93.2%
525DN0350	2.400	8.373.721	93.2%
525EB0172	2.400	8.376.121	93.2%

525EL1737	2.400	8.378.521	93.3%
525EL2302	2.400	8.380.921	93.3%
525EL1840	2.387	8.383.308	93.3%
222GE0174	2.380	8.385.688	93.4%
525EL3035	2.371	8.388.059	93.4%
525EL2821	2.368	8.390.427	93.4%
501BN0594	2.352	8.392.779	93.4%
525EL0915	2.343	8.395.122	93.5%
525EL2843	2.323	8.397.445	93.5%
525EL2850	2.300	8.399.745	93.5%
525EL3018	2.300	8.402.045	93.5%
525EL2556	2.294	8.404.339	93.6%
525EL1296	2.290	8.406.629	93.6%
525EL3062	2.280	8.408.909	93.6%
525EL2272	2.259	8.411.168	93.6%
525EL2588	2.250	8.413.418	93.7%
525EL2846	2.247	8.415.665	93.7%
525EL2988	2.223	8.417.888	93.7%
525EL2156	2.216	8.420.104	93.7%
501DB0139	2.213	8.422.317	93.8%
525EL2566	2.208	8.424.525	93.8%
525EL2450	2.207	8.426.732	93.8%
525EL1567	2.200	8.428.932	93.8%
525EL2847	2.196	8.431.128	93.9%
525EL2840	2.171	8.433.299	93.9%
525EL2852	2.165	8.435.464	93.9%
525EL1885	2.159	8.437.623	93.9%
525DV0038	2.122	8.439.745	94.0%
525EB0173	2.100	8.441.845	94.0%
525EL2447	2.064	8.443.909	94.0%
501BN0561	2.045	8.445.954	94.0%
525EL1636	2.041	8.447.995	94.0%
525EL1876	2.020	8.450.015	94.1%
525DS0601	2.018	8.452.033	94.1%
525EL1635	2.015	8.454.048	94.1%
525EL1878	2.011	8.456.059	94.1%
525EL2341	2.010	8.458.069	94.2%
525DN0206	2.000	8.460.069	94.2%
525EL0817	2.000	8.462.069	94.2%
525EL1875	2.000	8.464.069	94.2%
525EL2342	2.000	8.466.069	94.2%
525EL2607	2.000	8.468.069	94.3%
525EB0156	1.982	8.470.051	94.3%
525EL2485	1.980	8.472.031	94.3%
525EL3053	1.949	8.473.980	94.3%
525EL1856	1.930	8.475.910	94.4%
525EL3010	1.920	8.477.830	94.4%
525EL1639	1.912	8.479.742	94.4%

525EL2889	1.911	8.481.653	94.4%
525EL1869	1.910	8.483.563	94.4%
525EL1866	1.908	8.485.471	94.5%
525EL2953	1.868	8.487.339	94.5%
525EL1889	1.851	8.489.190	94.5%
525EL2587	1.845	8.491.035	94.5%
525EL2153	1.824	8.492.859	94.5%
525EL0908	1.820	8.494.679	94.6%
525EL1622	1.820	8.496.499	94.6%
525EL2890	1.804	8.498.303	94.6%
525GA0090	1.802	8.500.105	94.6%
525EL2623	1.801	8.501.906	94.6%
525EL2622	1.800	8.503.706	94.7%
525DN0204	1.777	8.505.483	94.7%
525EL2990	1.775	8.507.258	94.7%
525DN0372	1.764	8.509.022	94.7%
525EL2254	1.750	8.510.772	94.7%
525EL2523	1.740	8.512.512	94.8%
525EL2816	1.685	8.514.197	94.8%
525EL2356	1.680	8.515.877	94.8%
525EL2380	1.680	8.517.557	94.8%
525EL2381	1.680	8.519.237	94.8%
525EL3048	1.680	8.520.917	94.9%
525EL1648	1.678	8.522.595	94.9%
525DN0386	1.673	8.524.268	94.9%
525EL3072	1.666	8.525.934	94.9%
506AX0015	1.640	8.527.574	94.9%
525EL1868	1.635	8.529.209	95.0%
525DO0639	1.620	8.530.829	95.0%
525EL2585	1.620	8.532.449	95.0%
525EL0917	1.602	8.534.051	95.0%
525EL1997	1.602	8.535.653	95.0%
525EL2160	1.600	8.537.253	95.0%
525EL2357	1.560	8.538.813	95.1%
525EL2196	1.504	8.540.317	95.1%
525EL3077	1.502	8.541.819	95.1%
501BN0647	1.500	8.543.319	95.1%
501BN0648	1.500	8.544.819	95.1%
525EL1835	1.500	8.546.319	95.1%
525EL2818	1.500	8.547.819	95.2%
525EL3021	1.500	8.549.319	95.2%
501BN0687	1.494	8.550.813	95.2%
525EL2579	1.490	8.552.303	95.2%
501BN0684	1.486	8.553.789	95.2%
525EU1278	1.449	8.555.238	95.2%
525EB0157	1.440	8.556.678	95.3%
525EL3019	1.440	8.558.118	95.3%
525EL2820	1.429	8.559.547	95.3%

525EL3075	1.408	8.560.955	95.3%
525EL3078	1.408	8.562.363	95.3%
525EL1663	1.404	8.563.767	95.3%
525EL2896	1.400	8.565.167	95.4%
525EL2873	1.384	8.566.551	95.4%
525EL2578	1.383	8.567.934	95.4%
525EL2976	1.380	8.569.314	95.4%
501BN0685	1.360	8.570.674	95.4%
525EL3079	1.360	8.572.034	95.4%
501BN0688	1.343	8.573.377	95.4%
525EL3088	1.340	8.574.717	95.5%
525DS0687	1.330	8.576.047	95.5%
525EL2619	1.329	8.577.376	95.5%
525EL2834	1.323	8.578.699	95.5%
501BN0682	1.320	8.580.019	95.5%
525EL2576	1.309	8.581.328	95.5%
525EL2307	1.305	8.582.633	95.5%
501BN0686	1.302	8.583.935	95.6%
525EL1674	1.302	8.585.237	95.6%
525EL2304	1.302	8.586.539	95.6%
525EL2300	1.300	8.587.839	95.6%
525EL2305	1.300	8.589.139	95.6%
525EL2308	1.300	8.590.439	95.6%
525EL2294	1.293	8.591.732	95.6%
525EL2309	1.293	8.593.025	95.7%
501BN0673	1.289	8.594.314	95.7%
525EL2872	1.284	8.595.598	95.7%
501BN0674	1.281	8.596.879	95.7%
525DS0681	1.281	8.598.160	95.7%
525DS0682	1.274	8.599.434	95.7%
525EL3052	1.262	8.600.696	95.7%
525EL2707	1.261	8.601.957	95.8%
525DN0251	1.251	8.603.208	95.8%
525EL3054	1.233	8.604.441	95.8%
525EL3089	1.229	8.605.670	95.8%
501BN0683	1.228	8.606.898	95.8%
525DS0683	1.228	8.608.126	95.8%
525EL3041	1.228	8.609.354	95.8%
525EL3022	1.226	8.610.580	95.9%
525EL3028	1.220	8.611.800	95.9%
525EL3057	1.220	8.613.020	95.9%
525EL1666	1.212	8.614.232	95.9%
525DN0253	1.206	8.615.438	95.9%
525EL2580	1.205	8.616.643	95.9%
525EL2944	1.204	8.617.847	95.9%
525EL2151	1.201	8.619.048	96.0%
525EL2301	1.201	8.620.249	96.0%
525EL0918	1.200	8.621.449	96.0%

525EL1832	1.200	8.622.649	96.0%
525EL1834	1.200	8.623.849	96.0%
525EL1836	1.200	8.625.049	96.0%
525EL1837	1.200	8.626.249	96.0%
525EL2146	1.200	8.627.449	96.0%
525EL2150	1.200	8.628.649	96.1%
525EL2306	1.200	8.629.849	96.1%
525EL2314	1.200	8.631.049	96.1%
525EL3027	1.196	8.632.245	96.1%
525DN0254	1.194	8.633.439	96.1%
526DS0202	1.194	8.634.633	96.1%
525DN0273	1.192	8.635.825	96.1%
501BN0582	1.188	8.637.013	96.2%
525DS0671	1.175	8.638.188	96.2%
501BN0583	1.173	8.639.361	96.2%
525EL2340	1.173	8.640.534	96.2%
525EL2316	1.170	8.641.704	96.2%
525DN0243	1.169	8.642.873	96.2%
525DS0684	1.169	8.644.042	96.2%
525DS0686	1.168	8.645.210	96.2%
526DS0183	1.164	8.646.374	96.3%
525DN0332	1.158	8.647.532	96.3%
525DN0252	1.140	8.648.672	96.3%
525EL2614	1.140	8.649.812	96.3%
525EL3058	1.137	8.650.949	96.3%
501BN0584	1.131	8.652.080	96.3%
525EL2706	1.108	8.653.188	96.3%
501BN0581	1.102	8.654.290	96.3%
525EL2195	1.095	8.655.385	96.4%
525EL1742	1.092	8.656.477	96.4%
525DS0685	1.088	8.657.565	96.4%
501DB0196	1.086	8.658.651	96.4%
525DS0688	1.068	8.659.719	96.4%
501DB0200	1.064	8.660.783	96.4%
525EL2888	1.059	8.661.842	96.4%
525DN0358	1.056	8.662.898	96.4%
525EL2323	1.056	8.663.954	96.5%
525DN0249	1.049	8.665.003	96.5%
525EL0910	1.048	8.666.051	96.5%
525EL1743	1.044	8.667.095	96.5%
525EL2344	1.030	8.668.125	96.5%
525DN0255	1.026	8.669.151	96.5%
525EL1667	1.009	8.670.160	96.5%
501DB0141	1.008	8.671.168	96.5%
525EL2445	1.008	8.672.176	96.5%
525EL1500	1.005	8.673.181	96.6%
501DB0198	1.000	8.674.181	96.6%
525EL1823	1.000	8.675.181	96.6%

525EL2347	1.000	8.676.181	96.6%
525EL2550	990	8.677.171	96.6%
518AJ0353	987	8.678.158	96.6%
525EL1739	982	8.679.140	96.6%
501BN0531	972	8.680.112	96.6%
525DV0037	960	8.681.072	96.6%
525DV0040	960	8.682.032	96.7%
525EL2194	955	8.682.987	96.7%
518AJ0352	950	8.683.937	96.7%
525EL1821	940	8.684.877	96.7%
525EL1593	924	8.685.801	96.7%
501DB0176	920	8.686.721	96.7%
525EL2968	909	8.687.630	96.7%
501BN0591	903	8.688.533	96.7%
525EL0911	900	8.689.433	96.7%
525EL1613	900	8.690.333	96.7%
525EL2152	900	8.691.233	96.8%
525EL2568	900	8.692.133	96.8%
525EL3060	880	8.693.013	96.8%
525EL3080	880	8.693.893	96.8%
501BN0759	864	8.694.757	96.8%
525EL2498	864	8.695.621	96.8%
525EL2502	864	8.696.485	96.8%
525EL1606	852	8.697.337	96.8%
525EL2687	844	8.698.181	96.8%
525EL2711	842	8.699.023	96.8%
525DS0600	822	8.699.845	96.9%
525EL3024	819	8.700.664	96.9%
525EL3034	816	8.701.480	96.9%
525DN0250	805	8.702.285	96.9%
501BN0753	800	8.703.085	96.9%
525EL1751	800	8.703.885	96.9%
525EL2451	800	8.704.685	96.9%
525EL2615	800	8.705.485	96.9%
501DB0194	798	8.706.283	96.9%
525EL3056	796	8.707.079	96.9%
525EL1560	792	8.707.871	96.9%
525EL2817	790	8.708.661	96.9%
525EL3047	790	8.709.451	97.0%
501BN0512	780	8.710.231	97.0%
501DB0149	780	8.711.011	97.0%
525EL3059	758	8.711.769	97.0%
525EL1665	753	8.712.522	97.0%
501DB0199	750	8.713.272	97.0%
525EL2604	747	8.714.019	97.0%
525EL3025	744	8.714.763	97.0%
525EL3049	735	8.715.498	97.0%
525EL3046	732	8.716.230	97.0%

501BN0524	720	8.716.950	97.0%
525EL2695	720	8.717.670	97.0%
525EL2786	720	8.718.390	97.1%
525EL3023	705	8.719.095	97.1%
525DN0355	704	8.719.799	97.1%
525EL3031	704	8.720.503	97.1%
525EE0041	700	8.721.203	97.1%
525DS0676	670	8.721.873	97.1%
525EL3087	670	8.722.543	97.1%
525EL2836	668	8.723.211	97.1%
525EL3044	666	8.723.877	97.1%
525EL3045	666	8.724.543	97.1%
525EL1870	652	8.725.195	97.1%
501BN0410	638	8.725.833	97.1%
525EL3033	628	8.726.461	97.1%
525DS0679	616	8.727.077	97.2%
525DN0213	615	8.727.692	97.2%
525DS0680	611	8.728.303	97.2%
526DS0203	610	8.728.913	97.2%
525EL2553	602	8.729.515	97.2%
525EL3050	601	8.730.116	97.2%
501DB0189	600	8.730.716	97.2%
525DS0672	600	8.731.316	97.2%
525EL1833	600	8.731.916	97.2%
525EL1865	600	8.732.516	97.2%
525EL2086	600	8.733.116	97.2%
525EL2124	600	8.733.716	97.2%
525EL3036	600	8.734.316	97.2%
526DS0188	599	8.734.915	97.2%
501BN0566	586	8.735.501	97.2%
525EL3029	570	8.736.071	97.3%
525DV0036	560	8.736.631	97.3%
525EL2171	550	8.737.181	97.3%
525EL2725	540	8.737.721	97.3%
525EL2745	540	8.738.261	97.3%
525EL1497	528	8.738.789	97.3%
525EL3026	528	8.739.317	97.3%
525EL1568	520	8.739.837	97.3%
525EL1569	520	8.740.357	97.3%
525DS0673	516	8.740.873	97.3%
525EL3065	512	8.741.385	97.3%
504AQ0680	510	8.741.895	97.3%
525EL1798	502	8.742.397	97.3%
525DZ0018	501	8.742.898	97.3%
525EL2085	500	8.743.398	97.3%
525EL2134	500	8.743.898	97.3%
525EL2158	500	8.744.398	97.3%
525EL2170	500	8.744.898	97.4%

525EL3076	500	8.745.398	97.4%
525ET0068	500	8.745.898	97.4%
526DS0114	499	8.746.397	97.4%
525DS0675	492	8.746.889	97.4%
501BN0558	490	8.747.379	97.4%
501BN0559	490	8.747.869	97.4%
501DB0195	486	8.748.355	97.4%
501BN0519	480	8.748.835	97.4%
525EL2773	480	8.749.315	97.4%
501BN0623	477	8.749.792	97.4%
504AQ0672	476	8.750.268	97.4%
525EL2636	469	8.750.737	97.4%
525DN0356	460	8.751.197	97.4%
525EL3020	460	8.751.657	97.4%
525EL2094	450	8.752.107	97.4%
525EL2095	450	8.752.557	97.4%
501DB0180	448	8.753.005	97.4%
526DS0116	444	8.753.449	97.4%
526DS0115	437	8.753.886	97.5%
525EL2787	436	8.754.322	97.5%
525EL3086	436	8.754.758	97.5%
526DS0192	404	8.755.162	97.5%
501DB0155	401	8.755.563	97.5%
525DZ0015	400	8.755.963	97.5%
525EL2395	400	8.756.363	97.5%
525EL2418	400	8.756.763	97.5%
525EL2629	400	8.757.163	97.5%
525EL2630	400	8.757.563	97.5%
525EL2631	400	8.757.963	97.5%
525EL2633	400	8.758.363	97.5%
525EL2634	400	8.758.763	97.5%
525EL2635	400	8.759.163	97.5%
525EL2961	396	8.759.559	97.5%
525EL2282	390	8.759.949	97.5%
525EL2639	380	8.760.329	97.5%
526DS0111	378	8.760.707	97.5%
525EL2632	375	8.761.082	97.5%
525EL1860	360	8.761.442	97.5%
525EL2405	360	8.761.802	97.5%
525EL2791	360	8.762.162	97.5%
525EL3015	357	8.762.519	97.5%
526DS0191	357	8.762.876	97.6%
526DS0190	353	8.763.229	97.6%
525EL2726	343	8.763.572	97.6%
501BN0396	342	8.763.914	97.6%
526DS0187	342	8.764.256	97.6%
525EL2598	338	8.764.594	97.6%
504AQ0674	330	8.764.924	97.6%

504AQ0675	330	8.765.254	97.6%
504AQ0678	330	8.765.584	97.6%
525DV0039	322	8.765.906	97.6%
525DV0035	320	8.766.226	97.6%
525EL1782	305	8.766.531	97.6%
526DS0204	305	8.766.836	97.6%
504AQ0667	303	8.767.139	97.6%
525EL2292	302	8.767.441	97.6%
504AQ0659	301	8.767.742	97.6%
504AQ0660	300	8.768.042	97.6%
504AQ0661	300	8.768.342	97.6%
504AQ0665	300	8.768.642	97.6%
504AQ0666	300	8.768.942	97.6%
504AQ0668	300	8.769.242	97.6%
504AQ0670	300	8.769.542	97.6%
504AQ0673	300	8.769.842	97.6%
504AQ0676	300	8.770.142	97.6%
504AQ0679	300	8.770.442	97.6%
504AQ0681	300	8.770.742	97.6%
525DN0196	300	8.771.042	97.6%
525EL1887	300	8.771.342	97.6%
525DN0218	292	8.771.634	97.6%
501BN0726	290	8.771.924	97.7%
525EE0039	288	8.772.212	97.7%
525EL3064	288	8.772.500	97.7%
501DB0181	280	8.772.780	97.7%
525EL2967	280	8.773.060	97.7%
525EL2685	279	8.773.339	97.7%
525DV0026	269	8.773.608	97.7%
501BN0667	268	8.773.876	97.7%
525DN0221	264	8.774.140	97.7%
525EL2278	252	8.774.392	97.7%
501BN0409	247	8.774.639	97.7%
501BN0521	246	8.774.885	97.7%
501BN0517	241	8.775.126	97.7%
501BN0513	240	8.775.366	97.7%
501BN0514	240	8.775.606	97.7%
501BN0518	240	8.775.846	97.7%
501BN0520	240	8.776.086	97.7%
501BN0522	240	8.776.326	97.7%
501BN0523	240	8.776.566	97.7%
525EL2279	240	8.776.806	97.7%
525EL2280	240	8.777.046	97.7%
525EL2776	240	8.777.286	97.7%
525DN0190	232	8.777.518	97.7%
526DS0185	228	8.777.746	97.7%
525EL2948	225	8.777.971	97.7%
501BN0515	222	8.778.193	97.7%

501BN0516	222	8.778.415	97.7%
525DN0222	220	8.778.635	97.7%
525DZ0039	220	8.778.855	97.7%
501DB0184	216	8.779.071	97.7%
525EL2949	212	8.779.283	97.7%
525EL3071	212	8.779.495	97.7%
525FR0145	210	8.779.705	97.7%
525FR0146	210	8.779.915	97.7%
526DS0064	208	8.780.123	97.7%
525EL3083	202	8.780.325	97.7%
526DS0184	202	8.780.527	97.7%
525DN0189	200	8.780.727	97.8%
525DZ0040	200	8.780.927	97.8%
525EL1843	200	8.781.127	97.8%
525EL2601	200	8.781.327	97.8%
525DS0629	193	8.781.520	97.8%
525EL2770	190	8.781.710	97.8%
525EL0315	189	8.781.899	97.8%
526DS0094	188	8.782.087	97.8%
526DS0189	184	8.782.271	97.8%
504AQ0671	182	8.782.453	97.8%
525DN0235	180	8.782.633	97.8%
525DN0236	176	8.782.809	97.8%
525EL2281	170	8.782.979	97.8%
525EL3085	168	8.783.147	97.8%
525FR0125	168	8.783.315	97.8%
526DS0199	166	8.783.481	97.8%
526DS0209	166	8.783.647	97.8%
525EL2325	165	8.783.812	97.8%
525EL1957	161	8.783.973	97.8%
525FR0144	160	8.784.133	97.8%
501BN0532	159	8.784.292	97.8%
504AQ0683	156	8.784.448	97.8%
526DS0196	156	8.784.604	97.8%
504AQ0664	154	8.784.758	97.8%
501BN0413	150	8.784.908	97.8%
504AQ0662	150	8.785.058	97.8%
504AQ0663	150	8.785.208	97.8%
504AQ0669	150	8.785.358	97.8%
504AQ0677	150	8.785.508	97.8%
504AQ0682	150	8.785.658	97.8%
525EL1874	150	8.785.808	97.8%
525EL1880	150	8.785.958	97.8%
525EU1279	150	8.786.108	97.8%
526DS0201	149	8.786.257	97.8%
525EW1119	147	8.786.404	97.8%
525EL1845	144	8.786.548	97.8%
501DB0193	138	8.786.686	97.8%

525EL0884	125	8.786.811	97.8%
525EL2868	124	8.786.935	97.8%
525EL0909	120	8.787.055	97.8%
525DN0375	117	8.787.172	97.8%
525DN0324	114	8.787.286	97.8%
526DS0098	114	8.787.400	97.8%
526DS0100	110	8.787.510	97.8%
525EL3090	108	8.787.618	97.8%
525EL3067	106	8.787.724	97.8%
525EL3069	106	8.787.830	97.8%
525EL3070	106	8.787.936	97.8%
525DN0352	103	8.788.039	97.8%
526DS0108	102	8.788.141	97.8%
525DN0224	100	8.788.241	97.8%
525DN0238	100	8.788.341	97.8%
525DV0010	100	8.788.441	97.8%
525EL2769	100	8.788.541	97.8%
525EL2830	100	8.788.641	97.8%
525EL2832	100	8.788.741	97.8%
525FE0028	100	8.788.841	97.8%
526DS0207	99	8.788.940	97.8%
526DS0200	94	8.789.034	97.8%
526DS0208	91	8.789.125	97.8%
525EL2969	90	8.789.215	97.8%
525EU1134	90	8.789.305	97.8%
525EL2681	88	8.789.393	97.8%
525EL2869	82	8.789.475	97.8%
526DS0198	81	8.789.556	97.8%
526DS0213	80	8.789.636	97.9%
525DN0306	78	8.789.714	97.9%
526DS0072	75	8.789.789	97.9%
525DV0041	71	8.789.860	97.9%
526DS0073	68	8.789.928	97.9%
526DS0079	66	8.789.994	97.9%
525DS0216	63	8.790.057	97.9%
526DS0084	63	8.790.120	97.9%
526DS0106	61	8.790.181	97.9%
525DV0034	60	8.790.241	97.9%
525EL1157	60	8.790.301	97.9%
525EU0056	60	8.790.361	97.9%
525DN0392	57	8.790.418	97.9%
526DS0107	55	8.790.473	97.9%
526EW0004	55	8.790.528	97.9%
501BN0767	54	8.790.582	97.9%
525EL2992	54	8.790.636	97.9%
526DS0078	54	8.790.690	97.9%
526DS0095	54	8.790.744	97.9%
525DN0344	50	8.790.794	97.9%

526DS0099	48	8.790.842	97.9%
526DS0186	42	8.790.884	97.9%
525EU0688	41	8.790.925	97.9%
525DS0267	40	8.790.965	97.9%
525EL1562	40	8.791.005	97.9%
525EL2349	40	8.791.045	97.9%
525EU0071	40	8.791.085	97.9%
501BN0483	36	8.791.121	97.9%
525DN0195	36	8.791.157	97.9%
526DS0076	36	8.791.193	97.9%
526DS0215	36	8.791.229	97.9%
525DN0176	35	8.791.264	97.9%
525DN0396	35	8.791.299	97.9%
526DS0214	35	8.791.334	97.9%
525EL1432	32	8.791.366	97.9%
201DB0028	30	8.791.396	97.9%
525DN0308	30	8.791.426	97.9%
525EL2898	30	8.791.456	97.9%
525EL2899	30	8.791.486	97.9%
525EL2900	30	8.791.516	97.9%
525EL2902	30	8.791.546	97.9%
525EW0745	30	8.791.576	97.9%
526DS0113	30	8.791.606	97.9%
526DS0194	29	8.791.635	97.9%
525DN0234	28	8.791.663	97.9%
525EL2602	28	8.791.691	97.9%
525DZ0042	27	8.791.718	97.9%
526DS0147	27	8.791.745	97.9%
525DS0425	25	8.791.770	97.9%
526DS0101	25	8.791.795	97.9%
526DS0146	25	8.791.820	97.9%
525DN0169	24	8.791.844	97.9%
525DN0376	24	8.791.868	97.9%
525EL1592	24	8.791.892	97.9%
525EL1792	24	8.791.916	97.9%
525EL1793	24	8.791.940	97.9%
525EL1795	24	8.791.964	97.9%
525EL2901	23	8.791.987	97.9%
525DN0393	22	8.792.009	97.9%
525DN0394	22	8.792.031	97.9%
525DN0395	22	8.792.053	97.9%
525DN0329	20	8.792.073	97.9%
525DS0270	20	8.792.093	97.9%
525DV0027	20	8.792.113	97.9%
525DV0029	20	8.792.133	97.9%
525EL1547	20	8.792.153	97.9%
525EL1794	20	8.792.173	97.9%
525EL2020	20	8.792.193	97.9%

525EL2028	20	8.792.213	97.9%
525EL2029	20	8.792.233	97.9%
525EL2348	20	8.792.253	97.9%
525EL2480	20	8.792.273	97.9%
525EL2903	20	8.792.293	97.9%
525EL2906	20	8.792.313	97.9%
525EU0780	20	8.792.333	97.9%
525EW0668	20	8.792.353	97.9%
525FR0029	20	8.792.373	97.9%
525DN0207	18	8.792.391	97.9%
526DS0096	18	8.792.409	97.9%
526DS0212	17	8.792.426	97.9%
525DN0172	16	8.792.442	97.9%
525DN0212	16	8.792.458	97.9%
525EL2905	16	8.792.474	97.9%
526DS0097	15	8.792.489	97.9%
526DS0103	15	8.792.504	97.9%
526DS0145	15	8.792.519	97.9%
222GE0197	14	8.792.533	97.9%
501DB0129	12	8.792.545	97.9%
525DN0246	12	8.792.557	97.9%
525DN0316	12	8.792.569	97.9%
525EL1327	12	8.792.581	97.9%
525EL2460	12	8.792.593	97.9%
525EL2476	12	8.792.605	97.9%
526DS0206	12	8.792.617	97.9%
222GE0184	10	8.792.627	97.9%
525DN0300	10	8.792.637	97.9%
525DN0326	10	8.792.647	97.9%
525DN0337	10	8.792.657	97.9%
525EJ0020	10	8.792.667	97.9%
525EL1543	10	8.792.677	97.9%
525EL1544	10	8.792.687	97.9%
525EL1545	10	8.792.697	97.9%
525EL1546	10	8.792.707	97.9%
525EL2461	10	8.792.717	97.9%
525EL2477	10	8.792.727	97.9%
525EL2904	10	8.792.737	97.9%
525EL3004	10	8.792.747	97.9%
525EL3005	10	8.792.757	97.9%
525EL3008	10	8.792.767	97.9%
525EL3009	10	8.792.777	97.9%
526DS0102	10	8.792.787	97.9%
525EL1324	8	8.792.795	97.9%
526DS0211	8	8.792.803	97.9%
201DB0038	7	8.792.810	97.9%
525DN0385	6	8.792.816	97.9%
526DS0104	6	8.792.822	97.9%

526DS0105	6	8.792.828	97.9%
526DS0210	6	8.792.834	97.9%
525DN0377	5	8.792.839	97.9%
525EL3074	5	8.792.844	97.9%
525EU1039	5	8.792.849	97.9%
526DS0149	5	8.792.854	97.9%
525DN0322	4	8.792.858	97.9%
525DN0391	4	8.792.862	97.9%
525DS0215	4	8.792.866	97.9%
526DS0234	4	8.792.870	97.9%
525DN0384	3	8.792.873	97.9%
526DS0235	3	8.792.876	97.9%
526DS0236	3	8.792.879	97.9%
526DS0237	3	8.792.882	97.9%
526DS0238	3	8.792.885	97.9%
526DS0239	3	8.792.888	97.9%
501BN0826	2	8.792.890	97.9%
501BN0830	1	8.792.891	97.9%

Production line efficiency improvement

Thesis bachelor Sc.

Quentin Cheret
BMS DEPARTMENT: BACHELOR INDUSTRIAL ENGINEERING AND MANAGEMENT