THE ROAD TO PREVENTIVE AND PREDICTIVE MAINTENANCE FOR THE COMBIPLAST

Mirthe Lanjouw
m.l.m.lanjouw@student.utwente.nl
s1884794

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NIVERPLAST SUPERVISOR
Evert Slagman

UNIVERSITY OF TWENTE SUPERVISORS
Dr. E. Topan (1st chair)
Dr. I. Seyran Topan (2nd chair)

UNIVERSITY OF TWENTE
Drienerlolaan 5
7522NB Enschede

NIVERPLAST
Baruch Spinozastraat 2
7442 PD Nijverdal

UNIVERSITY OF TWENTE.

Niverplast
PASSIONATE PEOPLE

Preface

Dear reader,

Before you lies my bachelor thesis, "The road to predictive and preventive maintenance for the CombiPlast". This bachelor thesis concludes my Bachelor's programme in Industrial Engineering & Management at the University of Twente. This thesis is conducted from September 2020 until June 2021 at the service department of Niverplast.

I would like to thank everyone at Niverplast that helped me during this time, especially my supervisor Evert Slagman. During these months I gained a lot of insight not only about the subject, but also about all the different aspects that need to be taking into account when selling and maintaining a packaging machine.

Furthermore, I would like to thank Engin Topan for his guidance and feedback, which helped bring this research to a higher level.

Finally, I would like to thank my friends and family for their support and interest throughout my bachelor.

I hope you enjoy reading my bachelor thesis!

Mirthe Lanjouw

De Lutte, June 2021

i. Management summary

Niverplast is a company that produces different kinds of packaging machines. One of these machines is the CombiPlast. This machine unfolds a box and places a bag in the box, so it is a case erector and bag placer in one. They sell these packaging machine to customers who have factories of all sorts, for example bakery, fish, and plastic caps.

i.i Maintenance problem

Niverplast really would like to use predictive maintenance for their machines. Currently, they use preventive maintenance based on intuition of the mechanics and they do not have a clear overview of the wearing parts of the CombiPlast. This causes a not optimal maintenance schedule. The main focus of this research would then be "How can we get a clear indication about when certain spare parts are breaking down?"

There are in total five different kind of maintenance. Firstly, corrective maintenance can be divided into deferred and immediate corrective maintenance. Deferred corrective maintenance being maintenance done after an error but not immediately and immediate corrective maintenance is maintenance after an error done immediately. Secondly, we have preventive maintenance, this can be divided into time-based maintenance, condition-based maintenance, and predictive maintenance. Time-based maintenance is maintenance based on failure times, condition-based maintenance is done by checking the condition of a component at that exact moment to see if it needs maintenance and predictive maintenance is based on a strategy after measurement of the condition of equipment to see if it will fail in the near future.

i.ii Data analyse

To get more inside in how often the CombiPlast receives maintenance and is cleaned, two surveys were made, a survey for both the customers and the mechanics. In total 16 customers and 10 mechanics filled in the survey. This survey consists of questions about maintenance, cleaning, and spare parts.

According to the order history there are a few wearing parts that are reordered more than 100 times. With one high outlier, namely the suction cups. When placing these wearing parts next to the recommended spare parts list, we see that not all these parts are recommended for the customer.

According to the mechanics there are five common problems that occur when maintenance is done on the CombiPlast. These problems exist of settings, boxes, and bag mistakes. There are no major problems with the machine itself.

Customers can choose to receive maintenance from Niverplast or use their own mechanic for maintenance. When looking at the results from the survey we can see that the answers about how often the CombiPlast receives maintenance and needs to be cleaned differs a lot. This means that do not have a clear indication on how often cleaning and maintenance is needed. They do, however, almost all use compressed air and a dry towel for cleaning.

After analysing this data, it became clear that the amount of cleaning and maintenance is really diverse by the customers

i.iii Roadmap

After concluding that Niverplast needs a lot more data for them to get any indication of the lifespan of spare parts of the CombiPlast, there has been made a concept maintenance framework.
This framework contains the following steps:

1. Collecting data
2. Identify data
3. Data preparation
4. Identify the most critical components
5. Choose the maintenance policy
6. Implement and evaluation
7. Updating of data collection

i.iv Conclusion

If Niverplast want to know more about their machine and give the customer more security about the lifespan of the CombiPlast, they need to gather more data for the next few years. With data such as, number of boxes made, error codes, humidity values, number of working hours, etc. Niverplast can investigate further to get more inside in the CombiPlast. With the right data they can draw certain conclusion about the parts of the machine and can provide the customer with a detailed maintenance and cleaning plan.

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1. Introduction

This chapter, Chapter 1.1, provides an introduction of the company Niverplast with an explanation of the customers, machine, mechanics, and the suppliers.
In Chapter 1.2 we explain the problem researched in this thesis. There will be an introduction about the problem, the motivation behind the research and the core problem. After this there will be a description about the norm and reality (Chapter 1.3) and the deliverables (Chapter 1.4). We end this chapter with the plan of approach and the research questions (Chapter 1.5).

1.1 Introduction Niverplast

Niverplast produces different kinds of packaging machines. In 1986 Niverplast (Nieuwenhuis verpakkingen en plastics) started with trading packaging materials. This became a success very fast and they soon decided to produce plastic bags themselves. After this success, they received the question from a customer if it was possible to place the bags into boxes automatically. This resulted in the first packaging machine in 1997, the EasyPlast. Currently, multiple kinds of packaging lines are built at Niverplast for customers all over the world (Nieuwenhuis, 2019).
These machines are built from different kinds of parts. To make this research manageable, we decided to focus on one of the machines, namely the CombiPlast. The CombiPlast is the machine that is sold the most at Niverplast.

1.1.1 Customers

Niverplast sells their machines to different kind of factories all over the world, these factories are the customers of Niverplast. They make a distinction between six different kind of factories: bakery, oils & fats, meat & fish, powder, fruits & vegetables and others. They make this distinction because the different kinds of factories need different kinds of machines.

1.1.2 CombiPlast

The CombiPlast is one of the twelve standard machines of Niverplast. The CombiPlast folds out a box, tapes the bottom close and places a plastic bag in the box. There are multiple customizable options, for example the size of the box, left- or right-handed version, etc.
Further, the machine has several settings for the customer to choose from. The customer can for example choose how many boxes per minute they want to machine to produce. This can go up to fifteen boxes per minute.

1.1.3 Mechanics

Niverplast has several mechanics, who repair the machines at the customers' factory. Niverplast strives for preventive maintenance, but sometimes a part of the machine has broken down before replacement. Therefore, the mechanics perform preventive maintenance as well as corrective maintenance.

1.1.4 Suppliers

To produce the machines, Niverplast needs a lot of parts. They make a lot of these parts themselves, but some parts are made by suppliers. These suppliers provide Niverplast with the parts when needed to build the machines.

1.1.5 Service contract

Customers can choose to agree on a service contract after they bought a machine from Niverplast. This service contract states that Niverplast executes maintenance a certain number of times a year. For example, a customer can choose that they want maintenance 2 times a year, then Niverplast will plan maintenance appointments every half year.

1.2. Problem analysis

When customers buy a machine from Niverplast, the service does not end there. After receiving a machine, the customers can receive technical assistance and preventive maintenance. This preventive maintenance is maintenance that is planned before anything is broken. Niverplast finds it important that machines can keep running and producing and do not break down. The downtime caused by a breakdown is much higher than the costs for parts and the small nuisance for production during maintenance. The problem Niverplast is currently facing is that they decide on preventive maintenance of the machines using intuition and not on the knowledge of the wearing parts. The mechanics use their years of experience to figure out if a wearing part needs to be replaced or not. This is not always the best way of maintenance because this can cause too early or too late replacement of certain parts.

1.2.1 Problem description

Looking at the problems Niverplast is currently experiencing and which are related to the expected lifespan of the wearing parts, we find multiple problems. The first problem is that Niverplast does not know exactly what all the wearing parts of the CombiPlast are. The parts that wear out regularly are known, but they do not know when they will break down.
Further they use preventive maintenance because they want to prevent the machine of the customers to break down. However, this maintenance is based on intuition because it is not clear when certain parts will break down.

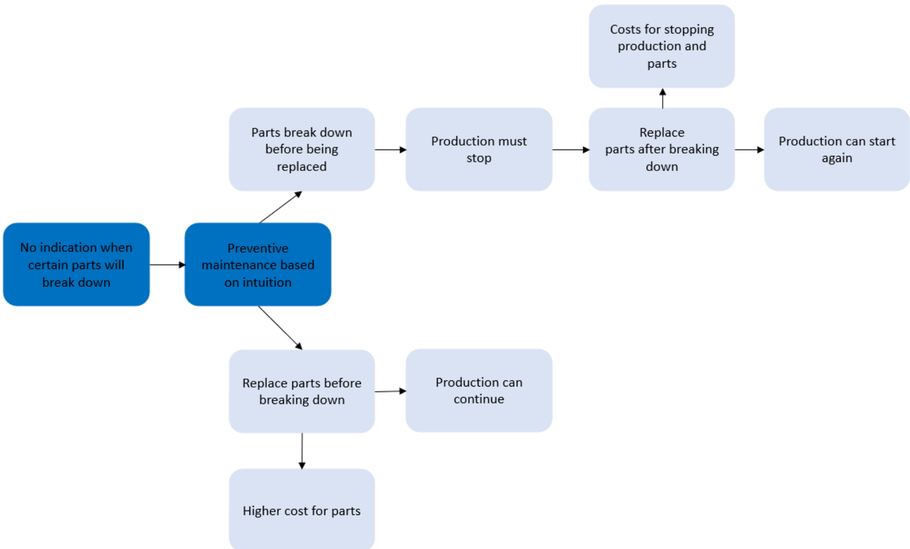

Figure 1.1 - Problem cluster

In the problem cluster, *Figure 1.1*, we can see that because the mechanics do their preventive maintenance based on intuition, there is no indication when parts will break down. This results in two options, either the parts break down before they are replaced, or they are replaced in time.

When the parts are replaced in time, the production will continue, and the company will only have extra costs for the parts being replaced too early. When the parts break down before being replaced, the production has to stop, and this will cost the company extra money because of stoppage of the production.

1.2.2 Core problem

To find the core problem we have to look which of these problems are the most important, and by solving can solve the other problems to.
Looking at the problems in the problem cluster, *Figure 1.1,* we can see that the core problem contains of two different parts. The mechanics execute preventive maintenance based on intuition and the fact that there is no indication when certain parts will break down. These two problems together cause our main problem; “How can we get a clear indication about when certain spare parts are breaking down?”

1.3 Norm and reality

If we want to describe the difference between the norm and the reality, we first need to look at the situation Niverplast is in now. Looking at the maintenance done on the machines, this is mostly preventive maintenance and based on intuition. When spare parts are replaced before they are worn down, the company has to buy spare parts more regularly than other companies. When the spare parts are only replaced when they already broke down, this will result in machine failures. The more times a machine fails, the more costs a company will have to stop the production.
To get a better understanding of this problem we look at the key performance indicators (KPI).
The KPIs for this problem are a decrease in planned and unplanned downtime and increase in lifespan of wearing parts.
The reality would then be that some wearing parts are only replaced before they broke down and some after they already broke down. This causes either planned downtime or unplanned downtime. The downtime of the machine should be as low as possible. The norm would be to decrease the amount of downtime by getting a better picture of the lifespan of the wearing parts of the machine. A good goal would be to decrease the downtime of the machine by 20 percent over a year. First Niverplast needs to collect data to find out what the downtime of the CombiPlast is for the different customers at this moment.

1.4 Deliverables

The goal of this research is to provide Niverplast with a roadmap for preventive and predictive maintenance.
Looking at all the different kind of maintenance from the literature and the different kind of maintenance Niverplast uses at this moment, we can make an overview which maintenance policies are best to use. Giving Niverplast an explanation on which data needs to be collected and how this data can be used to find the parameters for the policies. Further finding out which parts of the CombiPlast are wearing parts is another goal.

1.5 Plan of approach and research questions

This chapter explains what approach is needed to tackle this problem and which research and knowledge questions need to be answered.

Wearing parts CombiPlast

“What are all the different wearing parts in the CombiPlast?”

First, we needed to know which parts of the CombiPlast are all wearing parts. We did this by looking at the bill of material of the CombiPlast and found all the wearing parts in the list. All the finding about the wearing parts are written down in *Chapter 4.2*.

Maintenance policies according to literature

“What is the difference between predictive, preventive and breakdown maintenance?”

- “What is corrective maintenance?”
- “What is condition based maintenance?”

For this question we needed to do a literature study. This question gave us much more inside in the different kind of maintenance that can be used by Niverplast. In Chapter 3.1 is written down which kind of maintenance there can be found in the literature. Chapter 3.2 gives an overview of the kind of maintenance policies that can be useful for Niverplast to use.

Maintenance used by Niverplast

“What are the different process speeds used by the different customers?”

- “What kind of maintenance is used by the different customers?”

The customers can decide themselves how many boxes they want the machine to produce per minute. The difference in process speeds makes a huge difference in the lifespan of the wearing parts in the CombiPlast. We wanted to solve this question by looking in the system of the customers. However, during the research, it turned out that it was not possible to find the data in the system of the customers. We choose for the other option, namely, to make a survey for the customers to answer this question. The full survey is placed in the *Appendix F*, the results of this survey are written in *Chapter 4.2*.

Also, the kind of maintenance is useful information. This way we can make a comparison between the customers that use mechanics of Niverplast or customers that use their own mechanics.

“What is the atmosphere in the different factories of the customers?”

- “Is there a difference between the kind of customers, such as bakery, powder, meat and Fish, etc.?”

The atmosphere in the different kind of factories of the customers can cause the wearing parts to wear down quicker. Some customers could for example have a lot of moisture, dust particles, etc. in the air. This could have an influence on the CombiPlast.

Knowing this information per kind of customer we can make an overview for the different kind of customers. This question was not totally answerable, there are some results in *Chapter 4* that indicate there is a difference between the different kind of customers, but this is not totally clear.

“How many times are spare parts reordered?”

Looking at the order history of the spare parts of the different customers, we could see if there was already a certain lifespan between orders. This was useful for the research because this showed that then I can already get an indication on the lifespan of some wearing parts.

2. Research design

This second chapter gives an overview on which kind of data research has to be done (Chapter 2.1), how this data can be gathered and how this data can be analysed (Chapter 2.2). In Chapter 2.3 we will talk about all the limitations we can encounter by doing this data research.

2.1 Type of research

There are different types of research, namely, descriptive, and explanatory research. With explanatory research you want to know the relationship between variables.
Descriptive research is research that ends with a result. (Heerkens, 2014)
What we do can be seen as an explanatory research because we will look at different variables to see if a wearing part will wear out faster.

2.2 Data gathering and analysing

During this research I will use more than one data gathering method. The first method I will use is literature study. During literature study I will look at multiple books, academic papers, and other scientific sources to get a complete overview on the subjects.
Further I will look at data Niverplast has already collected and try to connect this data with each other, this will be the analysis of primary sources.
The last data gathering method will be observation. By observing at one or multiple clients I can get a better overview on how the machine works and what the certain wearing parts could be. Also, I can get a better understanding on what the machine must endure in the different factories.

To analyse and process data we have two methods, namely, quantitative and qualitative (Heerkens, 2014). Quantitative research collects the results in standardised and numerical data (Saunders et al., 2009, p.482).
Qualitative research is focused on the underlying reasons and motivations.
In this research I will use both methods to do my research. For the data delivered from Niverplast is a quantitative research but the observations and surveys are clearly a qualitative research.

2.3 Limitations of research design

Since we will be doing observations and interviews there will be limitations in our research. There may be threats on information reliability, according to Saunders (2009), when looking at collecting information, there are four different kind of threats to reliability. The first limitation is the 'subject or participant error', the timing in a week can cause for different answers. Second, we have the 'subject or participant bias'. This error is caused when there is employment insecurity. As third we have the 'observer error'. This error is caused by the way of asking questions, there are sometimes multiple ways of asking a question which can cause different answers. Last, we have 'observer bias', the wrong interpretation of the answers given by the participant.
The second limitation is about the insecurity's employers can have in the amount of information they can share. Sometimes employers are not allowed to share certain aspects with the researcher. This limitation is less relevant for my research because we talk more with the customers than with the employers.

He third limitation is the validity of the outputs of this research. "Validity is concerned with whether the findings are really about what they appear to be about." (Saunders et al, 2009, p.157). "Internal validity refers to the extent to which an experimenter can be confident that his or her findings result from experimental manipulations" (McDermott, 2011) There are multiple threats for internal validity

but the most important for my research are, history and testing. History can cause a threat, for example, when the machine just broke down a few days ago. This will give a different answer in comparison to a few weeks before that. Testing can also cause a threat because this data can be wrongly measured.
The external validity is about the outcome of the study and how well it can be applied to other settings. For external validity there are a few threats, the most important for my research is the people. There is a possibility that it will be difficult to contact the right persons at the customers' factory. This can result in information that is not totally accurate because this person does not know enough about the problem or the machine.

3. Literature review

Chapter 3.1 gives an overview of all the different types of maintenance that can be found in literature. Further, we talk about what maintenance types are used by Niverplast or can be useful for Niverplast (Chapter 3.2) and lastly, we talk about the framework that can be used (Chapter 3.3).

3.1 Maintenance policies according to literature

In literature we can find five different types of maintenance, which can be categorised in corrective or preventive maintenance. This chapter explains all these different types of maintenance. Further, we look at the different types of maintenance that can be used by Niverplast.

Maintenance is used to keep an asset in good working condition as long as possible. This includes service and repairs. "The term maintenance includes tasks performed to prevent failures and tasks performed to restore the asset to its original condition" (Gulati & Smith, 2009, p.42).
The table below, *Figure 3.1,* shows how the five different types of maintenance are categorised.

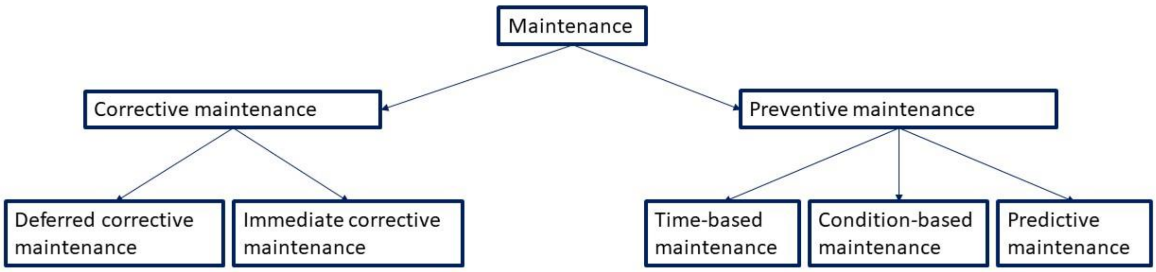

Figure 3.1 - Types of maintenance

3.2.1 Corrective maintenance

Corrective maintenance (CM) is also known as reactive maintenance or run-to-failure maintenance. CM is used to repair or replace some of the equipment after it has failed (Ahmad & Kamaruddin, 2012).

Immediate corrective maintenance

This is maintenance performed immediately without any postponement after an error occurs. Immediate corrective maintenance (ICM), also known as unplanned corrective maintenance, is very unpredictable and cannot be planned in advance. This makes the maintenance very unpredictable. (Al-Turki et al., 2014)

Deferred corrective maintenance

Deferred corrective maintenance (DCM), also known as planned corrective maintenance or backlog, is maintenance done after an error occurs, but not immediately. Companies with not enough money for ICM or with a machine that has a really low production, they can decide to wait until the next planned maintenance to repair the errors.
This is the least popular option for most businesses and only interesting for factories that can choose to wait until planned maintenance to fix the machine.

3.2.2 Preventive maintenance

Preventive maintenance (PvM) is maintenance done at a regular interval, even though the equipment is still working (Gulati, 2009, p.44). PvM can be based on time, for example every week, but it can also be based on the amount of usage, so for example every 100 cycles. There are four different kind of PvM, which are explained below.

Time-based maintenance

With time-based maintenance (TBM), the decisions for maintenance are based on failure time analysis. The failure behaviour is based on failure rate trends, also known as the bathtub curves. They assume that failure rate is predictable.

The bathtub curve, *Figure 3.2*, is a graphical representation of the failure rate versus the time. The first part is called the *burn-in*, the early failure period. This period shows the weak parts of the installation. After this we have the *useful life*, this phase has an almost constant failure rate. Lastly, we have the *wear-out* phase. This is the last part of the lifecycle and has an increase of failure rate. (Ohring, 1995, p.762)

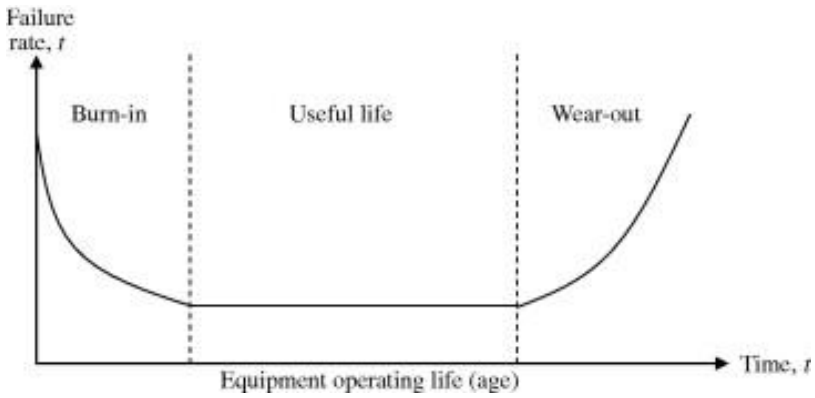

Figure 3.2 - Bathtub curve (Ahmad, 2012)

Condition-based maintenance

With condition-based maintenance (CBM), a component is checked and inspected to see what the condition is at the current moment. Maintenance is only done when this specific component is performing under level or broken down when this part is inspected (Gulati, 2009).

Predictive maintenance

This is a maintenance strategy based on measurements of the condition of equipment to see if it will fail in the near future. Predictive maintenance (PdM) is a lot like CBM, but with PdM the condition is predicted for the future. With this information there can be done a prediction when a component will break down and when maintenance is needed.

3.2 Maintenance policies Niverplast

The five different types of maintenance can also be used for Niverplast, but not all these different types are useful. First, we are going to look at the different types of corrective maintenance. ICM is needed when there is an error and there is maintenance needed before the machine can function properly again. When a customer finds themselves in this situation, there is immediate maintenance needed and Niverplast provides for this maintenance. They can help the customer by looking in the system to see what kind of things are going wrong with the machine and if it cannot be fixed extern there will be send a mechanic.

DCM is needed when there occurs an error, but the customer does not want immediate maintenance. This never occurs with customers of Niverplast because the customers in possession of a CombiPlast have a lot of operating hours, so they always want the machine working again as fast as possible.

Secondly, we are going to look at the types of preventive maintenance. TBM is a kind of maintenance based on failure-time analysis. Niverplast uses only the first part of this maintenance type. When looking at the bathtub-curve, *Figure 3.2*, we can see that TBM is made up of three different phases. After a machine has been installed at a customer, there will be regular contact and maintenance checks with the customer. This will be done to make sure the machines are working accordingly, and the customer is satisfied. This would be the first phase of the bathtub-curve, the *burn-in* phase. After this first phase the customer can chose to have periodic service, this would be the *useful* phase. However, there is no data used to make an overview on how regularly maintenance is needed, the customer themselves chose how regularly they want maintenance for their machine. The last phase, *wear-out* phase, is not used by Niverplast.
Second, we have CBM, this is maintenance used when certain parts are not working optimal and need maintenance or replacing. CBM is used a lot because when the mechanics perform periodic maintenance, they check the different parts of the machines and see if they are working optimal. They also check if certain parts would break down soon. This is based on intuition of the mechanics and not based on any data.
Lastly, we have PdM. This is maintenance done after there has been done a prediction. This type of maintenance is something Niverplast would like to execute in the future but is not able to use this now a days. They do not have enough data to calculate a predicted lifespan of different parts.

3.3 Maintenance concept framework

Over the years there have been multiple frameworks designed to help with maintenance. We will give a few examples in this chapter.

According to Gits (1992) you should start with getting technical system data and finding out what the requirements are. This data together gives the maintenance rules. The maintenance rules combined with the composite requirements are used for an evaluation. With this feedback there are new maintenance rules created and feedback given. These steps will repeat itself until there is cannot be given any feedback anymore. The maintenance rules that are left are used as the maintenance concept.

There has also been developed a CIBOCOF framework. This stands for The Dutch abbreviation of the Centre for Industrial Management Maintenance Concept Development Framework (Waeyenbergh & Pintelon, 2009). This framework really helps companies to design a customized maintenance concept. The cycles used in this framework are initiation, technical and functional analysis, policy decision and parameter optimization, implementation and evaluation and feedback.

Lastly, Sarih (2019) states that to analyse data from existing equipment to get relevant information about the state this equipment is in, you could use prognostic and health management (PHM). PHM has seven functional levels, namely, data acquisition, data processing, condition assessment, diagnostics, prognostics, decision analysis, human machine interface. This can really help in monitoring the health of this equipment and make good decisions about increasing the availability of the equipment.

We can conclude from the literature that there are some common steps that need to be followed to get the best maintenance concept, this would be an efficient framework for Niverplast to follow.

1. Collecting data
2. Identify data
3. Data preparation
4. Identify the most critical components
5. Choose the maintenance policy
6. Implement and evaluation
7. Updating of data collection

4. Data analysis and survey

In this chapter we give an overview of all the results found during the research. We start this chapter with an explanation about the different factories of the customers (Chapter 4.1). Chapter 4.2 explains how the different wearing parts of the CombiPlast are composed. Chapter 4.3 is about the maintenance that is done with the CombiPlast according to the customers.

4.1 Factories customers

Niverplast has customers with factories in different kind of sectors. They make a distinction between six different kind of factories: bakery, oils & fats, meat & fish, powder, fruits & vegetables, and others. These different kinds of factories all have different circumstances in the factories, due to use of chemicals or substances in the air.

To find out what the difference in the factories is, there has to be put a sensor of some sorts in the machines to see if this can affect the machine. This can be useful for monitoring of the machine because the data can then be split in different categories. This can really help Niverplast to give all the customers the best possible information on how to take care of the machine.

In the current situation there is no data on the difference between the different kind of sectors. However, in the future this would be really useful to have as a guideline for the kind of maintenance needed.

4.2 Wearing parts CombiPlast

After customers buys a machine from Niverplast, and the machine is installed at their factory, the customers have the possibility to order spare parts. They order spare parts when their machine does not work optimally or when they want extra spare parts in inventory. They are not obligated to buy these parts from Niverplast, there are also other companies that sell the same kind of spare parts.

Niverplast has made a list with all the spare parts, based on experience with maintenance and service. This list contains all the common replaced spare parts. They have a recommended spare parts list with spare parts for every standard machine, also for CombiPlast. A few of these spare parts for CombiPlast is given in *Table 4.1*.

In this table, you can see that they make a distinction between de different sections of the machine under the column, 'Description'.
The part numbers are also written down in this table. The numbers starting with 25.0000 are buy-parts and numbers starting with 50.0000 are make-parts. Buy-parts are bought from a supplier and the made-parts are made by Niverplast themselves.
All the other article numbers are parts from a different company named Lantech, which is the company that provides Niverplast with some of the mechanical parts of the machines.
Looking at the table, we see that some of the parts have the same name but have a different part-number. This is due to the fact that these parts are used for different types of the machines. The column 'Choice' shows if there are any options to choose for this machine. For example, the C450, is a shorter version than the C600.

Table 4.1 - Recommended spare parts CombiPlast

Recommended spare parts CombiPlast				Pricing Valid till:	31-8-2021	
Description	**Part-number**		**Quantity**	**Price a Piece**	**Total**	**Choice**
Mechanical parts						general
1-600 Plano opener						general
Vacuum cartridge VC202P	157738B		4	€ 76,12	€ 304,47	venturi suction cups box
Vacuum cups	000529A		16	€ 12,26	€ 196,16	general
Balancer	201033A		1	€ 129,95	€ 129,95	general
1-700 Box size adjustment						Man adjustment
Hand wheel width adjustment	179547A		1	€ 29,33	€ 29,33	Man Adjustment
1-900 Pusher						Pusher
Gear belt Box Pusher L=2510mm	078083C		1	€ 93,48	€ 93,48	Pusher
1-1500 Z-axis						
Timing belt Z-as	25.0471		1	€ 47,20	€ 47,20	C450
Timing belt Z-as	25.0473		1	€ 53,87	€ 53,87	C600
Timing belt Z-as	25.1860		1	€ 53,96	€ 53,96	C850
1-1800 Bag store						
Cylinder	25.0192		1	€ 383,02	€ 383,02	2 sided bag store

The number of spare parts that are ordered by the customers are saved in the order history. The total order history is provided in *Appendix C*. In this chapter we only look at the most reorder parts in the order history.
We chose the spare parts that were reordered at least 100 times in the last ten years. We chose this amount because after talking with multiple mechanics, this amount would really show the outliers.

Looking at all the different item numbers we concluded that some parts have multiple item numbers, one for the drawing in SolidWorks and a different number for the depot. This makes the analysis a bit difficult, but after integrating these numbers we created an overview with the most reordered parts. This gives us nine parts that are ordered the most, as can be seen in *Table 4.2.*
In the table, the column 'Combine with' are the different numbers used for the same spare parts. The amount of sold parts of these different numbers are combined to give the total amount of parts that have been purchased.
As can be seen there is one big outlier which is almost sold 2000 times. This part, the vacuum cup, is reordered a lot because it is a part that is used a lot and has a tendency of getting obstructed. Further there are 16 in total in the machine at the same time, so this means that when they break down, they often replace all 16 at the same time.

Looking at the pricing of the different spare parts, the cheapest one costs € 10,22 and the most expensive one costs € 397,49. The vacuum cups cost € 12,26 each, so this part is one of the cheapest parts. This is convenient for the customer because there are 16 of these cups present in the CombiPlast.

Table 4.2 – Order history with the 9 most reordered spare parts.

Artikel-nummer	Description	Amount	Combine with	Amount in machine	Total amount of parts purchased
000529A	Suction cup	1595	26.0007, 23.0001,25.0987	16	1984
25.0198	Rail stripper	526	20.0140	6	551
MC90196	Blade TH-250 With blank cover	268		4	268
076264F	Roller Complete	259		18	259
076264D	Roller Complete	190		18	190
MC90195	Rubber Roller	150		4	150
157738B	Vacuum cartridge VC202P	118		4	118
000593B	Linear bearing blue	110		4	110
25.3840	Bullet snapper messing 68.4x13,0	109	25.0330		139

Placing these 9 most reordered spare parts next to the total spare parts list, *Appendix C*, we see that the bullet snappers, rubber rollers and linear bearing blue are not included in the recommended spare parts list. Even though these parts are reordered a lot by the customers. This means that the recommended spare parts list is not complete, and some parts should be added in this list.

4.3 Maintenance according to the customers

To gather more information about the maintenance done by the customers and the kind of obstacles mechanics come across when they do maintenance, we asked customers and mechanics to fill out a survey. The survey for the customers existed of 17 questions, with a mix between open and multiple-choice questions, as can be seen in Figure 4.1. The survey was sent to the customers that owned only one CombiPlast machine. In total the survey was sent to approximately 60 customers, but only 16 customers took the time to fill in the survey. It was difficult to get a response from the customers because not all the emailed persons knew enough to answer the questions.

The survey for the mechanics contained 10 questions, also open and multiple-choice questions. These questions are shown in Figure 4.2. All the 10 mechanics that were contacted filled in the survey. All the results from the surveys are in Appendix D and E. In this section, we summarize the results.

Questions customers:

1. How many hours does the CombiPlast run approximately every week?
2. How many boxes are made by the CombiPlast approximately every hour?
3. How regularly does the CombiPlast undergo maintenance (including planned and unplanned maintenance, excluding cleaning)?
    - Once a week
    - Once a month
    - Once a quartile
    - Once every half year
    - Once a year
    - Otherwise,……
    - I don't know
4. How regularly does the CombiPlast get cleaned?
    - Once a day
    - Once a week
    - Once a month
    - Once a quartile
    - Once every half year
    - Once a year
    - CombiPlast is never cleaned
    - I don't know
5. How does the CombiPlast get cleaned? (More than one answer possible)
    - Machine is never cleaned
    - Water
    - Soap
    - Dry towel
    - Wet towel
    - Otherwise,……
6. How much time approximately is used to repair and clean the CombiPlast every month? – Planned maintenance
7. How much time approximately is used to repair and clean the CombiPlast every month? – Unplanned maintenance
8. How much time approximately is used to repair and clean the CombiPlast every month? – Cleaning
9. When a malfunction occurs, is the CombiPlast repaired by your own mechanics or by mechanics from Niverplast?
    - Completely by mechanics from Niverplast
    - Mostly by mechanics from Niverplast, sometimes by own mechanics
    - Mostly by own mechanics, sometimes by mechanics from Niverplast
    - Completely by own mechanics
    - Malfunction never occurs
10. Is planned maintenance done by mechanics from Niverplast or your own mechanics?
    - Completely by mechanics from Niverplast
    - Mostly by mechanics from Niverplast, sometimes by own mechanics
    - Mostly by own mechanics, sometimes by mechanics from Niverplast
    - Completely by own mechanics
11. How regularly is the z-axis oiled?
    - Once a week
    - Once a month
    - Once a quartile
    - Once every half year
    - Once a year
    - Otherwise,……
    - Never
    - I don't know
12. Are there other parts of the CombiPlast which are also oiled?
    - Yes, these parts:…….
    - No
13. When the last question is answered with yes. How often are these parts oiled?
14. Do you have often problems with the CombiPlast?
    - Yes, these problems occur: ……..
    - No
15. Do you have spare parts in inventory?
    - Yes
    - No
16. Where do you buy these spare parts?
    - Completely by mechanics from Niverplast
    - Mostly by mechanics from Niverplast, sometimes by own mechanics
    - Mostly by own mechanics, sometimes by mechanics from Niverplast
    - Completely by own mechanics
17. When you have more comments or questions, you can ask them here.

Figure 4.1 – Questions survey customers

Questions mechanics

1. What are the most common problems for the CombiPlast?
2. What are the parts that need to be replaced most often?
3. On what is time span of planned maintenance for the CombiPlast based??
    - Based on amount of operating hours
    - Based on time
    - Other, based on: ………
4. How many times a year are you called for breakdown maintenance with a CombiPlast?
    - Less than once a year
    - 1 to 3 times a year
    - 4 to 6 times a year
    - 7 to 9 times a year
    - 10 to 12 times a year
    - More than 12 times a year
    - Never
5. Which parts have to be replaced the most with breakdown maintenance of the CombiPlast?
6. How many times do you think the CombiPlast needs planned maintenance (excluding breakdown maintenance and cleaning), when there is 24/7 production?
    - Once a month
    - Once a quartile
    - Once every half year
    - Once a year
    - Once every 2 years
    - Other,….
7. How often do you think the CombiPlast needs to be cleaned? When there is 24/7 production.
    - Once a week
    - Once a month
    - Once a quartile
    - Once every half year
    - Once a year
    - Other,…..
8. How much time on average do you need for mainteance on CombiPlast?
    - Less than ½ hour
    - Between ½ and 1 hour
    - Between 1 and 2 hours
    - Between 2 and 3 hours
    - Between 3 and 4 hours
    - More than 4 hours
9. What can be improved about the CombiPlast, so it is less likely to breakdowm.
10. If you have more questions or remarks, please write them below.

Figure 4.2 – Questions survey mechanics

Customers can choose to have a service contract with Niverplast. This service contract states that the customer will receive periodic maintenance, for example once a year or every 2 months. The kind of contract can be chosen by the customer themselves. The service contracts chosen by the customers who filled in the survey are depicted in *Table 4.3* in the last row. For example, '0' indicated that the customer receives no maintenance, the '1' indicates that the customer has a service contract with Niverplast to receive maintenance one time a year and the '2' means they receive service twice a year.

The row 'Maintenance' stands for the amount of maintenance the customers think the CombiPlast needs, so for example every half year or every year. We can see that the maintenance is quite random. For example, the Customer A and K have the same amount of runtime, but A has double the amount of boxes per hour. However, looking at the maintenance we see that customer K prefers maintenance every week and customer A only every half year. This could be caused by the difference in sector between the different customers, namely customer A produces fish and customer K produces bread. In factories that produce fish is the humidity much higher a lot of the time then other factories. This would result in needing more regularly maintenance. Due to lack of information on the different sectors we cannot surely say that this is the causes the difference in maintenance, but this would be really interesting to investigate further.

In the results, we can see that there is a big difference between the number of runtimes and the number of boxes produced by CombiPlast at different customers. Also, there is a big difference in when the customers are getting maintenance and the amount of maintenance, they receive from Niverplast according to the service contract. We can assume that the other times the maintenance is done by their own employees. This can also be seen in *Figure 4.3*, more than half of the participants are using their own mechanics and only sometimes the mechanics from Niverplast. This shows that usage of the machine differs a lot per customers. This indicates that there is a need for analysis of maintenance requirements based on usage. When Niverplast can make a maintenance plan per customer based on the runtimes, this can be very useful for the customers.

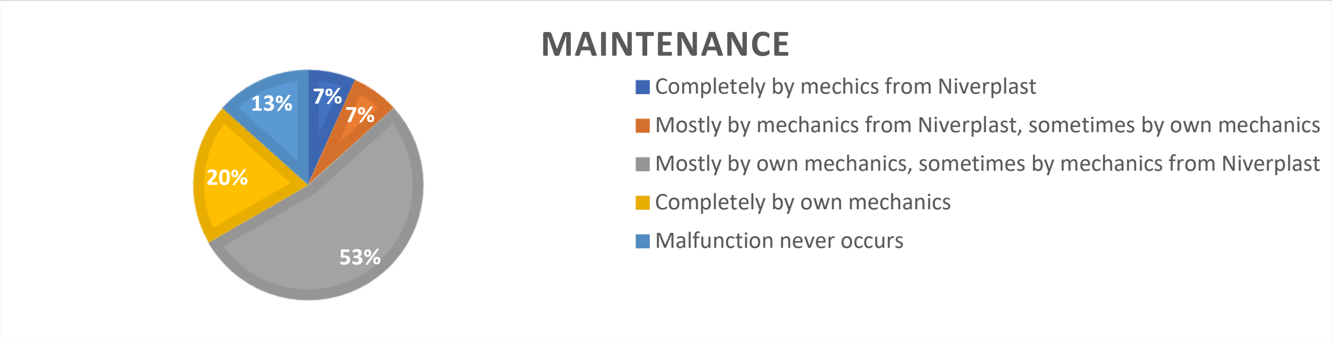

Figure 4.3 – Maintenance done by who, according to the customers

Customers do not need a contract to receive maintenance when there are breakdowns or immediate problems. It is always possible for a customer to call and receive paid 'breakdown maintenance'.
It is also possible for customers to buy spare parts from Niverplast. When there is something wrong with the machine, they can repair it themselves.

Table 4.3 – Customer survey results

Customer	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Runtime every week in hours	50	24-32	32	ca 65	85	40	128	168	70	96	50	Average of 12 hours at the present time	80	120 hours	50
Amount of boxes per hour	300	120	300	80	240	200	90	depends on run rate and box size (average 60/hr)	360	20	150	200	80	108 boxes on average	50
Maintenance	Once every half year	Once a year	Once every half year	Once a year	Once every half year	Once every half year	Once a month	Once a quartile	Once a year	Once every half year	Once a week	Once a quartile	Once a week	Once a week	Once a quartile
Service contract	0	1	0	1	1	2	0	1	1	0	0	1	0	0	1

The mechanics think that it is really useful to have regularly maintenance as can be seen in *Figure 4.4.* The mechanics voted for how regularly they think the CombiPlast needs maintenance. More than half of them voted that the CombiPlast needs maintenance at least every half year to make sure the machine is still working accordingly.

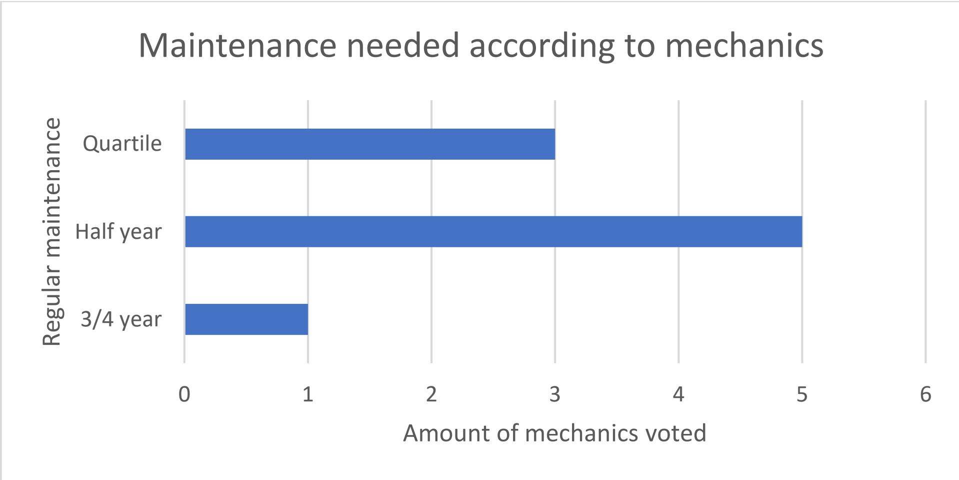

Figure 4.4 - Maintenance needed according to mechanics

Cleaning of the machines is done by the customers themselves. How much time the customers use for cleaning varies a lot. As you can see in *Figure 4.5*, almost half of the customers clean their machine once a week.
All the mechanics think the machine should be cleaned once a week. This is to prevent any bigger problems with the CombiPlast.
The way all the customers clean the CombiPlast is pretty much the same. As can be seen in *Figure 4.6,* almost everyone at least uses a dry towel and almost all of them also used compressed air. Only a few use a wet towel, water or soap.

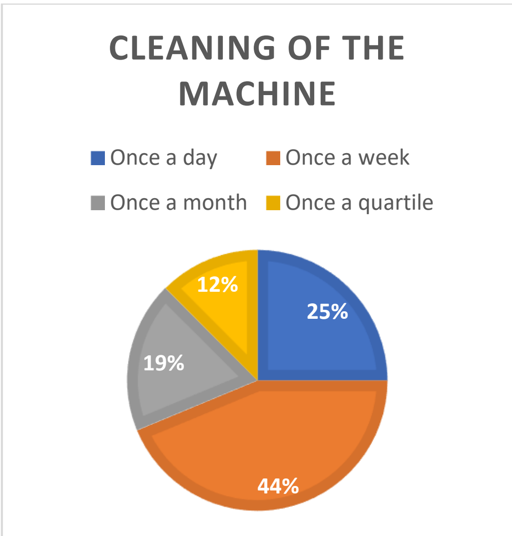

Figure 4.5 - Ways to clean machine according to survey customers

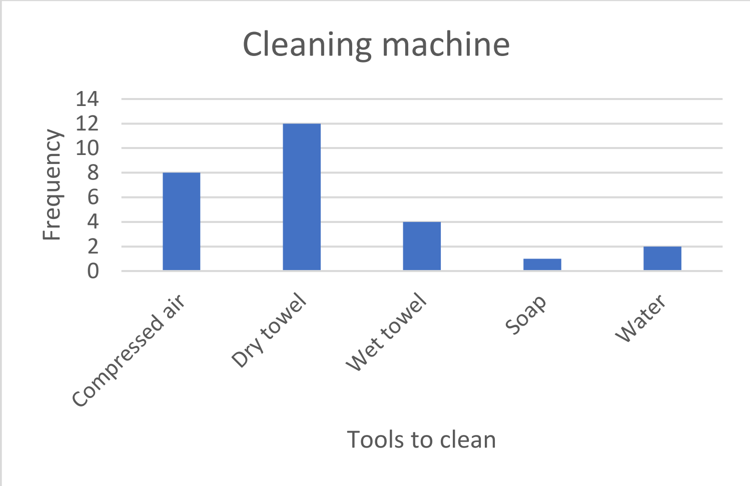

Figure 4.6 - Cleaning of machine according to survey customers

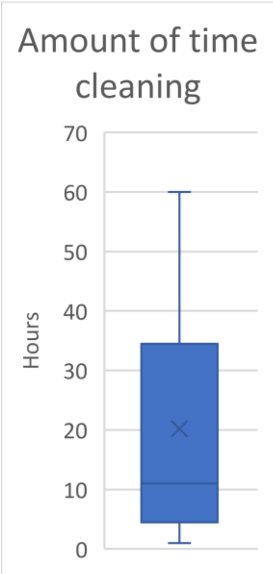

Figure 4.7 - Boxplot of amount of time cleaning

The amount of time the customers use to clean the machine every month, differs a lot, *Figure 4.7*. According to the boxplot 50 precent of the customers indicate that they clean between 5 and 35 hours every month. This is still a wide range. This can again be caused by the different sectors but is not certain. Niverplast can really benefit from this when it is clear how regularly the customers need to clean their machine. When this can be organized per sector, they can really inform the customer on how to increase the lifespan of the machine by cleaning often enough.

When looking at the survey of the mechanics, all mechanics think that it is necessary to clean the machine every week.

Further we asked questions about if there occurred problems often and what these problems are. Twelve of the sixteen participants told us that they never had any problems with the CombiPlast. The other participants indicated about a few problems that occurred: vacuum problems, the quality of the plastic bags and carton boxes and the variation of the different boxes. These three problems are no major problems and only the first one is really related to the machine.

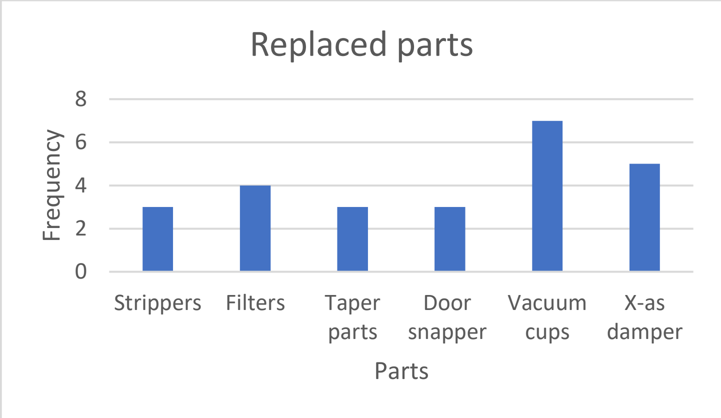

Figure 4.8 - Most replaced parts according to mechanics

The last interesting part from the survey is about the parts that need to be oiled. The results from these questions are again really divers. Some of the participants say that they almost never oil the parts and other customers oil them almost every day. Also, the number of parts that are oiled diverse a lot. This again can be sufficient for the customers if they when and which parts need to be oiled.

The mechanics have a lot of experience with maintenance of the CombiPlast. One of the questions on the survey was about the kind of parts that are repaired the most, *Figure 4.8*. This gave us a nice overview on six of the most replaced parts. Most of the mechanics thought the vacuum cups and the x-a damper were replaced most often. These are parts that can be seen in the order history, but they are not all in the top 9. Also, they are not all in the recommended spare part list.

Also, the most common problems the mechanics see during maintenance are categorised in five problems. These problems, as you can see in *Table 4.4,* are mostly problems occurring with the box type and bags. There are no big common problems with the machine itself.

Table 4.4 - Most common problems according to mechanics

Most common problems	Number of mechanics listing this problem
Wrong settings	2
Bad quality boxes	2
Conduction folding brackets	2
Tape mistakes	2
Boxes/bag mistakes	4

From these results we can conclude that there are certain spare parts that break down more often than other parts. It is however still not how often these parts break down. More data is needed to know for certain how long it takes for certain parts to break down.

Further, there is a lot of variety between the answers of the customers and it is clear that the customers do not have a certain maintenance and cleaning plan in place for the CombiPlast. This is something Niverplast can work on to help the customers by giving them a substantiated time plan for replacing of certain wearing parts, maintenance, and cleaning.

5. Roadmap

For Niverplast to get a better view on what kind of maintenance is needed for the CombiPlast, they really need to collect more data. The best way to do this and which data can be useful is explained in this chapter.

From the literature we concluded that the best framework for Niverplast to follow is given in *Figure 5.1.*

Collecting data

↓

Identify data

↓

Data preparation

↓

Identify the most critical components

↓

Choose the maintenance policy

↓

Implement and evauation

↓

Updating of data collection

Figure 5.1 - Maintenance concept framework

Step 1 Data collecting

In this step it is important to figure out which kind of data is needed to be collected to be able to get to the right conclusions. Due to the fact that this data is about the workings of a machine, it is advised to gather data for multiple years.

After figuring out which kind of data is needed, all this data needs to be collected.
Also, it is really good to look at the kind of customers this data is going to be collected from. It is in the interest of Niverplast to categorize these customers in the different sectors they use, bakery, oils & fats, meat & fish, powder, fruits & vegetables and others. When all the data from the customers can be categorized in these different sectors, Niverplast can really establish a plan to give each customer the best needed plan for their maintenance.

The data that can be collected from the different customers, depends on how willing the customers are in sharing data. We can categorize the data in discrete and continuous data. The data that is stored by the sensors is continuous monitored data, and data that is stored in a different way is discrete data.

The continuous monitoring data that is useful to be collected are humidity, dust in the air, vibrations, running speed, error codes.

The humidity, dust and vibrations are important in establishing the lifespan of certain spare parts. High or low values of these can increase or decrease the lifespan of the spare parts and with the that the lifespan of the machine. These values will also be different when comparing the different sectors.

In the new model of the CombiPlast there is an option to see the data of malfunctions, number of boxes a minute, number of rejected boxes, number of working hours, type of error, failure hours, etc. This data can be stored and collected by the customers or by Niverplast themselves. If customers are willing to share this kind of data with Niverplast, they can already see for example which malfunctions are shown more frequently, what precedes the malfunction, etc.

The discrete data that is important to store are the parts that are being replace or the amount of maintenance the machine receives. When it will be saved when and which parts are being replaced and cleaned, this can help in figuring out the lifespan of the parts. Currently, the data stored after maintenance is done for a customer is not optimal. When mechanics are going to a customer to repair something of the machine, the data is only stored under the name of the customer. There is made no distinction between the different machines a customer has. This means that when a customer has more than 1 machine from Niverplast, it is hard to recall for which machine maintenance and parts have been used.

When this data is stored with more information, it can really help in setting out a timespan on how often some part are replaced for a particular machine.

Lastly, when looking at the most used parts in the order history we see that the recommended spare parts list does not include all these parts. It is important for the customers to have an optimal list to prevent them to have unnecessary inventory, but still have all the spare parts they need. For this we need to gather data about the lifespan of the different parts. This should be possible to figure out with the discrete data.

Step 2 Identifying data

In this step it is important that the data collected in step 1 is understood. The data should be organized in different groups and explained. This way the meaning of every different outcome is written down.

Step 3 Data processing

After understanding the data, the raw data needs to be made usable. There are a few steps to follow to make sure all the data is usable.

First make sure that all the duplicates and incomplete data are either removed or made complete. Second, data that does not have any meaning has to be removed.

Step 4 Identify most critical components

The most critical components (MCC) have a big impact on the reliability of the system. To identify the MCCs we need to use tools such as the FMECA, according to Sarih (2019). The Failure mode effects and criticality analysis (FMECA) is a technique to identify and eliminate potential failures that can occur in the system.

The problems that occur with the bags and boxes according to the mechanics and the customers, is clearly something that does not always go smoothly. When doing an FMECA and analysing what the reasons are that these problems occur, Niverplast can work on a solution to prevent this in the future.

In the survey of the customers, we see that there are a lot of inconsistencies with the number of times the customers think maintenance is needed. This is something that should be communicated thoroughly with the customers. Niverplast should work on optimal maintenance intervals. This should be done by looking at failure times of the different parts.

When looking at the number of boxes produced and the amount of time the machine is running, there should be made an analysis on how many runs it takes before a certain part breaks down. When this information can be collected from multiple customers, Niverplast can make a clear overview with the number of intervals and parts that are likely to break down.

To calculate the optimal maintenance intervals, there are multiple data needed. The formula to calculate theses intervals is $CPUT(t) = \frac{C_p \cdot R(t) + C_u \cdot (1 - R(t))}{\int_0^t R(s)ds}$, with

CPUT = Cost per unit time
R(t) = reliability at time t
C_u = corrective maintenance costs (unplanned maintenance)
C_p = preventive maintenance costs (planned maintenance)
When the costs can be calculated, we can find out what the optimal interval would be for maintenance.

All the customers should know how regularly the machine should be checked. When customers keep the maintenance schedule Niverplast provides, it would be much better for the machine and result in less malfunctions.

Also, the cleaning and oiling of some of the parts is really different with the customers according to the survey. There should be collected a lot of data to make optimal cleaning intervals. This will go in the same way as the optimal maintenance intervals.

Step 5 Select maintenance policy

After looking at all the data and analysing the critical components, we can figure out which of five maintenance types, given in *Chapter 3*, are the best to use. This needs to be evaluated for every spare part and in combination with the different sectors.

Step 6 Implementation and evaluation

In this step the selected maintenance policies selected in step 5 need to be implemented. After this maintenance concept is implemented it can be evaluated after some time.

Step 7 Updating and data collection

After this maintenance concept is implemented, we can generate data again. New data can be added at the right place and the analysis can be done again. It is important to check if the right decision are made by making the maintenance concept and if this can be seen in the data. It is possible that some decision are still not optimal and this should than be updated.

6. Roadmap Data

In Chapter 5 there is a roadmap given about the best way for Niverplast to gather the right information. Chapter 6 gives an example on how this data will look and what can be done with it. In Chapter 6.1 and example about error codes and Chapter 6.2 a data example of the number of boxes. With both examples are the first three steps of the roadmap explained.

6.1 Error codes

Since this year the new design of the CombiPlast are being sold, this new design has more options on software to store data. It would be useful for Niverplast to ask the customers if they mind data being stored at Niverplast or if they for example store the data themselves and share this with Niverplast. For Niverplast to continue improving their machine and maintenance it is really needed to collect this data from the customers.

At this moment the CombiPlast machine does not store any data yet. It is possible to see what the machine is doing on the screen, but it is not possible to save this data. It is however possible to program the machine in a way that it will store the data.

To get a better overview what kind of data can be collected from the CombiPlast, I made some dummy data.

Table 6.1 – Operating mode of the CombiPlast

Time	OperatingCode
02/13/2021 13:30:00	10
02/13/2021 13:31:00	10
02/13/2021 13:32:00	10
02/13/2021 13:33:00	10
02/13/2021 13:34:00	10
02/13/2021 13:35:00	10
02/13/2021 13:36:00	10
02/13/2021 13:37:00	10
02/13/2021 13:38:00	10
02/13/2021 13:39:00	10
02/13/2021 13:40:00	10
02/13/2021 13:41:00	10
02/13/2021 13:42:00	10
02/13/2021 13:43:00	10
02/13/2021 13:44:00	10
02/13/2021 13:45:00	10
02/13/2021 13:46:00	0+100+120
02/13/2021 13:47:00	0+100+120
02/13/2021 13:48:00	0+100+120

This data is generated by looking at the actual downtime every minute. The current downtime at that moment is given by a code. These codes all are related to a different kind of reason for the downtime. It is also possible to have multiple codes at the same time because there can be multiple reasons at the same time why the CombiPlast is not working. An example of these codes can be seen in *Table 6.1*. This would be step 1 and 2 of the roadmap.

Table 6.2 - Frequency of operating code

OperatingCode	Amount
10	16
0	3
100	3
120	3

For step 3 we need to get a clear overview of this data we need to split the double codes. This can be done with VBA, code in appendix B, after splitting these lines we can count the number of times a code is used. *Table 6.2,* gives an overview on how this will look. In this overview you can clearly see which of the codes are more used than others.

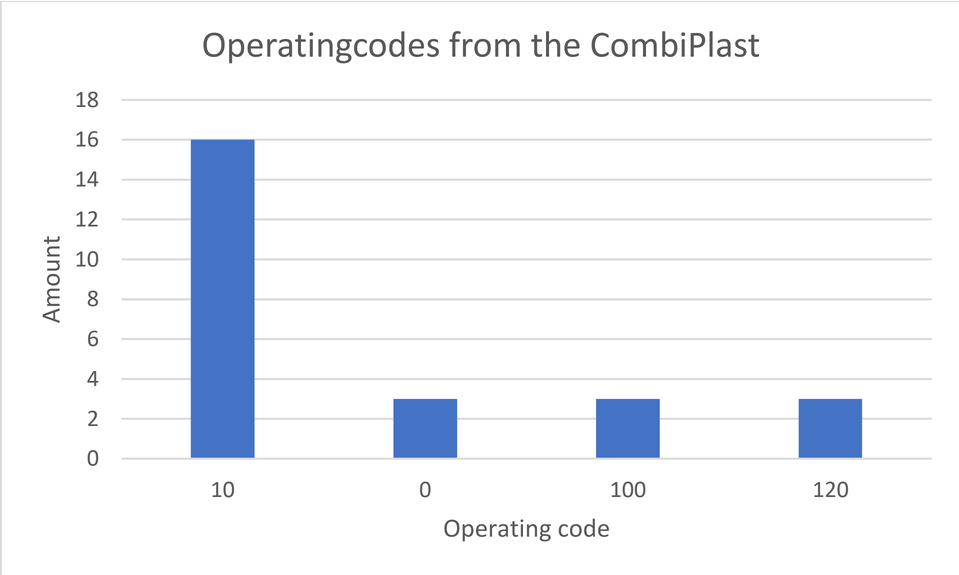

Figure 6.1 – Operating codes from the CombiPlast

In this graph, *Figure 6.1*, is shown how many times these codes are registered by the CombiPlast. In this example I have chosen some operating codes. 'Code 10' is the code registered when there is nothing wrong with the machine and the machine is working normally. 'Code 0' is that there is a problem with the box unfolder, 'Code 100' a problem with the bag placer and code 120 an obstruction on the line. The data set I implanted is not really big. After Niverplast has collected for multiple years, this amount will be large. It would then be wise to delete this code out of the graph. By deleting this code, there will be a better overview for the codes used to show that something is wrong. This overview can be very useful to see which are the most common problems.
When having an overview of the error codes that occur with the CombiPlast, this can be linked to the wearing parts. It is possible that certain errors occur when one of the parts is not working correctly. When this happens, it will give a good indication on when certain parts need to be replaced. This can both benefit Niverplast and the customer.

6.2 Amount of boxes

Another kind of data that can be collected is the number of boxes made by the CombiPlast and the number of boxes that are rejected by the CombiPlast, as can be seen in *Table 6.3*. This table gives the raw data, which compares with step 1 of the roadmap. This data is stored every five minutes, but this can be chosen differently. With this information Niverplast can calculate what the process speed is from different customers and how many hours the machine is working.

This is very important information, because when the running time and the speed is known this can be used as a time indication of the number of runs. A machine working 24/7 with maximum speed will result in earlier wearing down than a machine working a few hours a day.

Table 6.3 - Data number of boxes and rejected boxes

Time	TotalCounterBox	TotalRejectedBox
02/13/2021 13:30:00	53	0
02/13/2021 13:35:00	52	0
02/13/2021 13:40:00	41	0
02/13/2021 13:45:00	32	2
02/13/2021 13:50:00	58	0
02/13/2021 13:55:00	62	0
02/13/2021 14:00:00	61	0
02/13/2021 14:05:00	62	0
02/13/2021 14:10:00	49	0
02/13/2021 14:15:00	51	0
02/13/2021 14:20:00	52	0
02/13/2021 14:25:00	52	0
02/13/2021 14:30:00	37	5
02/13/2021 14:35:00	25	0
02/13/2021 14:40:00	55	0
02/13/2021 14:50:00	58	0
02/13/2021 14:55:00	54	0
Average	**50,23529412**	**0,411764706**
Total	**854**	**7**

Implementing this data in step 3, we can make a graph, *Figure 6.2,* gives a clear overview of this data. The trendline gives a clear image that the average amount of boxes is slightly decreasing. When this graph can be seen with data from different years, you can see when for example there are less, or no boxes made during a certain period.

This data can be useful to put next to changes in settings, it is possible that when certain settings are changed, more boxes will be rejected. When an optimal setting can be found from this data, that can be used during maintenance.

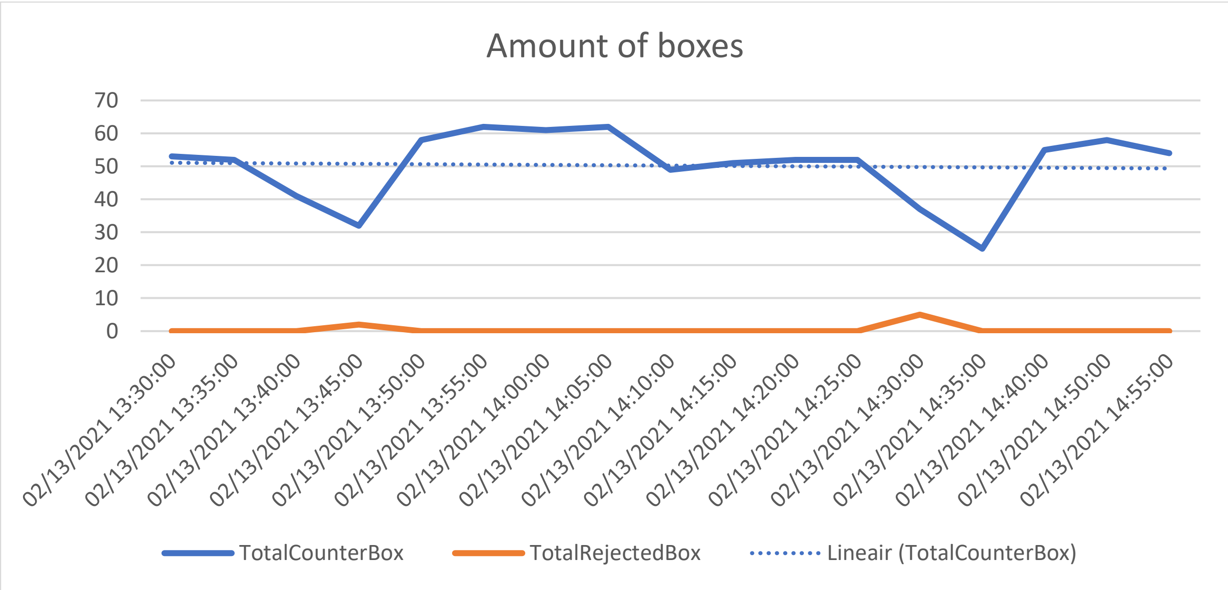

Figure 6.2 - Number of boxes CombiPlast

7. Conclusion and recommendations

In this chapter the conclusion and recommendations of this report will be discussed. First the conclusion will be elaborated. At last, the recommendations will be given.

7.1 Conclusion

The core problems of this research where, that the mechanics execute preventive maintenance based on intuition and that there is no indication when certain parts will break down.
This gave us our main problem for this research; “How can we get a clear indication about when certain spare parts are breaking down?”
We concluded rather quickly that the amount of data that Niverplast had stored was not enough to give a clear indication on the lifespan of the spare parts. With the use of surveys, we found out that there are certain spare parts that break down more than others. With the most reordered part, the suction cups. Also, from the survey it was clear that there is a lot of uncertainty with the customers and mechanics about when there needs to be done maintenance and what kind of maintenance. The different maintenance policies can be categorised in corrective and preventive maintenance. Corrective maintenance can be divided in deferred corrective maintenance and immediate corrective maintenance. Deferred corrective maintenance is planned and immediate corrective maintenance is done at that instance.

Preventive maintenance is categorised in time-based maintenance which is maintenance based on failure time analysis, condition-based maintenance, and predictive maintenance. With condition-based maintenance a single component is checked if it needs maintenance and with predictive maintenance it is based on measurement of condition for a longer period to predict if it will fail soon. At this moment all the other different sub-questions can only be answered after there has been selected more data.
The amount of data Niverplast has now stored is not enough to give any clear indication on the maintenance that is needed for the CombiPlast. If Niverplast wants a better understanding of the malfunctions occurring with the CombiPlast they really need to collect more data from different customers, as described in the roadmap.

The roadmap is based on literature and exists of seven steps.

1. Collecting data
2. Identify data: understand the data and organize.
3. Data preparation: delete any unnecessary data.
4. Identify the most critical components
5. Choose the maintenance policy
6. Implement and evaluation
7. Updating of data collection

The roadmap should give a clear guide for Niverplast to gather enough data to get these problems solved in the future.

7.2 Recommendations and further research

The best way in optimizing the maintenance and the lifespan of the CombiPlast, Niverplast really needs to collect more data. The best way to organize this is asking the customers receiving a new CombiPlast if they are willing to share the information that is stored. Older customers can also be asked, but with the new CombiPlast it is easier to gather information because it is already programmed.

After collecting enough data, this research can easily be taken and extended. When following the roadmap, there can be said a lot about the parts of the CombiPlast. This can really help in answering the unanswered questions in this thesis. With all this data collected there can be made a thorough research about all the critical components collected from this data.
When this research is done with the CombiPlast, it is also recommended to do this with other machines. When this data can already be gathered simultaneously with the CombiPlast, it is always possible to choose to figure out the maintenance and lifespan of the other machines. This way they can say to the customer with certainty how their machines need to be maintained to increase their lifespan.

7.3 Contribution to practice and theory

Contribution to practice

We recommend the following to Niverplast:

- To get any information about the lifespan of the CombiPlast, all the data that can be gather needs to be stored as stated in Chapter 5. All the customers buying a new CombiPlast need to be asked if they are willing to share this information.
- For all the other machines it is recommended to start with storing data at the same time as the CombiPlast. This will give Niverplast the opportunity to investigate not only the wearing parts of the CombiPlast, but also the other packaging machines.
- We recommend using Excel to get all the data analysed and gathered.

Contribution to theory

- In the literature there is made a distinction between five different kind of maintenance. We recommend using the data to figure out which kind of maintenance is best in which situation.
- The concept framework for the roadmap is gather by looking at different literature studies. It is possible that a different step shown in literature would be good to use in the roadmap when the data is gathered. Niverplast should evaluate if for some of the data it would be wise to use an extra step.

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Appendix

Appendix A – systematic literature review

The knowledge problem "How can we optimize the lifespan of the different wearing parts of the CombiPlast and decrease the downtime?"

Criteria

- All the articles about machine maintenance, methods and policies should not be older than 5 years, because sources that are too old have a high chance of being obsolete.
- Articles about different kind of maintenance and methods that can be used.

Database

For this literature search I will use the following databases: Google scholar and the UT library. Both these databases give the option to search with more restriction, so you can get more specific results.

Search terms and strategy

The search strategy is done with the use of a CIMO matrix, Context, Intervention, Mechanism, and Outcomes (CIMO). The table below shows the subjects that I will be focussing on.

CIMO	Constructs	Related terms	Broader terms	Narrower terms
Context	Lifespan	Machine parts		
Intervention	Types of maintenance	Preventive maintenance, corrective maintenance	Machine maintenance	
Mechanism	Sensors inspection	Condition machines		Humidity, dust machines
Outcomes				

Article list

Search string	Scope	Date of search	Data range	Number of entries
Google scholar				
"preventive" AND "maintenance" AND "corrective" AND "breakdown" AND "predictive"	All	2-01-2021	2015 - 2021	3790
"lifespan" AND "wearing parts" AND "machine"	All	2-01-2021	2015 - 2021	37
UTwente Library				
"preventive" AND "maintenance" AND "corrective" AND "breakdown" AND "predictive"	All	2-01-2021	2015 - 2021	19

“lifespan” AND “wearing parts”	All	2-01-2021	2015 - 2021	1

Conceptual matrix

Journal	Authors	Key findings
Strategic approach breakdown maintenance	Ahamed Mohideen, P.B. & Ramachandran M.	How to handle corrective maintenance
Preventive maintenance planning	Basri, E.I, Razak, I. H. A., Ab-Samat, H., Kamaruddin, S.	How the methods are affected. Preventive maintenance is mostly planned on costs, time or failures.
An optimal procurement policy for multiple consumable accessories with different lifespan distributions	Li, C. R., Sarker, B. R., Cui, G. Chen, X. L. Luo, W. L.	Lifespan of different parts will be different, optimal deadline for usage of parts can be determined before failure.

Integration of theory

With these sources there is clearer view on what different maintenance contain and how you can look at the lifespan of different parts. This is already useful information to get a clear background for the knowledge problem. However, there need to be done extensive research in order to get a clear answer on the knowledge problem.

Appendix B - VBA-code

Split the values by the +-sign and place them in different cells.

```
Sub SplitCell()
Dim i As Integer
Dim j As Integer
Dim Name As String
Dim SplitName As Variant

For i = 2 To 20
        Name = Cells(i, 2).Value
SplitName = Split(Name, "+")
For j = 0 To UBound(SplitName)
Cells(i, 2 + j).Value = SplitName(j)
                Next j
Next i
End Sub
```

Appendix C – Recommended spare parts list

Recommended spareparts CombiPlast					Pricing Valid till:	3-12-2021	
Description Dutch	Description English	Part.number	Description	Quantity	Price a Piece	Total	Choice
Mechanical parts							alg
1-600 plano opener							alg
Vacuum cartridge VC202P	Vacuum cartridge VC202P	157738B		4	€ 76,12	€ 304,47	venturi suctioncups box
Zuignappen	Vacuum cups	000529A		16	€ 12,26	€ 196,16	alg
Balancer	Balancer	201033A		1	€ 129,95	€ 129,95	alg
1-700 Box size adjustment							Man Verstelling
Handwiel breedteverstelling	Hand wheel width adjustment	179547A		1	€ 29,33	€ 29,33	Man Verstelling
1-900 Pusher							Pusher/Afnameraam Mechanisch
Transportband doosaandrukker	Gearbelt Box Pusher L=2510mm	078083C		1	€ 93,48	€ 93,48	Pusher/Afnameraam Mechanisch
1-1100 Output conveyor right							alg

Zijtransportband zakkenplaatsmodule	Sidebelts bag placing module	001265C	L=2265mm	1	€ 168,00	€ 168,00	(alg)normale zijbanden
Zijtransportband zakkenplaatsmodule	Sidebelts bag placing module	228738A	L=2365mm	1	€ 174,34	€ 174,34	lange zijbanden 1
Zijtransportband zakkenplaatsmodule	Sidebelts bag placing module	060180D	L=2665mm	1	€ 181,50	€ 181,50	lange zijbanden 2
1-1200 Output conveyor left							alg
Zijtransportband zakkenplaatsmodule	Sidebelts bag placing module	001265C	L=2265mm	1	€ 168,00	€ 168,00	(alg)normale zijbanden
Zijtransportband zakkenplaatsmodule	Sidebelts bag placing module	228738A	L=2365mm	1	€ 174,34	€ 174,34	lange zijbanden 1
Zijtransportband zakkenplaatsmodule	Sidebelts bag placing module	060180D	L=2665mm	1	€ 181,50	€ 181,50	lange zijbanden 2
1-1500 Z-axis							alg
Tandriem Z-as	Timingbelt Z-axel	25.0471	AT10B25L3060	1	€ 47,20	€ 47,20	C450
Tandriem Z-as	Timingbelt Z-axel	25.0473	AT10B25L3360	1	€ 53,87	€ 53,87	C600
Tandriem Z-as	Timingbelt Z-axel	25.1860	AT10B25L3840	1	€ 53,96	€ 53,96	C850
1-1600 Spreading unit							alg
Tandriem Spreidunit	Timingbelt Spreading unit	25.0199	T10 W=16 L=1350 endless	1	€ 46,99	€ 46,99	C450
Tandriem Spreidunit	Timingbelt Spreading unit	25.0536	T10 W=16 L=1650 endless	1	€ 48,01	€ 48,01	C600
Cilinder	Cylinder Spreading	25.0203	DSNU-20-320-PPV-A	1	€ 90,68	€ 90,68	C450

Cilinder	Cylinder Spreading	25.0537	DSNU-25-395-PPV-A	1	€ 102,35	€ 102,35	C600
Cilinder	Cylinder Relax bag	25.0205	DSNU-20-50-PPV-A	1	€ 61,44	€ 61,44	C450
Cilinder	Cylinder Relax bag	25.0205	DSNU-20-50-PPV-A	1	€ 61,44	€ 61,44	C600
Cilinder	Cylinder Folding arms	25.0206	DSNU-20-250-PPV-A	1	€ 66,38	€ 66,38	C450
Cilinder	Cylinder Folding arms	25.1948	DSNU-20-320-PPS-A	1	€ 55,73	€ 55,73	C600
Afstrijker AB 32	Cleaner Rail AB32	25.0198		4	€ 21,04	€ 84,16	alg
1-1700 Bag open unit							alg
OEM .50 PRO PLATINUM schokdemper	Hydraulic damper	25.1373		1	€ 158,73	€ 158,73	alg
Cilinder	Cylinder Suction Mouth	25.5682	ADVUL-32-40-P-A	1	€ 259,39	€ 259,39	C600
Cilinder	Cylinder Suction Mouth	25.5100	ADVUL-16-45-PA	1	€ 143,13	€ 143,13	C450
1-1800 Bagstore							alg
Cilinder	Cylinder Rotating	25.0192	DSR-40-180-P-1	1	€ 383,02	€ 383,02	2 sided bagstore
Hotmelt							hotmelt Problue 7
Hotmelt Nozzle	Hotmelt Nozzle	003285A	Saturn nozzle dual30 90 degrees	1	€ 189,08	€ 189,08	hotmelt Problue 7
Filter hotmelt	filter hotmelt	MC91138		1	€ 206,04	€ 206,04	hotmelt Problue 7
1-1000 Taper TH375							Taper TH375

Veer	Main Spring (Bottom use)	MC90199		1	€ 29,62	€ 29,62	Taper TH375
Veer links/rechts	Cover Spring left/right (set)	MC90339		1	€ 12,82	€ 12,82	Taper TH375
Borstel	Brush	MC90522		1	€ 29,75	€ 29,75	Taper TH375
Rubber Roller	Rubber Roller	MC90507		1	€ 33,26	€ 33,26	Taper TH375
Mes TH375	Cutting Blade 3 inch TH375	MC90515		1	€ 32,03	€ 32,03	Taper TH375
1-1000 Taper TH250							Taper TH250
Veer	Main Spring (Bottom use)	MC90199		1	€ 29,62	€ 29,62	Taper TH250
Veer links/rechts	Cover Spring left/right (set)	MC90339		1	€ 12,82	€ 12,82	Taper TH250
Borstel	Brush	MC90197		1	€ 24,61	€ 24,61	Taper TH250
Rubber Roller	Rubber Roller	MC90195		2	€ 28,07	€ 56,14	Taper TH250
Mes TH250	Cutting Blade 2 Inch TH250	MC90196		5	€ 20,02	€ 100,10	Taper TH250
Busch Vacuumpump SV1040C							Big PumpSV1040
Luchtfilterinzet SV1040C	Filter Vacuumpomp SV1040C	25.2894	SV1025C/SV1040C	1	€ 60,03	€ 60,03	Big PumpSV1040
Rotorschuif per 7	Rotorblade 7 pieces	25.4235	SV1040C	1	€ 339,45	€ 339,45	Big PumpSV1040
Busch Vacuumpump SV1016C							PumpSV1016C

Filter Vacuumpomp C64/3	Filter Vacuumpomp C64/3	90.0401	C64/3	1	€ 17,41	€ 17,41	PumpSV1016C
Rotorschuif per 7	Rotorblade 7 pieces	90.0402	SV1016C	1	€ 254,38	€ 254,38	PumpSV1016C
Electrical parts							alg
Photocell case unfolded	Photocell	75.0305	WT2S-P261	1	€ 145,93	€ 145,93	alg
Vacuum Generator with integrated Vacuumswitch	Vacuum Generator with integrated Vacuumswitch	75.1417	VADM-200-P	1	€ 397,49	€ 397,49	venturi bag
Photocell case unfolded	Photocell	75.0453	WTB2S-2P3160	1	€ 117,30	€ 117,30	alg
Veiligheidssensor	Safety Sensor	75.0257	PSEN 2.1p-21/PSEN 2.1-20	1	€ 127,58	€ 127,58	alg
Photocell zak open unit in rustpositie	Photocell Bag open unit in home position	75.0310	IME12-08NPSZCOS	1	€ 26,14	€ 26,14	alg
WTB9-3P2411S14	fotoelectric proximity sensor	75.0450	WTB9-3P2411S14	1	€ 89,70	€ 89,70	alg

Reedcontact	Magnetic Sensor	75.2810	MZT7-03VPS-KPO	3	€ 21,78	€ 65,34	alg
M8, 3 polig, recht female, PUR, 10 meter, zwart	sensor cable	75.0901	7000-08041-630-1000	1	€ 16,05	€ 16,05	alg
PUR Cable, Yellow, M8 female, straight, 4-pin, 10 meter	sensor cable	75.0849	7000-08061-031-1000	1	€ 20,62	€ 20,62	alg
M8, 3 polig, recht female, PUR, 5 meter, zwart	sensor cable	75.0900	7000-08041-630-0500	1	€ 10,22	€ 10,22	alg
M12, 4 polig, haaks female, PUR, 10 meter, zwart	sensor cable	75.0904	7000-12341-634-0500	1	€ 14,06	€ 14,06	alg
					Total	**€ 5.975,16**	

Appendix D - Order history list

Artikelnummer	Description	Amount	Totaal
000529A	Suction cup	1595	1984
25.0198	Rail stripper	526	551
23.0001	Zuignap t.b.v. Combiplast	343	343
MC90196	Blade TH-250 With blank cover	268	268
076264F	Roller Complete	259	259
076264D	Roller Complete	190	190
MC90195	Rubber Roller	150	150
157738B	Vacuum cartridge VC202P	118	118
000593B	Linear bearing blauw	110	110
25.3840	Kogelsnapper messing 68.4x13,0	109	139
MC90515	Blade T3204800 With blank cover	74	74
MC90339	Cover spring left / right (set)	71	71
MC90641	Sponge for 2"	68	68
90.0402	Rotorblad grafiet t.b.v vavuum pomp set 7 pieces	61	61
23.0013	Transportband combiplast L=2265	60	98
005112B	Track roller	54	54
000592B	Linear bearing blauw	52	52
25.4021	Runnerblock	48	58
23.0003	Balancer	47	97
90.0401	Filterpatroon t.b.v vavuum pomp VT 4.16	47	47
25.0053	Runnerblock	47	47
25.0687	Suction cup	46	46
000265A	Balancer 2-3.5 KG	45	45
75.2810	Magn. cylinder sensor, DC 3-wire,for T-slot cyl.	45	51
MC90197	Brush	40	40
001265C	Conveyorbelt L= 2265	38	38
25.1502	Hydraulic damper	38	56
MC90199	Main spring (Bottom use)	37	37
25.4281	PVC transparant 200x75x4mm	32	62
25.0330	Double ball catch	30	30
50.0906	Shoulder	30	30
000435A	Slide bearing PAF16170 P10	30	30
25.0981	Runnerblock	29	34
001814A	DIN912 M5x40	28	28
MC90507	Rubber roller T3201300	28	28
000491A	Slide bearing PAP2520P10	28	28
000155A	Screw for suction cup	26	26
75.0453	W2S-2, Photoelectric proximity sensor, Background suWppTrBe2sSs-io2Pn3160	26	32
20.0140	Afstrijker AB 32	25	25
01.0002	SONDER PROGRAMMIERUNG	25	25
20.0404	Filter module Vadm-200	23	23

75.0257	SAFETYSWITCH + LED, 8mm	23	23
51.7073-A	Standard bag pin B=17,5mm	23	23
20.0401	Geluidsdemper vacuumgenerator	22	22
25.2654	One-way flow control valve	22	22
25.0028	Shock absorber, hydraulic	22	22
076275A	Sleeve	22	22
90.0112	Looprol	21	21
75.0309	Mounting systems	21	21
75.0450	W9-3, Photoelectric proximity sensor, Background suppression, M12	21	21
25.0214	Bearing bush	20	20
25.0212	Bolt	20	20
001560A	Stainless washer	20	20
01.0066	Programma aanpassing zoals overeengekomen	19	19
201033A	Balancer 9303NY/2,5	18	18
001638A	DIN472 47x1_75	18	18
25.1373	Shock absorber	18	18
000133A	Sliding block	18	18
001369A	Spacer	18	18
10.0243	Verwarmingselement L300	18	18
MC90433	Breaker T2100600	17	17
75.0310	Inductive sensor Sensing range 8 mm Normaly Open PIMNEP12-08NPSZC0S	17	17
75.0901	M8, 3 polig, recht female, PUR, 10 meter, zwart	17	17
20.0402	veer vacuumgenerator	17	17
25.2894	Luchtfilterinzet	16	16
MC90413	Screw 1/8x3/8 MBLOT001	16	16
50.0937	Shaft LFS 32 SF VA	16	16
25.0206	Zylinder DSNU-20-250-PPV-A_19243	16	16

Appendix E – Results survey mechanics

Vragen:

1. Wat zijn de meest voorkomende problemen bij de CombiPlast?
2. Wat zijn de onderdelen die bij de CombiPlast het vaakst vervangen moet worden?
3. Waarop wordt gebaseerd dat een CombiPlast gepland onderhoud nodig heeft?
    - Gebaseerd op het aantal draaiuren
    - Gebaseerd op tijd
    - Anders, gebaseerd op: ………
4. Hoe vaak per jaar gemiddeld word je opgeroepen om storingsafankelijk onderhoud (breakdown maintenance) bij een CombiPlast uit te voeren?
    - Minder dan 1 keer per jaar
    - 1 tot 3 keer per jaar
    - 4 tot 6 keer per jaar
    - 7 tot 9 keer per jaar
    - 10 tot 12 keer per jaar
    - Meer dan 12 keer per jaar
    - Nooit
5. Welke onderdelen moeten het vaakst vervangen worden bij storingsafhankelijk onderhoud (breakdown maintenance) van de CombiPlast?
6. Hoe vaak denk jij dat de CombiPlast gepland onderhoud nodig heeft (exclusief storingsafhankelijk onderhoud en schoonmaak), wanneer er 24/7 productie is?
    - Een keer per maand
    - Een keer per kwartiel
    - Een keer per half jaar
    - Een keer per jaar
    - Een keer per 2 jaar
    - Anders, ……
7. Hoe vaak denk jij dat de CombiPlast schoongemaakt moet worden? Als er 24/7 productie is.
    - Een keer per week
    - Een keer per maand
    - Een keer per kwartiel
    - Een keer per half jaar

- Een keer per jaar
- Anders, ……

8. Hoeveel tijd ben je gemiddeld kwijt aan onderhoud van een CombiPlast?
    - Minder dan ½ uur
    - Tussen ½ en 1 uur
    - Tussen 1 en 2 uur
    - Tussen 2 en 3 uur
    - Tussen 3 en 4 uur
    - Meer dan 4 uur
9. Wat kan er volgens jou verbeterd worden aan de CombiPlast, zodat hij minder snel kapot gaat?
10. Als je nog meer opmerkingen of vragen hebt, plaats deze dan hieronder.

Kandidaat:	**A**	**B**	**C**	**D**	**E**
1.	Foutieve instellingen, tape fouten, doos openen	Dozen van matige kwaliteit slecht kunnen draaien, weinig vergevingsgezind op afwijkingen in doosformaten	Geleiding van de invouwbeugels gaan soms los zitten, bij een servo machine komt speling op de arm die het afnameraam bediend.		Doos open fout
2.	Afstrijkers, filters, vacuumcups	ik doe geen onderhoud, maar als ik moet gokken, x-as voor het zak openen, en invouwbeugel cilinders. en lagers in het dozen opzet gedeelte	Buiten onderhoud om eigenlijk niets. Hooguit een cilinder van de invouwbeugels.	Afstrijker. Suction cups. X-as demper. En natuurlijk martin poets filter.	Demper x-as, filterset vad-m, suction cups, taper mesje
3.	Gebaseerd op tijd	Anders, gebaseerd op: Onderhouds contract, door de planner van de service afdeling	Gebaseerd op tijd	Gebaseerd op tijd	Anders, gebaseerd op: Jaarlijkse e-mail interval vanaf Anton
4.	Meer dan 12 keer per jaar	Nooit	1 tot 3 keer per jaar	7 tot 9 keer per jaar	10 tot 12 keer per jaar

5.	Vacuumcups readcontact cilinders lekke vacuum slangen	niet van toepassing	Cilinders, sensoren	Dat verschild heel erg.	Afstrijkers, filterset vad-m, suction cups,
6.	Anders, 3/4 per jaar	Anders, gebaseerd op: Onderhouds contract, door de planner van de service afdeling. Ligt aan de productie snelheid, als ik moet gokken elke 600.00 tot 750.000 geproduceerde dozen	Een keer per half jaar	Een keer per kwartiel	Een keer per half jaar
7.	Een keer per week	Anders, 1 keer per week groote schoonmaak, en ik zeg de shift opperator altijd om aan het einde van de shift even met de bezem en de luchtspuit door de machine te gaan. er vallen namelijk veel dozen snippers uit de planos die worden opgezet.	Een keer per week	Een keer per week	Een keer per week
8.	Tussen 3 en 4 uur	Minder dan 1/2 uur	Tussen 3 en 4 uur	Meer dan 4 uur	Tussen 3 en 4 uur
9.	Deur snappers	Hoe lager de productie snelheid van machine hoe langer alles meegaat. verder vind ik het doosopzet gedeelte wat meer variatie moet kunnen opvangen in de doosafmeting.	Constructie vd zwenkarm die het afnameraam bediend. Er komt soms overmatig speling op de bus die op de motor is bevestigd. Dit zou conisch moeten zijn ipv een bus met spiebaan.		Is per klant anders. Licht aan de omgeving, snelheid van de machine. Sommige klanten hebben veel capaciteit nodig en de andere weinig.
10.					Succes Mirthe

Kandidaat:	F	G	H	I	J
1.	De meeste problemen zijn voornamelijk verkeerde instellingen van de machine, maar dit heeft niks te maken met de technische staat van de machine. Kwa technische problemen denk ik vooral de slijtdelen zoals lagers, cilinders, kabels en slangen die in rupsen zitten.	Afname fout, zak fout, tape fout	Afname dozen	Instabiliteit invouwbeugels	verkeerde dozen/tape
2.	x-as demper, filters, suction cups, deur snappers.	Deur snapper	Vacuum cups	Afstrijkers - x as dempers - vacuüm cups	zuignappen, deursluiter, demper x-as en taperonderdelen
3.	Gebaseerd op tijd	Anders, gebaseerd op: Op tijd en wat de klant zelf wil	Gebaseerd op tijd	Gebaseerd op tijd	Gebaseerd op tijd
4.	Meer dan 12 keer per jaar	10 tot 12 keer per jaar	Nooit	1 tot 3 keer per jaar	4 tot 6 keer per jaar
5.	DIt is heel varierend. Dit kan een ventiel zijn, PLC, Regelaar, motor etc. Vaak wel van onderdelen die niet op halve kracht werken. Zoals een motor. Als een cilinder bijv. lek is dan functioneerd die vaak nog wel. Het vaakst komt denk ik voor dat een readcontact of kabel kapot is.	Motoren, cilinders en vacuüm systeem.		Invouwbeugel geleiding luchtslang scheurtjes in rups scharnier afname rack maar ook de arm onder de motor . Persoonlijk vind ik de luchtfilters in de elektrische kast heek belangrijk	grote onderdelen, denk bijvoorbeeld aan een servomotor. of constructiedelen zoals de arm van het afnameraam
6.	Een keer per kwartiel	Een keer per half jaar	Een keer per half jaar	Een keer per half jaar	Een keer per kwartiel
7.	Een keer per week	Een keer per week	Een keer per week	Een keer per week	Een keer per week
8.	Tussen 2 en 3 uur	Tussen 3 en 4 uur	Tussen 3 en 4 uur	Tussen 3 en 4 uur	Tussen 3 en 4 uur

9.	Het zal mooi zijn dat de machine weet hoeveel draaiuren een bepaald onderdeel heeft gehad en wat de gemiddelde levensduur van zo'n onderdeel is. Dan kunnen we in de software een melding maken wanneer de onderdeel bijv. 80% van levensduur heeft overschreden. En als we dan online gaan op de machine zouden we met deze data beter voor kunnen bereiden voor het onderhoud.	Andere deursnappers😃	Suction frame	Snelheid verlagen , dat houd in dat je een nirmake combiplast niet moet verkopen door te zeggen dat deze 18 dozen in de minuut loopt door eeb te hoge snelheid slijt de machine sneller en mist de machine het oppakken van doze dan wek het plaatsen van zakken . 12 in de minuut is een goed haakbaar tempo afhankelijk vab de grite van de doos. Als de opbrengst groter miet worden ziy ik een 2e combi adviseren met cobie korting	de meeste slijtage heeft de combiplast door het gebruik. operators zijn zich niet bewust van de waarde van een machine en gaan er vaak slordig mee om
10.	Ik ben geen onderhoudsmonteur maar service programmeur. Ik doe zelf zo goed als nooit periodiek onderhoud, dus heb er niet de volle ervaring mee.	Breakdown maintenance gaat de laatste tijd veel beter omdat we veel onderhoud doen.		Klant is zelf verantwoordelijk voor de tijdsduur van zij/haar machines. Optijd schoon maken en smeren + her vervangen van de stif filters garandeert eeb veel langere levens duur . Zien wij als monteur dat dat niet gebeurt moet de klant rekening dat je zi 1 of 2 x per jaar vaker moett komen dan wel voor onderhoud of storing .	door de jaren heen is de combiplast dusdanig verbeterd dat het een heel betrouwbare machine is geworden

Appendix F – Results survey customers

Questions:

1. How many hours does the CombiPlast run approximately every week?
2. How many boxes are made by the CombiPlast approximately every hour?
3. How regularly does the CombiPlast undergo maintenance (including planned and unplanned maintenance, excluding cleaning)?
    - Once a week
    - Once a month
    - Once a quartile
    - Once every half year
    - Once a year
    - Otherwise,……
    - I don't know
4. How regularly does the CombiPlast get cleaned?
    - Once a day
    - Once a week
    - Once a month
    - Once a quartile
    - Once every half year
    - Once a year
    - CombiPlast is never cleaned
    - I don't know
5. How does the CombiPlast get cleaned? (More than one answer possible)
    - Machine is never cleaned
    - Water
    - Soap
    - Dry towel
    - Wet towel
    - Otherwise,……..
6. How much time approximately is used to repair and clean the CombiPlast every month? – Planned maintenance
7. How much time approximately is used to repair and clean the CombiPlast every month? – Unplanned maintenance(breakdown maintenance)
8. How much time approximately is used to repair and clean the CombiPlast every month? – Cleaning
9. When a malfunction occurs, is the CombiPlast repaired by your own mechanics or by mechanics from Niverplast?

- Completely by mechanics from Niverplast
- Mostly by mechanics from Niverplast, sometimes by own mechanics
- Mostly by own mechanics, sometimes by mechanics from Niverplast
- Completely by own mechanics
- Malfunction never occurs

10. Is planned maintenance done by mechanics from Niverplast or your own mechanics?
    - Completely by mechanics from Niverplast
    - Mostly by mechanics from Niverplast, sometimes by own mechanics
    - Mostly by own mechanics, sometimes by mechanics from Niverplast
    - Completely by own mechanics
11. How regularly is the z-axis oiled?
    - Once a week
    - Once a month
    - Once a quartile
    - Once every half year
    - Once a year
    - Never
    - Otherwise,……
    - I don't know
12. Are there other parts of the CombiPlast which are also oiled?
    - Yes, these parts:…….
    - No
13. When the last question is answered with yes.
    How often are these parts oiled?
14. Do you have often problems with the CombiPlast?
    - Yes, these problems occur: ……..
    - No
15. Do you have spare parts in inventory?
    - Yes
    - No
16. Where do you buy these spare parts?
    - Completely by mechanics from Niverplast

- Mostly by mechanics from Niverplast, sometimes by own mechanics
- Mostly by own mechanics, sometimes by mechanics from Niverplast
- Completely by own mechanics

17. When you have more comments or questions, you can ask them here.

	A	B	C	D	E	F	G	H
1	50 uur	24-32 uur	32	ca 65 uur	85 uur	40	128	168 hours
2	300	120	300	80	240 dozen	200	90	depends on run rate and box size (average 60/hr)
3	1 keer per half jaar	1 keer per jaar	Anders, 2x per jaar	1 keer per jaar	1 keer per half jaar	1 keer per half jaar	Once a month	Once a quartile
4	Een keer per week	Een keer per dag	Een keer per dag	Een keer per week	Een keer per week	Een keer per week	Once a month	Once a quartile
5	Anders, pers lucht en zuiger	Anders, Nat en droog, met lucht	Anders, perslucht	Droge doek	Droge doek, Anders, lucht	Natte doek, Anders, lucht	Otherwise,Using compressed air	Dry towel
6	10	8	6	0	3	5	60	30
7	10	2		0	0	5	30	30
8	10	12	6	2	20	2	30	30

9	Meestal door eigen monteurs, soms door monteurs van Niverplast	Meestal door eigen monteurs, soms door monteurs van Niverplast	Meestal door eigen monteurs, soms door monteurs van Niverplast	Storing komt nooit voor	Meestal door monteurs van Niverplast, soms door eigen monteurs	Meestal door eigen monteurs, soms door monteurs van Niverplast	Mostly by own mechanics, sometimes by mechanics from Niverplast	Mostly by own mechanics, sometimes by mechanics from Niverplast
10	Meestal gedaan door monteurs van Niverplast, soms gedaan door eigen monteurs	Volledig gedaan door monteurs van Niverplast	Meestal gedaan door monteurs van Niverplast, soms gedaan door eigen monteurs	Volledig gedaan door monteurs van Niverplast	Volledig gedaan door monteurs van Niverplast	Volledig gedaan door monteurs van Niverplast	Mostly by own mechanics, sometimes by mechanics from Niverplast	Mostly by own mechanics, sometimes by mechanics from Niverplast
11	Een keer per maand	Een keer per jaar	Een keer per week	Nooit	Weet ik niet	Een keer per maand	Once a month	Once a quartile
12	Nee	Nee	Ja, namelijk deze onderdelen: Vet nippels	Ja, namelijk deze onderdelen: kussentje van de taper	Nee	Nee	No	Yes, these parts: as per schedule
13			1x maand	1x per week				3 monthly using PTFE spray
14	Nee	Ja, deze problemen komen voor: Vacuumprob lemen	Nee	Nee	Nee	Nee	Yes, these problems occur: quality of plastic bags and carton boxes	Yes, these problems occur: box variation
15	Ja	Ja	Ja	Nee	Ja	Ja	Yes	Yes

16	Volledig bij Niverplast	Volledig bij Niverplast	Volledig bij Niverplast	Volledig bij Niverplast	Volledig bij Niverplast	Meestal bij Niverplast, soms bij een ander bedrijf	Mostly from Niverplast, sometimes from another company	Mostly from another company, sometimes from Niverplast
17				3x is de machine op thermische beveiliging uitgevallen, met reset opgelost maar graag door een Niverplast monteur er even laten nakijken.				

	I	**J**	**K**	**L**	**M**	**N**	**O**	**P**
1	70 hours	96	50	Average of 12 hours at the present time	80	120 hours	50	32
2	360 boxes every hour	20	150	200	80	108 boxes on average	50	100
3	Once a year	Once every half year	Once a week	Once a quartile	Once a week	Once a week	Once a quartile	Once a year
4	Once a week	Once a week	Once a week	Once a day	Once a day	Once a month	Once a month	Once a quartile

5	Dry towel	Dry towel	Dry towel,Wet towel, Otherwise, compressed air	Dry towel,Wet towel	Dry towel	Water,Dry towel	Dry towel,Otherwise, vaccum cleaner	Water,Soap,Dry towel
6	10	40	81	4	40	30	3	1
7	10	49	10			60		1
8	10	60	50	10	36	40	4	1
9	Mostly by own mechanics, sometimes by mechanics from Niverplast	Mostly by own mechanics, sometimes by mechanics from Niverplast	Completely by own mechanics	Completely by own mechanics	Completely by mechanics from Niverplast	Completely by own mechanics	Malfunction never occurs	Malfunction never occurs
10	Completely by mechanics from Niverplast	Completely by own mechanics	Completely by own mechanics	Completely by own mechanics	Completely by mechanics from Niverplast	Completely by own mechanics	Mostly by own mechanics, sometimes by mechanics from Niverplast	Completely by mechanics from Niverplast
11	Once every half year	Never	Never	Once a month	Once a month	Never	Once a quartile	Once a year
12	No	No	No	No	No	No	Yes, these parts: unit for spreading bags - linear movement	No
13							once a quartile	

14	No	No	No	No	No	Yes, these problems occur: every week, usually for adjustment	No	No
15	Yes	Yes	Yes	No	Yes	Yes	Yes	No
16	Completely from Niverplast	Completely from Niverplast	Completely from Niverplast	Mostly from another company, sometimes from Niverplast	Completely from Niverplast	Mostly from Niverplast, sometimes from another company	Completely from Niverplast	Completely from Niverplast
17								