MASTER

Optimisation of the supply chain of DFS Seclin in order to reduce the number of end products not produced as planned

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Optimisation of the Supply Chain of DFS Seclin in order to reduce the number of end products not produced as planned

by
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in partial fulfilment of the requirements for the degree of

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in Operations Management and Logistics

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I. Preface

The report you are about to read is the result of my graduation project in completion of the Master of Science degree in Operations Management and Logistics at the Eindhoven University of Technology, the Netherland and my engineering school Grenoble-INP Génie Industriel, France. This report symbolizes the end of a very important phase in my life and the start of a new chapter.

This research project has been carried out at DSM Food Specialties. The graduation project was lasted from September 2011 till January 2012. I have conducted a challenging project from which I have learnt a lot. For this experience I would like to thank several people who supported me during the project.

From TU Eindhoven I would like to thank my first supervisor, Ir. Dr. S.D.P. Flapper. I very much appreciate for all the critical remarks, helpful comments and advices that supported me during the project. Always available to answer my questions and doubts, his guidance and endless enthusiasm for my project motivated me to strive for good results.

From Grenoble INP-Génie Industriel, I would like to thank Jean-Philippe Gayon, my second supervisor for his encouragement, interesting reviews and comments.

From DSM Food Specialties I owe thanks to Jean-Baptiste Ghestem for initiating the project and for answering the questions I had in his valuable time. I would also like to thank all my colleagues from the Finance and Planning department for always having answered my questions with interest and patience: Muriel, Virginie, Ofure, Kathy, Giel, Matthieu, Christophe, Michel and Olivier.

Finally, I would like to thank my parents, my brother and all my family for their support during my entire study and for believing in me. Last but not least, I thank my boyfriend for his encouragement and patience.

Gaëlle Jonet

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II. Abstract

In this master thesis project, we have studied what were the potential causes for a produced batch not to be on time, in good quality or in good quantity using a cause and effect analysis. Integrated in a working group concerning the product non conformed in terms of quality, we have identified the causes, found and implemented solutions. Investment costs and gains have been computed. Interviews with all the departments have been realized to qualify the relations between these departments. Concerning both problems of delays and quantity, the problems due to the maintenance have been studied in more detail. Optimal maintenance policies have been found for two different components of a same machine and clustering has been discussed. Conclusion and recommendations for the causes that have not been studied have been done for the company.

III. Management summary

This Master thesis is the result of the final phase of the double degree: Master Operations Management and Logistics at the Eindhoven University of Technology (The Netherland) and Engineering diploma in Industrial Engineering at Grenoble INP – Génie Industriel (France). It is based on the research project conducted for a multinational called DSM located in Seclin, France.

The Supply Chain Management department of DSM Food Specialties initiated this project, since there are [redacted] of the produced batches that are not perfect according to the company's criteria.
These batches are not produced on time, not in good quality or not in good quantity.

The causes of the above have been identified using databases, interviews, and brainstorming. Cause and effect analyses are done for each of the criteria:

- Too late
- Quality issues
- Quantity issues

A detailed analysis has been made and taking into account the scope and the time for realizing this project, some causes have been chosen to be discussed in more detail and solutions have been found to solve them.

The causes concerning the quality issues have been studied. A working group has been created to tackle this problem. Using the DMAIC method, we have found solutions to reduce these quality problems. Investments and gains have been computed. Additional improvements have been proposed to tackle potential causes that have been identified.

The common causes for being late and in good quality have been studied. Interviews have been realized to understand the relations between the different departments in the Supply Chain. The maintenance department has been studied in more detail [redacted].
An improvement of the weekly meeting between the planning department and the maintenance department has been made to take into account variation of workforce for the maintenance activities.
An analysis has been made to determine if it is required to make preventive maintenance for the two critical components [redacted]. [redacted].

Conclusion is made with the savings made by the company.
In the recommendations, it is indicated to the company that the other potential causes that have been identified should be studied in order to achieve 100% perfect batches. Considerable gains seem possible based on the results of the analysis of the maintenance. It should be interesting to consider this type of calculations for other components in the company.

Different main theoretical supports have been used in the context of this project. Indeed, the cause and effect analysis has been implemented. It is the case also for the method of

continuous improvement: DMAIC. A method to find the optimal maintenance policy using the costs for preventive and corrective maintenance activities has been used for this subject.

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V. Report outline

1. General introduction

DSM Food Specialties wants to improve the global reliability of the site in Seclin (France). [redacted] of the batches produced during weeks 1- 35 of 2011 are considered as non-perfect because:

- Too late
- Quality issues
- Quantity issues

The goal of this master project is to reduce this number of non-perfect batches, have a Supply Chain more reliable so that gains of money can be done. The safety stocks can be decreased, the customer service level can be increased and extra time can be invested in improvements.

2. Introduction to the problem

2.1. Short description of DSM Food Specialities

Dutch States Mines (DSM) is an international Dutch group which creates innovative products and services in Life Sciences and Materials Sciences, contributing to the quality of life. DSM's products are used globally in a wide range of markets and applications, supporting a healthier, more sustainable and enjoyable way of life. This company, located on five continents, is present in more than 49 different countries. Indeed, it is worthly known as supplier of the chemical industry. It employs more than 24,000 people worldwide and with a turnover of almost EUR 8.1 billion it is even listed on Euronext Amsterdam.

DSM Food Specialties (DFS) is part of the nutrition cluster of DSM. It is a global supplier of advanced ingredients for food and beverage industries with the aid of fermentation and enzyme technology. Its products contribute in a major way to the success of the world favorite dairy, processed food, soft drink, fruit juice, alcoholic beverage and functional food brands.
Its headquarters are located in Delft in the Netherlands. DFS [redacted] has the highest number of employees (1900 persons).

DFS Seclin (France) is specialized in manufacturing of functional enzymes for the food industry [redacted]. More than [redacted] end products are produced. 200 persons are working in Seclin. [redacted].

[redacted]

[redacted]

The site of Seclin is divided in two parts:

- U-Prod [redacted]
- U-Flex [redacted]

Detailed company and process descriptions are available in Appendix 1.

2.2. Problem

The efficiency of the production is measured with the perfect batch indicator.

A non-perfect batch is a batch that is not good with respect to at least one of the following criteria:

- Time: [redacted]
- Quality: [redacted]
- Quantity: [redacted]

At the moment, the statistics show [redacted] of the produced batches are non-perfect (data weeks 1 to 35 in 2011).
This has a negative influence on the results of the company.
Reducing the non-perfect batches can lead to a gain of time (so production capacity) and money. For instance, they plan to produce-to-order end products [redacted]

2.3. Scope of the project

To analyse the performance killers that lead to non-perfect batches, the supply chain of DSM Foods Specialties Seclin will be studied, starting from the production plan up to the last step of production, the packaging of end products.

The headquarters located in Delft [redacted] have the direct contact with the customers. [redacted]
The scope of this project is consequently restricted to the orange square in Appendix 2.

We have focused on U-Flex [redacted]

Two different persons do the scheduling of U-Prod and U-flex. [redacted]

2.4. Research questions

What are the causes of being too late, bad quality and/or incorrect quantity? How often does each cause occur? What are the consequences of each of them for the plant?

What are the solutions that can be implemented to reduce the number of non-perfect end products and related costs?

2.5. Setup research project

A cause and effect analysis will be made to identify the potential cause of being too late, bad quality and incorrect quantity. For this, interviews will be realized and available databases will be used.

Then, suggestions of improvement will be made and some will be implemented. For these improvements will be estimated: how much to invest compared to how much to win.

Now that the problem, the scope and the research questions have been defined, the current situation will be described in more detail.

3. Current situation

3.1. Non-perfect batches

The person in charge of scheduling U-flex tries to justify the non-perfect batches every 2 weeks.

A batch is considered perfect if it scores 1 in each of the 3 following binary criteria or non perfect if it scores 0 in any of the following binary criteria:

- Production reliability [redacted]
- Quality reliability [redacted]
- Overall reliability (quantity and time) [redacted]

The information concerning the perfect batch is gathered in an Excel sheet called Perfect batch.

For each non-perfect batch, 4 aspects are registered: Main group, Category, Reason for deviation and Additional comments.

[redacted]

For the three first criteria, you must select from a list.

In the context of the project to analyse the non-perfect batches, the data from January 2011 has been used.

[redacted]

The production activity for the beginning of 2012 is expected to be close to the one of 2011 because the portfolio is the same in 2012.

[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 1: Monthly workload between January and November 2011

[redacted]

A consolidation is made with the main shareholders (production, maintenance, quality and planning (departments present in the orange box in Appendix 2)) in order to determine the reasons why a batch is not perfect.
They discuss each non-perfect batch and they agree on justifications. For example, this non-perfect batch is due to the maintenance department because there was a breakdown; this other one is due to a cancellation of production.

The perfect batch indicator takes into account only part of the deviations, [redacted]
Every day, events that lead to minor changes in planning [redacted] are collected during the daily meeting with production and planning. The daily meeting gives an overview of what can disturb the production and the perfect batches overview gives the reasons for the changes in the planning at medium term [redacted].

For this project, all the possible causes will be listed but only the issues concerning the supply chain in Seclin: planning, scheduling, systems, maintenance, quality, rework, production, raw materials, and production documents, will be studied.

3.2. Non-conformities

Products that are not good in quality are considered as non-conform products.

Each product has its own characteristics also called specifications, for instance enzymatic activity, salt rate. The values of the characteristics have to be between defined values. If at least one characteristic is out of specification, the product is non-conformed.

From January 2011 to the end of September 2011, there were [redacted] non-conform batches whereas [redacted] batches have been produced.
[redacted]
All the other batches have been reworked except when there is a contamination.

Using the assumption that all the products can be reworked which is realistic because it is the case for 90% of the products, the cost of rework [redacted] is estimated [redacted] (Appendix 3).

To reduce the number of non-conformed products [redacted], a working group has been created. It has been decided to decrease this rate [redacted] because they plan to formulate and package to order. It is not conceivable in [redacted] of the case to tell to the customers that it is not possible to deliver him. Seclin and Delft (owner of end products) have decided that [redacted] was acceptable.

The working group was composed of a person from the Quality department, the Planning department, the Maintenance department, the person in charge of the reworks (she follows the planning and checks if she can use reworks to produce end products that are planned), three persons from the Production department and the student because it is part of her project. It is a multidisciplinary team. Almost all the departments present in the scope of this project (Appendix 2, orange square) are represented except the persons who are in charge of the logistic because problems in logistic cause delays but no quality problems.
This group meets every week.

To attain its objectives, the Six Sigma concept, definition, measurement, analysis, improvement and control (DMAIC) quality improvement method (Li, 2011) has been used. The DMAIC approach has been used in a wide range of applications and most importantly, this approach has pointed out how the engineering organisation can achieve its competitive advantages, handle efficiently the decision-making tasks and assist the problem-solving capabilities within a business context (Hamza, 2008).

The Pareto based on € and occurrence principle will be used to identify the main reasons for deviation. Then improvements and solutions will be suggested and discussed with the main actors of this project. Advices for the implementation should be given to reduce the number of products produced with delays, problems of quantity or quality.

4. Cause and effect analysis

This method is described in Ishikawa (1990).

During weeks 1- 35 of 2011, [redacted] batches have been analysed where [redacted] are perfect batches and [redacted] are not perfect batches (only these 35 weeks are considered because these weeks are representative of what can happen in 2012). In the database of the non-conformities, it is said that [redacted] batches have been produced, it is due to the fact that some batches really produced in 2010 have been analysed according to the perfect batch criteria only in 2011.

The reasons why the batches were not perfect are summarized in the following table:

Reasons	Number of non perfect batches
Time	[redacted]
Quality	[redacted]
Quantity	[redacted]
Time & Quality	[redacted]
Time & Quantity	[redacted]
Quality & Quantity	[redacted]
Time & Quality & Quantity	[redacted]

Table 2: Causes and occurrence of non-perfect batches analysed between weeks 1 and 35 2011

Note: The non perfect batches due to quality problems are equal to [redacted], which is superior to the number of non-conformities [redacted] because in the definition of the criterion "quality" in the prefect batch, it can be either real problems of quality or release done too late [redacted].

For each of the criteria time, quality and quantity, a list of the different possible potential causes that lead to undesired situations has been made using the perfect batch database and points that have been pointed out by the student since the beginning of this project during the daily meeting with the production department.

To have a completely open analysis, five points should be studied through the process of production of a product: processes, organization, planning & control, information and resources (Flapper et al, 2005).
The five criteria are described as follows:

- Processes deal with physical production, distribution, and quality control.
- Organization is related to who is responsible for what and the decision processes.
- Planning & Control is about measurement of how an actual process is running and control of activities realized.
- Information is related to the information and data used.
- Men, machines, warehouses are resources used for the production.

Each point described just above has been studied for each criterion: Too late, Quality issues and Quantity issues.
If one of the points (processes, organization, planning & control, information and resources) is not present in a cause and effect diagram, it means that no possible cause linked with this aspect has been found.

For the six fish bones diagrams described in the four next sections, the caption is the following:

4.1. Quality

First, Quality has been studied. Four of the five criteria are relevant in this context.

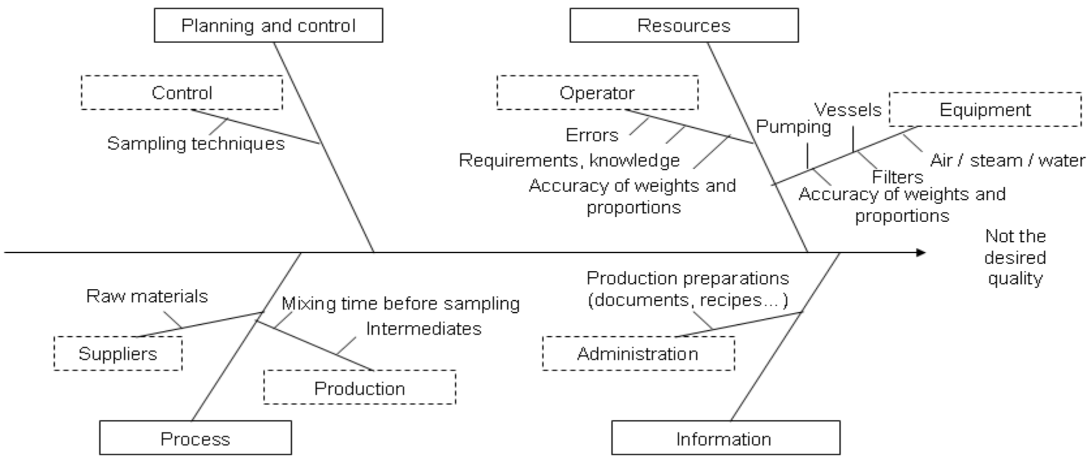

Figure 3: Potential cause and effect analysis related to the problem of not producing the desired quality

a) Planning and control

Planning and control concerns the control of how activities are realized. At different moments in the process of production, quality controls are realized. In order to have results that are representative of reality, it is important that the sample is taken during the production under good conditions. For instance, if the sample should be sterile, it is important that the method concerning this technique is known by all and applied in a correct manner. Sampling techniques should be known by everyone and used as defined.

b) Resources

Accuracy of weights and proportions is linked with resources: either operators who can make a mistake in entering the quantity that should be added in the vessel; or machines when the operators ask for a certain quantity, the quantity really added is not the one asked. This can lead to quality problems because adding 100 kilograms of enzymes more than wished may lead to a non-conformity if the specification concerning the enzymatic activity is not fulfilled.

Operators should have basic knowledge; they are trained and validated by the manager responsible for the part of the plant. Operators independently of their willingness can make mistakes.

Cleanness is really important in this context because otherwise it is source of contaminations. That is why pumping, vessels, filters and networks of air, steam and water should work and be cleaned to ensure the quality of the product.

c) Process

The raw materials provided by the suppliers are causes that can lead to quality problems. The intermediates produced earlier in the process are possible sources of quality problems. Raw materials and intermediates should be in good quality to have an end product in a good quality as well.

Mixing time before sampling is related to processes. Indeed, it is mentioned by Production that it is important to mix the preparation during a certain amount of time before taking the sampling so that the mixture is homogenous.

d) Information

It is important to consider the production preparations. Indeed, if a mistake is made with respect to the recipe or in the documents, this can lead to quality problems.

4.2. Time

Second, time has been studied. All the criteria are relevant in this context.

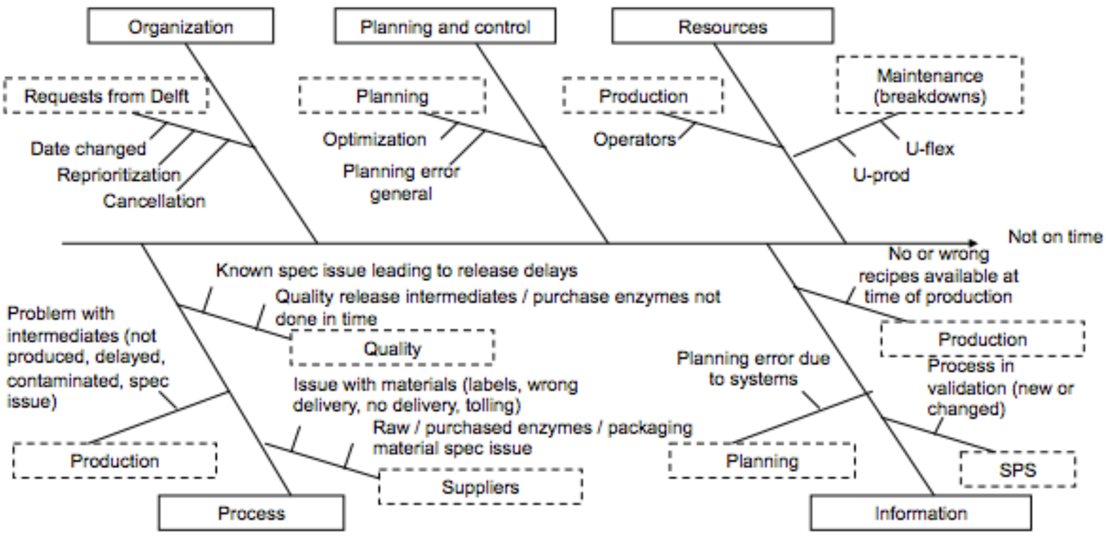

Figure 4: Potential cause and effect analysis related to the problem of not producing on time

a) Organization

[redacted]. According to customers' wishes, they have the possibility to change the date of production, to cancel production or to give new priorities; which may mean some products scheduled are not produced on time.

b) Planning and control

The persons in charge of the planning can optimize the planning so that two products from the same family can be produced at the same time and this wins one cleaning. Errors can be committed and a product not desired can be produced (wrong packaging or product).

c) Resources

Operators can be slower than usually and then productions are delayed.
Breakdowns of the machines can lead to delays.

d) Process

Problems with raw materials or intermediates (deliveries not on time) can lead to delays of production. Quality controls are sometimes in the production one of the keys to continue the production; quality controls not done on time are a cause of delays of production. Quality issues are part of processes.

e) Information

Errors in the recipe or in the documents can lead to delays. The operators ask for help to the administration to be sure that there is no mistake. It is a loss of time. If the duration of an activity is under-estimated in the recipe, it can lead to delays, because not enough time will have been reserved for this activity and the following will be delayed.

Process in validation is related to the lack of information at the right time, at the right place, it is linked with information.

4.3. Quantity

Third, quantity has been studied. All the criteria are relevant in this context.

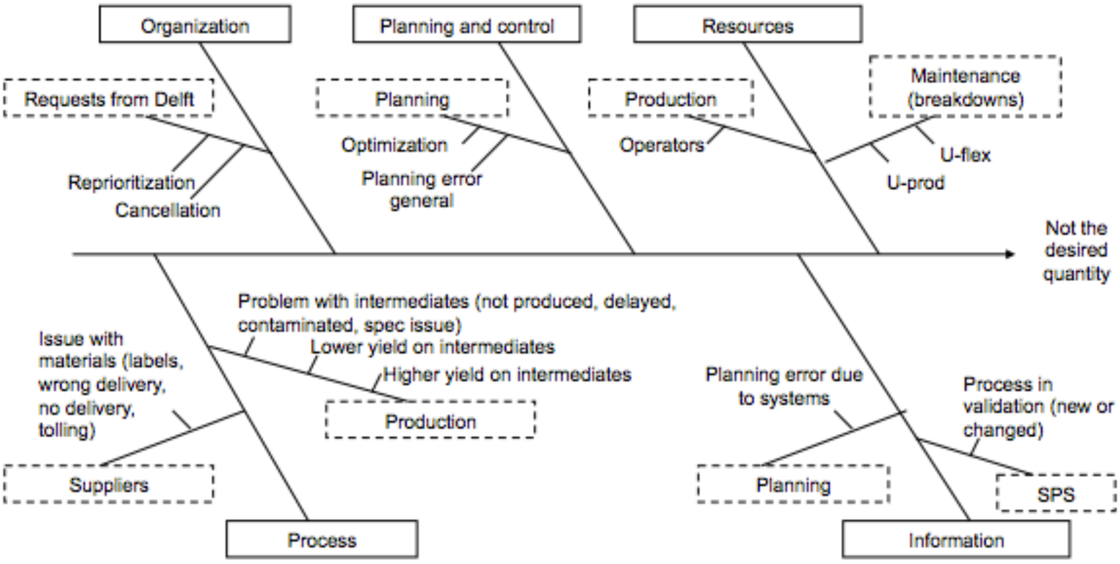

Figure 5: Potential cause and effect analysis related to the problem of not producing the desired quantity

a) Organization

[redacted] According to stocks' levels, they have the possibility to change the quantity to produce and so the products that were scheduled can be produced in smaller batches.

b) Planning and control

The persons in charge of the planning can optimize the planning so that two products from the same family can be produced at the same time and more products are produced. Errors can be committed and not the good quantity of the product can be produced. Errors in creation of production order can lead to errors in quantity.

c) Resources

Operators can make wrong manipulations and a part of the product may have to be thrown away, then the quantity produced will be lower than expected. Breakdowns (corrective maintenance) either in U-flex or in U-prod can lead to variations in quantity if the production is stopped or a part of the product remains in the machine.

d) Process

Problems with raw materials or intermediates can lead to quantity variations, for instance if the product is not delivered in the right quantity. Yield can lead to fewer or higher quantity.

e) Information

An error in a recipe, if the available quantity in stocks is not well estimated, can lead to errors in quantity.

The three causes and effects analyses described above in the paragraphs 4.1., 4.2. and 4.3. have been validated with my company supervisor.

4.4. Conclusion

In the context of this project, due to the time limit, the issues concerning 'time & quantity' and 'quality' have been studied because they represent [redacted] of the reasons why a batch is not perfect. ([redacted](cf. Table 2))

A lot of causes are outside the scope of this master project:

- Organization: [redacted]
- Process: variations of yield in production can be explained by biologists or chemists. During the project, there has not been contact with suppliers.
- SPS: it is the field of the chemists.

Looking in more detail in the three cause and effect diagrams presented in Figures 3, 4 and 5, we can point out that mainly there is a communality between not on time and not the desired quantity.

The two cause and effect analyses concerning not on time and not the desired quantity can be simplified as follows taking into account only the potential causes that are in the scope of this master project.

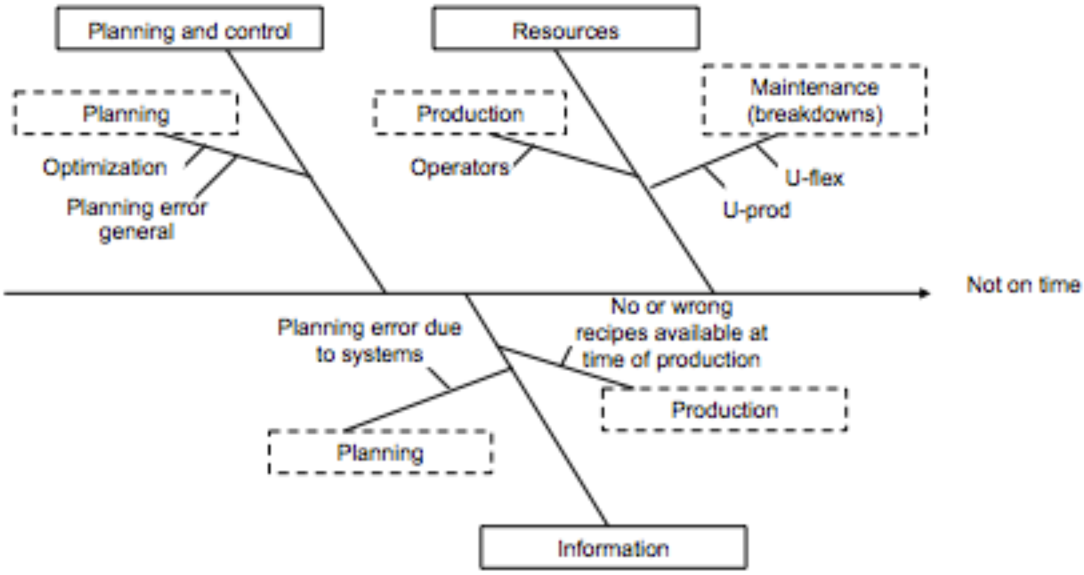

Figure 6: Potential cause and effect analysis for the criterion: not on time

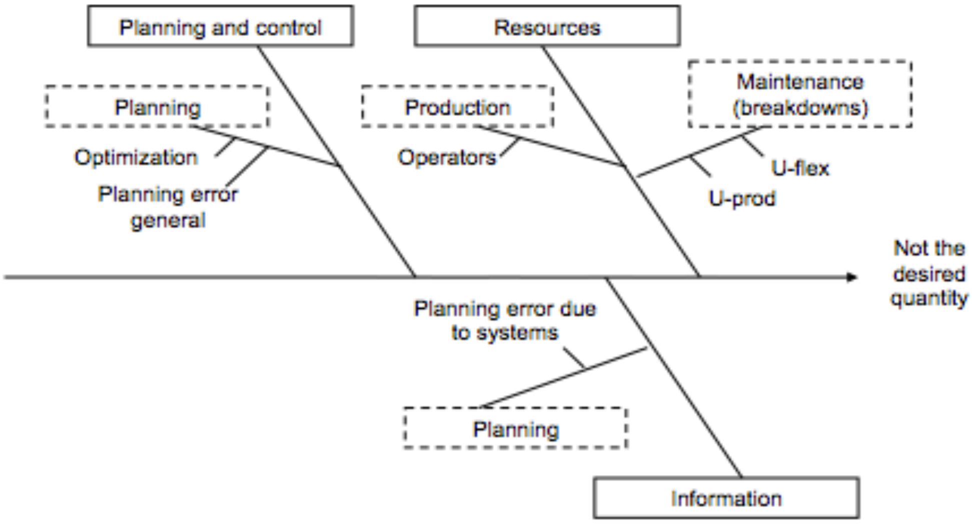

Figure 7: Potential cause and effect analysis for the criterion: not the desired quantity

In the context of this project, we will focus on the links between the planning department and the other departments of the Supply Chain in Seclin and the maintenance department to ensure that the communication is good and lets a flow of information fluid.

Concerning the cause and effect analysis related to no good quality, all the potential causes are in the scope except the ones concerning raw materials and intermediates because the scope of the master project is limited to U-Flex.

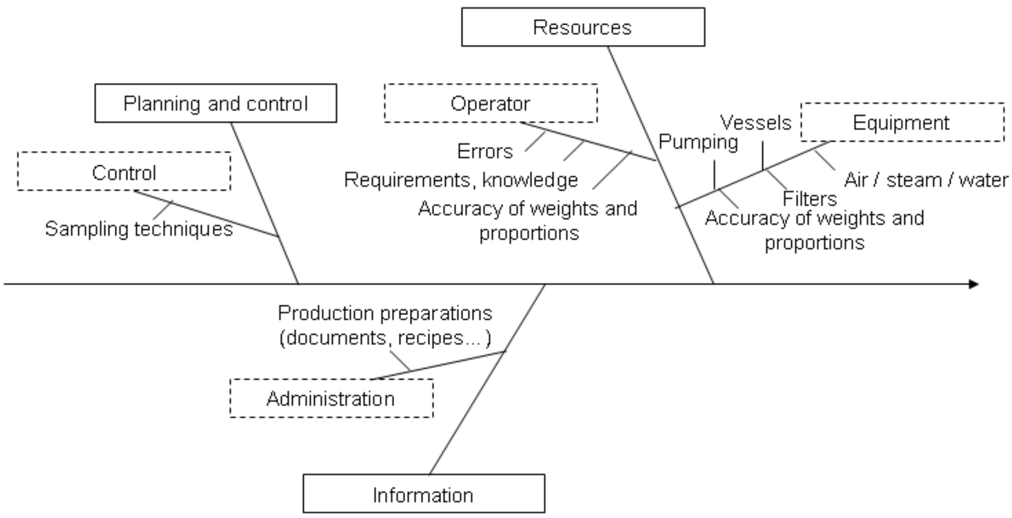

Figure 8: Actual cause and effect analysis related to the problem of not producing the desired quality

The core causes for the problems seen are the ones [redacted] They are summarized in the following table:

Aspect	Cause
Time & Quantity	Planning and control: Optimization
Time & Quantity	Planning and control: Planning error general
Time & Quantity	Resources: Operators
Time & Quantity	Maintenance: breakdowns
Time & Quantity	Information: Planning error due to systems
Quality	Planning and control: sampling techniques
Quality	Resources: Operator
Quality	Resources: Equipment
Quality	Information: Production preparations

Table 9: Core causes for 'Time and Quantity' and 'Quality'

In this conclusion, the potential causes in the scope of this project have been identified. In the following section, causes concerning quality will be discussed. In the section 6, causes concerning quantity and time will be analyzed. In both sections, solutions will be found and costs benefits estimations will be made.

5. Solutions to solve the quality problem

5.1. Measurements

There are some issues that seem to be the potential causes of non-conformities but they need to be measured.

After discussing with different operators, it has been pointed out that the mixing time before sampling was always good.
For the accuracy of weights and proportions, it is important to know if it is a possible cause because an error in the quantity to add can cause to be out-of-specification for one of the specification and then the product is non-conformed. The student has been in charge of organizing this measurement.
For each preparation, the production documents have been collected after the production.
On this document, it is possible to find the recipe.
All the ingredients that should be added in the preparation are mentioned with the quantity to add. For the intermediates (enzymatic solutions), the batch number is mentioned to ensure the traceability whereas for other materials like the salt, for instance, there is no batch number.

During the preparation, the operator fills in the column with the real quantity he has added. There is a tolerance.

It is possible to follow different indicators concerning the vessels, for instance, weights, pH, and temperature.

Observing the curve of the vessel where the preparation has taken place, it is possible to know exactly the quantity that has been added.

For each batch, for each ingredient, the weight added is registered and the following table is filled.

Operator	Date	Product	Batch number	Vessel	Material	Weight in the recipe	Weight filled in by the operator	Wight in Process Explorer

Figure 10: Information to fill in for each ingredient to add in a production

27 different preparations have been studied.

5.2. Analysis

The causes of non-conformities are split as follows:

	Number of occurrences	Costs estimation (€)
Administration / Production preparations	[redacted]	[redacted]
Equipment / Pump	[redacted]	[redacted]
Equipment / Accuracy of weight	[redacted]	[redacted]
Equipment / Vessels	[redacted]	[redacted]
Operator / Errors	[redacted]	[redacted]
Control / Sampling techniques	[redacted]	[redacted]

[redacted]

Figure 11: Causes identified with the number of occurrences between January and the end of September 2011

For the costs estimation in the figure 11, [redacted]. In Appendix 3, the average volume of a rework is [redacted] kg. Using the average cost per kilogram for a rework of a liquid, we have found that the average cost of a rework can be estimated by: [redacted]. In the column costs estimation, these [redacted] euro are multiplied by the number of occurrences.

For the potential causes that have been proved to be relevant and in the scope of the group, solutions have been found and implemented.

5.3. Improvements

Each improvement will be estimated with the number of occurrences using the method described in the previous section. For the percentage of non-conformity that is gained, it is a absolute value. It is the number of non-conformities that can be avoided divided by the total number of non-conformities, which is equal to [redacted]. For example, it is 5% of the initial [redacted] that is saved.

Note that in all the following, the student has only indicated direct gains. It is possible that even more is gained but there was not enough time to examine this further.

5.3.1. Resources

5.3.1.1. Operator

[redacted] non-conformity is due to the fact that there was an error in the interpretation of the pH. The operator has read the pH not well and has made a wrong correction. [redacted] can be won if the operator pay more attention. He has been informed and will read more carefully next time the instructions. It is possible to reduce the rate of non-conformity by [redacted] by this action.

5.3.1.2. Accuracy of weights and proportions

It is not easy to know the quantity really added in case of pumping in the vessel because there is no counter in the pump. Some modifications are planned on the pump. Links with air and steam will be added to make a sterilization of the pump. As the same time as these changes, it may be possible to add a counter at the exit of the pump so that it is easier to know exactly the quantity that is added to the vessel. [redacted] non-conformities are due to errors in measurements. A feasibility study will be done. [redacted] can be won each year by making the pumping more reliable. [redacted] of non-conformity can be gained by this improvement.

For the small quantities, weighing is done with small scales. There is a printer that should print tickets with the quantity that has been weighed but it is not working. It is planned to bring back this machine under service. The printer was broken. A new one has been bought. Moreover, it is also useful for the administration of production so that they can check which quantity has been added and also update the stocks with the real consumptions. [redacted] non-conformity is due to errors of weighing for a small quantity. A new printer costs 50€ whereas [redacted] can be won. [redacted] of non-conformity can be won with this investment.

5.3.2. Equipment

5.3.2.1. Vessels

To ensure that the vessels are cleaned, it has been pointed out that the air vents and the traps should be cleaned every week, it was not automatically done before. The production people can do this operation; it is included in the part auto maintenance, preventive maintenance done by the production. The replacement and the cleaning of the air vents are implemented.
[redacted] non-conformities are due to the facts that the traps and the air vents were not cleaned. By a auto maintenance which is done by the persons in production, it is possible to save [redacted] per year.
[redacted] of non-conformities will be gained with this improvement.

5.3.2.2. Pump

To avoid cross contamination, products that are pumped are automatically filtrated. This extra filtration is integrated in the planning and also in the production documents. [redacted] are due to contamination because of pumping. [redacted] of non-conformities and [redacted] for reworking these non-conformities can be saved per year. The cost for filtrating again the product is estimated to be [redacted] using the same method as the one for the rework described in Appendix 3 with [redacted] (only losses due to filtration taken into account).

5.3.3. Information

Production preparations

In each production document, when it consists of small batches, constraints should be added because it is not possible to use any types of vessels so that the preparation can be mixed correctly. [redacted] non-conformities are due to incorrect documents. Updating these documents which is costless (because documents are often updated by the person who is responsible for this) lets to win [redacted] per year. [redacted] of non-conformities can be gained with this update.

The yield during the filtration will be updated in the documents. [redacted] non-conformities are due to filtration yield incorrect. Updating these numbers which is costless lets to win [redacted] per year. [redacted] of non-conformities can be saved.

[redacted] non-conformities are due to the fact that changes have occurred in the recipes but the documents have not been updated taking into account these changes. [redacted] of non-conformities can be saved.

5.3.4. Planning and control

Sampling techniques

It has been pointed out that the sampler for the liquid (machine that is used to take the samples) was not working. An analysis of what is going wrong has been made. An intervention has been scheduled. Now the sampler is revamped and cleaned. This sampler is part of the packaging line but is not a critical part. In the future, it will be cleaned after each use of the line.
[redacted] non-conformity is due to the fact that the machine used for sampling was not working properly. A maintenance activity that has cost [redacted] lets to gain [redacted]/year. The difference is positive; the company can gain with this improvement. The number of non-conformities can be reduced by [redacted] with this change.

5.3.5. Conclusion

To summarize, the following table can be made:

		Investment (€)	Gain (€/year)	Number of non-conformities solved (per year)	Absolute percentage gain (%)
Resources	Operators	[redacted]	[redacted]	[redacted]	[redacted]
Resources	Accuracy of weights and proportions	[redacted]	[redacted]	[redacted]	[redacted]
Resources	Accuracy of weights and proportions	[redacted]	[redacted]	[redacted]	[redacted]
Equipment	Vessels	[redacted]	[redacted]	[redacted]	[redacted]
Equipment	Pump	[redacted]	[redacted]	[redacted]	[redacted]
Information	Production preparations	[redacted]	[redacted]	[redacted]	[redacted]
Information	Production preparations	[redacted]	[redacted]	[redacted]	[redacted]
Information	Production preparations	[redacted]	[redacted]	[redacted]	[redacted]
Planning and control	Sampling techniques	[redacted]	[redacted]	[redacted]	[redacted]

Table 12: Summary of the improvements presented in this section with costs and gains

[redacted] of the non-conformities are already solved with the solutions that have been found and implemented.

5.4. Additional improvements

On top of what has been presented in the section 5.3., in this section 5.4., additional improvements that have been implemented are described. They are not directly linked with non-conformities that happened last year but these actions can let to avoid possible future non-conformities.

5.4.1. Resources

5.4.1.1. Operator

The instructions concerning the use and cleaning of sterile water have been modified and updated. The operators have been informed about the use of the sterile water. This action is costless because done by the person who is in charge of updating of this kind of files.

5.4.1.2. Accuracy of weights and proportions

To ensure that there is no problem about weights, the first step has been to check the calibration of the vessels. Moreover, it has been reminded to the maintenance and improvement team that it is important in case of changes on a vessel to do a new calibration.

For the vessels V400, it is planned to reset the weights cells. Indeed, when changes are made, it is possible that the global weight of the vessel changes so to ensure an accuracy of the weights, it is really important to reset the vessel.
The two previous points are points of attention.

5.4.2. Equipment

5.4.2.1. Filters

The exchanger is used to warm water so that it is purified and then this water is used to clean the filter. The temperature should be above [redacted]. [redacted]
The problem was that it was not possible to warm the water above [redacted].
When the maintenance has studied the problem, in fact only [redacted] plates were inside the exchanger so they have put new plates.
The problem was not solved and the machine was full of fur very quickly.
After a second analysis, [redacted].

The sterilization of the filter is really important because it decreases the risk of microbiologic contamination.
The cost for these two maintenance activities is estimated to be equal to [redacted].

5.4.2.2. *Air / steam / water*

To ensure a better cleanliness of the vessel and avoid microbiologic contamination, the stainless steel filters on the air and steam networks should be standardized so that it is easier to change and clean because only one model will be needed. An Improvement Plan (IP) has been written for this. The process of improvement is on the way. The change will be implemented if money is invested in this type of changes.

It is planned to clarify who is responsible for what concerning the sterilization of the water circuit and inform the operators of who is doing what.

5.4.3. Planning and control

Sampling techniques

The instructions concerning the sampling techniques have been updated and explained to all the operators to be sure that this technique is know by everyone.

If there is a non-conformity, in order to understand in more detail what has happened, each week, a poster is made and put up for the operators. Then, they are aware of the problems and they can give their feelings about what has occurred during this production.

6. Analyses of the causes related to 'Time and Quantity'

6.1. Analysis: losses due to problems of maintenance

The site in Seclin is a manufacturing site of DSM Foods Specialties that produces enzymes. [redacted]

[redacted]

The fixed costs are spread over all the equipment so that it is possible to compute a fixed cost per hour per equipment.
For the machines in U-flex, the costs per hour are given in table 13.

	Cost/hour/equipment (€/hour)
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	F = [redacted]

Table 13: Fixed cost per hour

[redacted]
To compute the costs of maintenance, real labour cost for the maintenance activity will be added to this loss.

For October and November 2011, each deviation concerning the realisation and the duration of the maintenance activities has been recorded.

In total, [redacted] hours have been lost in [redacted], [redacted] hours for the [redacted], [redacted] hours for the [redacted] and [redacted] hours for the [redacted] (no production was possible, although desired).
Lost hours are time reserved for maintenance; either downtimes or time reserved for preventive maintenance but the activity cannot be realized so the production capacity is reduced.

Multiplying each hour lost by the fix cost per hour, we can make the conclusion that [redacted] are lost due to non production.

According to the company supervisor and the person in charge of the finance, these two months are representative of what can happen. On average, [redacted] are lost each month due to maintenance actions.

The maintenance department has a key performance indicator that is the percentage of actions realized compared to the number of actions scheduled. The objective is: [redacted] for this indicator. It is not the case at the moment: [redacted] (see Appendix 4 for the data used for this computation).

6.2. Organisation change

It is possible to solve one of the causes that lead to delays in the execution of maintenance activities.

Every week there is a meeting with the maintenance and the administration of production.

The responsible person for centers preparation, planning and expertise and the responsible person for preparation and planning of mechanic activities, are in charge of the preparation of the planning. They should select the activities so that the spare parts are available for the maintenance activities.

There is a lack of communication between the persons who are in charge of the preparations (spare parts) and the person who is responsible of the people who take care of the maintenance. Spare parts are available for the maintenance activities but there are not enough persons to realize the works planned or vice versa, there are men to do the maintenance activity but the spare parts are not available.

The weekly meeting has been changed; new participant has been invited. The manager of the maintenance men takes now place in the meeting. The aim is to schedule maintenance activities taking into account the workload of maintenance men.

The objectives are the following:

- Discuss the activities done the week before by the maintenance men. If something is not done, try to find out the reason and the recurrences. Why some stops in production are organized for the maintenance and they are not used?
- Check if all the resources (men and spare parts) are available to do all the activities that are planned for the next two weeks (preventive maintenance).
- Check the KPI: percentage of Work Order (WO) executed compared to the number of WO scheduled (preventive maintenance).
- Discuss the stops of production for the long interventions (more than 3 days).

Taking into account the number of persons available the next two weeks can improve the possibility that all the activities will be realized. In fact, if you think that there are 10 persons the following weeks and you schedule works for these 10 persons, if only 8 persons work, only 80% of the works can be done.

6.3. Preventive and corrective maintenance

A preventive maintenance is maintenance performed at predetermined intervals or according to prescribed criteria and intended to reduce the probability of failure or degradation of a component.
A corrective maintenance can be defined as a maintenance task performed to identify, isolate, and rectify a fault so that the failed equipment, machine, or system can be restored to an operational condition within the tolerances or limits established for in-service operations.

If the maintenance preventive is done on time and correctly, the more preventive maintenance, the less corrective maintenance.
The policy about maintenance in the company is either preventive maintenance or corrective maintenance. There is no minimal repair policy. In the company, a maintenance activity is equivalent to replace a component by a new one.

6.3.1. Maintenance policies considered

Three policies will be studied:

- Failure-based policy
- Age based policy
- Block policy

We make the assumption that time to replace is negligible. This is realistic because the average time to do a corrective maintenance is equal to [redacted] hours whereas the average time between to failures is equal to [redacted] days so [redacted] hours (cf. Appendix 5).

Optimization:

- Determination of the optimal T for the age policy and block policy.
- Finding the optimal type of policy.

6.3.1.1. *Definitions of the policies studied*

Notation:
C_u: Cost for a corrective (unplanned) maintenance action
C_p: Cost for a preventive (planned) maintenance action ($\leq C_u$)
If $C_u = C_p$, it is useless to do preventive maintenance.
F(t): Failure distribution function
f(t): Corresponding probability density function
μ: = $\int_0^\infty xf(x)dx$ = Mean time to failure
M(t): Corresponding renewal function and represents the total number of failures in the interval $[0; t]$.
h(t): Corresponding failure rate function

Renewal reward theory:

g: Asymptotic cost per time unit (=average costs)
ECC: Expected Cycle Cost
ECL: Expected Cycle Length

g = ECC/ECL

a) Failure-based policy

This policy is defined as follows:

Wait till the component fails and apply a corrective maintenance

Cycle: Time between two corrective maintenance actions

ECC = C_u
ECL = μ
g = C_u/μ

b) Age based policy

This policy is defined as follows:

Apply a preventive maintenance action when the component reaches age T and apply a corrective maintenance if the component fails earlier.

Cycle: Time between two maintenance actions

ECC = $\mathrm{F(T)} * C_u + \left(1 - \mathrm{F(T)}\right) * C_p$
ECL = $\int_0^T xf(x)dx + \mathrm{T} * (1 - \mathrm{F(T)})$
g = ECC/ECL

c) Block policy

This policy is defined as follows:

Apply a preventive maintenance action at set times T, 2T, 3T, …, and apply a corrective maintenance if the component fails in between these set times.

Cycle: Time between two preventive maintenance actions

$ECC = C_p + M(T)*C_u$
$ECL = T$
$g = ECC/ECL$

6.3.1.2. Application above policies in the company

In the context of this project, it has been decided with the persons from the maintenance department to study the two critical components of the [redacted]:

[redacted]

These components are critical because if they are not working, it is impossible to [redacted]. It is only the case for these two components.

6.3.1.3. Application above policies to [redacted]

We have applied the theory for the equipment [redacted] which is a critical one of the [redacted]. If this component fails, it is impossible to package [redacted] products.

a) Computation of C_u and C_p

The way of computing C_u and C_p has been discussed with one person of maintenance and one person of the finance department.
The cost of one hour of maintenance is [redacted]€ per hour (data given by the finance department, labor costs).

For the two types of maintenance, the average number of hours spent by the maintenance of the equipment and the average cost of spare parts have been calculated.

Variables:
F: real cost (described in Table 13)
H_p: average number of hours spent on a preventive maintenance (hour)
H_u : average number of hours spent on a corrective maintenance (hour)
M: cost for one hour of maintenance. [redacted] (labor)
P_p : average cost of spare parts for a preventive maintenance (€)
P_u: average cost of spare parts for a corrective maintenance (€)
[redacted].

$C_u = P_u + H_u*(M+F)$
$C_p = P_p + H_p*M$

Numerical application for the FFS:
[redacted]

b) Determination of the failure time distribution

After having gathered the data that you can find in Appendix 5, for each time between two successive failures, the number of occurrences has been computed. The results are given in Appendix 6.

[redacted]

Figure 14: Distribution of the inter arrival time between two successives failures for [redacted]

There is no trend in the time of a breakdown after a repair action (cf. data in Appendix 7).

Using the method pages 356 to 360 described in Montgomery et al. (1999), the mean of the assumed Exponential distribution is unknown and must be estimated from the sample data.

Guess: $f(x) = \lambda e^{-\lambda x}$. $E(x) = \int_0^\infty x f(x) dx = 1/\lambda => \lambda = 1/E(x)$.
The estimation of the mean inter arrival time of failures is the sample average, that is, [redacted] (cf. Appendix 6 for the data). So, the parameter of the exponential distribution is equal to: [redacted].

From the Exponential distribution with parameter [redacted], we may compute the theoretical probabilities p_i for having i days between two successive corrective maintenance activities.

The expected frequencies E_i are computed by multiplying the sample size n=[redacted] times the probability p_i.

Variables:
n: size of the population.
k: number of bins or class intervals
O_i: observed frequency in the i^{th} class interval
E_i: expected frequency in the i^{th} class interval from the hypothesized probability distribution

The chi-square test statistic defined by: $X_0^2 = \sum_{i=1}^{k} \frac{(O_i - E_i)^2}{E_i}$.

For the FFS, there are [redacted] degrees of freedom because the mean was estimated from the data (cf. Appendix 8).

The eight-step hypothesis-testing procedure may now be applied, using α= 0.05, as follows:

i. The variable of interest is the form of the distribution of inter arrival time of failures.
ii. H_0: the form of the distribution of occurrences is Exponential.
iii. H_1: the form of the distribution of occurrences is not Exponential.
iv. α= 0.05
v. The test statistic is: $X_0^2 = \sum_{i=1}^{k} \frac{(O_i - E_i)^2}{E_i}$
vi. Reject H0 if $\chi^2_0 > \chi^2_{0.05,16}$
vii. Computations : χ^2_0=10.91
viii. Conclusions: Since χ^2_0=[redacted] < $\chi^2_{0.05,16}$ = [redacted], we are unable to reject the null hypothesis that the distribution of inter arrival time of failures is Exponential.

c) Applications for the different policies described in 6.3.1.1.

- Failure based policy

ECC = C_u = [redacted]
ECL = μ = [redacted]
g = C_u/μ = [redacted]

- Age based policy

$$ECC(T) = F(T) * C_u + (1 - \mathrm{F(T)}) * C_p$$
$$ECC(T) = (1 - \exp(-\lambda T)) * C_u + \exp(-\lambda T) * C_p$$

$$ECL(T) = \int_0^T x f(x) dx + T * \left(1 - F(T)\right) = \int_0^T \lambda x e^{-\lambda x} dx + T e^{-\lambda x}$$
$$ECL(T) = \frac{1}{\lambda}(1 - \exp(-\lambda T))$$

$$g(T) = {ECC}/{ECL}$$
$$g(T) = {\lambda * (1 - \exp(-\lambda T)) * C_u + \lambda * \exp(-\lambda T) * C_p}/{1 - \exp(-\lambda T)}$$

$$g'(T) = {-\lambda * \exp(-\lambda T) * C_p}/{(1-\exp(-\lambda T))^2}$$

$g'(T) < 0$ => $g(T)$ is striclty decreasing. So minimum values of g occurs when T goes to infinity. This policy is then equivalent to the failure-based policy.

- Block policy

ECC(T) = C_p+ M(T)*C_u
ECL(T) = T
g(T) = ECC(T)/ECL(T)

$$ECC(T) = C_p + \lambda * T * C_u$$

$$ECL(T) = T$$
$$g(T) = \frac{C_p + \lambda * T * C_u}{T}$$
$$g'(T) = -\frac{C_p}{T^2} < 0$$
$g(T)$ is striclty decreasing. So g is mimimum when T goes to infinity. This policy is then equivalent to the failure-based policy.

d) Conclusion

In the case of the [redacted], using the distribution function of the inter arrival time between two failures and the costs for preventive and corrective maintenance, the best maintenance to apply is the failure-based policy.

6.3.1.4. Application above policies to the [redacted]

We have applied this theory for the equipment [redacted] which is a critical one of the [redacted]. If this component fails, it is impossible to package [redacted] products.

a) Computation of C_u and C_p

Numerical application for the mixing machine:
C_u = [redacted]
C_p = [redacted]

b) Determination of the failure time distribution

After having gathered the data, for each time between two successive failures, the number of occurrences has been computed.

[redacted]

Figure 15: Distribution of the inter arrival time between two successives failures for the [redacted]

Using the same method as described in 6.3.1.3.b), we have found that the exponential distribution with the parameter equal to : [redacted] is the best approximation for this distribution of inter arrival time of failures.

c) Numerical applications for the different policies presented in 6.3.1.

- Failure based policy

ECC = C_u = [redacted]
ECL = μ = [redacted]
g = C_u/μ = [redacted]

- Age based policy

$$ECC(T) = F(T) * C_u + (1 - \mathrm{F(T)}) * C_p$$
$$ECC(T) = (1 - \exp(-\lambda T)) * C_u + \exp(-\lambda T) * C_p$$

$$ECL(T) = \int_0^T x f(x) dx + T * (1 - F(T))$$
$$ECL(T) = \frac{1}{\lambda}(1 - \exp(-\lambda T))$$

$$g(T) = {ECC}/{ECL}$$

$$g(T) = {\lambda * (1 - \exp(-\lambda T)) * C_u + \lambda * \exp(-\lambda T) * C_p}/{1 - \exp(-\lambda T)}$$

$$g'(T) = {-\lambda * \exp(-\lambda T) * C_p}/{(1 - \exp(-\lambda T))^2}$$

$g'(T) < 0$ => $g(T)$ is striclty decreasing. So g is mimimum when T goes to infinity. This policy is then equivalent to the failure-based policy.

- Block policy

ECC(T) = C_p+ M(T)*C_u
ECL(T) = T
g(T) = ECC(T)/ECL(T)

$$ECC(T) = C_p + \lambda * T * C_u$$

$$ECL(T) = T$$
$$g(T) = {C_p + \lambda * T * C_u}/{T}$$
$$g'(T) = -\frac{C_p}{T^2} < 0$$

$g(T)$ is striclty decreasing. So g is mimimum when T goes to infinity. This policy is then equivalent to the failure-based policy.

d) Conclusion

In the case of the [redacted], using the distribution function of the inter arrival time between failures and the costs for preventive and corrective maintenance, the best maintenance to apply is the failure-based policy.

6.3.2. Clustering

It is interesting in the case of systems composed of several parts to consider clustering (Van Dijkhuizen et al. (1997)).
Time and money can be gained if two activities with the same frequency on the same equipment are combined.
This method consists in, taking into account the different frequencies at which each component of the system must be changed, clustering the maintenance activities to save set-ups costs. It is sometimes less costly to do a preventive activity in advance if it can be combined with another activity so that the set ups costs are saved.
It does not make sense to consider clustering with the two components used before [redacted] because the best policy in the two cases is the failure based policy.

6.3.3. Conclusion

At the moment, in the company, they use preventive maintenance for the two components that have been considered in this study. The frequency of preventive maintenance is [redacted] and [redacted]. Taking into account that the cost for a preventive maintenance for the [redacted], respectively [redacted], is equal to: [redacted], respectively [redacted].
Using the results of the study done in the sections 6.3.1.3. and 6.3.1.4., [redacted] can be saved [redacted] if no preventive maintenance is done for the [redacted] as required by the computations and [redacted] can be saved for the [redacted].
In total, [redacted] are used each year for preventive maintenance activities that are not useful.

7. Conclusions

In this project, the aim was to reduce the number of non-perfect batches. Indeed, before this study, there were [redacted] of the non-perfect batches. A batch is non-perfect if at least one of the following criteria is not fulfilled: production on time, in good quality and in good quantity.
The reasons why the batch is non-perfect can be numerous.
In the first part of this report, we have identified the potential causes of these deviations of production. The results of the cause and effect analyses are given in the chapter 4. and more precisely in the figures 3, 4 and 5.

The causes that lead to problems of quality have been studied in more detail. Solutions have been implemented. [redacted] of the non-conformities are solved by the actions. The investment is [redacted]. [redacted] can be saved [redacted] by these improvements. Moreover, other improvements have been implemented in order to avoid possible non-conformities. These changes are costless but it is not possible to estimate the potential gain because there is no non-conformity that is linked with these improvements.

Then, the common causes to be both late and not in good quantity are studied and more specially maintenance issues. On the one hand, the change of the weekly meeting between the planning and the maintenance departments has been made. On the other hand, a study of the usefulness of the preventive maintenance for different components has been made. Three maintenance policies have been studied in detail, which have been applied to two components [redacted]. Then clustering has been evocated because it is not possible to use it in this case because it appears that the optimal policy for these two components is the failure based policy. In total, [redacted] can be saved [redacted] in not doing preventive maintenances for these two components.

To summarize, [redacted] of the causes of non perfect-batches have been solved, the number of non-perfect batches can be then reduced from [redacted] to [redacted] during weeks 1 – 35 2011, which is equivalent to [redacted] of non-perfect batches compared to the [redacted] at the beginning of the project.

Different main theoretical supports have been used in the context of this project. Indeed, Ishikawa diagrams have been created for the three different criteria (not on time, quality and quantity issues). The method DMAIC of continuous improvement has been used to solve the quality problems. A method to find the optimal maintenance policy based on costs for preventive and corrective maintenance activities and different maintenance policies has been used for this project.

Extra research has been conducted to qualify the communication between the planning departments and all the departments involved in the Supply Chain in Seclin. Communication is the activity of conveying information. Communication requires a sender, a message, and an intended recipient. The communication process is complete once the receiver has understood the message of the sender. Feedback is critical to effective communication between parties.

Interviews have been conducted to point out eventual lack of communication or miscommunications between the different departments of the Supply Chain in Seclin. [redacted]

8. Recommendations

In order to save the amount of money that has been estimated in this report, it is important that the actions that have been taken be respected in the future.

For the two components considered for the maintenance study, it is useless according to the computations to do preventive maintenance. Not doing these maintenance activities leads to considerable potential gains. I should be good if persons in the company can do this type of calculations for maintenance for all or many components.

Due to the limited time and the scope defined with the company supervisor of this project, it will be useful to study in more detail the causes that have been identified as potential causes that lead to non-perfect batches to decrease this number of non-perfect batches.

9. Definitions

Enzyme: active protein that makes possible to transform a complex natural substance into simpler and more easily absorbable substance.

Fermentation: growth of microorganisms in vessels of various sizes, from a laboratory scale to an industrial one.

Formulation: Blending of several enzymes to obtain a product, which will be packed into several forms.

Microorganism: organism that is unicellular or lives in a colony of cellular organisms.

Non-conformity: a product is non conform if at least one of its characteristics (=specification) is out of the specification.

Perfect batch: A batch is perfect if it ranks 1 on each of the three following characteristics (total score of 3):

- Production reliability [redacted]
- Quality reliability [redacted]
- Overall reliability [redacted]

References = end products. It can be the same composition but packaged in two different ways, for instance bulk and in containers.

10. Abbreviations

[redacted]
KPI : Key Performance Indicator
Spec: specification
U-flex: [redacted]
U-prod: [redacted]
WO : Work order

11. References

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12. Table of figures

13. Table of appendices

14. Appendices

Appendix 1: Detailed description of the company and the process

1) DSM group

Dutch States Mines (DSM) is an international Dutch group which creates innovative products and services in Life Sciences and Materials Sciences, contributing to the quality of life. DSM's products are used globally in a wide range of markets and applications, supporting a healthier, more sustainable and enjoyable way of life. This company, located on five continents, is present in more than 49 different countries. Indeed, it is worthly known as supplier of the chemical industry. It employs more than 24,000 people worldwide and with a turnover of almost EUR 8.1 million it is even listed on Euronext Amsterdam.
Initially, DSM was focused on the coal market but nowadays, as shown in Figure 16, it is more diversified and includes human and animal nutrition and health, personal care pharmaceuticals, automotive, coatings and paint, electrics and electronics, life protection and housing.

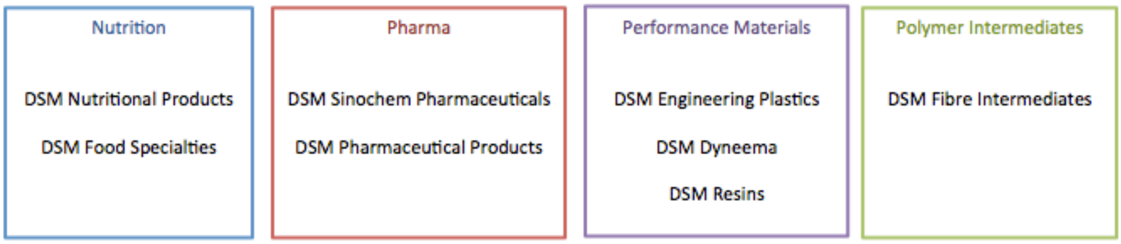

Figure 16: Market of DSM (DSM website, 2011)

2) DFS group

DSM Food Specialties (DFS) is part of the nutrition cluster of DSM. It is a global supplier of advanced ingredients for food and beverage industries, primarily manufactures, with the aid of fermentation and enzyme technology. Its products contribute in a major way to the success of the world favorite dairy, processed food, soft drink, fruit juice, alcoholic beverage and functional food brands.
Its headquarters are located in Delft in the Netherlands. [redacted] DFS employs more than 1,600 people spread over 20 business agencies, Research and Development sites and 10 production factories.

[redacted] Indeed, as shown in Figure 17, DFS is composed of different business groups.

[redacted]

Figure 17: Structure of DSM Food Specialties (Documents from the company, 2008)

These various specialties let DFS to have a large market position in several areas:

[redacted]

With its two manufacturing plants (France-Seclin and Italy-Lavis), DFS Enzymes is present all around the world.

3) DFS Seclin

3)1) History of DFS Seclin

DFS Seclin has been a pioneer of industrial biotechnology. It began in 1906 when Auguste Boidin discovered an amylase produced by bacteria. Because of its capacity to accelerate the liquefaction of starch, it had been called Rapidase. In 1922, Auguste Boidin and Jean Effrint setup a first industrial production of enzymes in Seclin: Company Rapidase. Then, as indicated in Figure 18, the company took different names through the last decades. It is in 1998 that it became DSM Food Specialties Seclin after a merger with the second Dutch chemist DSM.

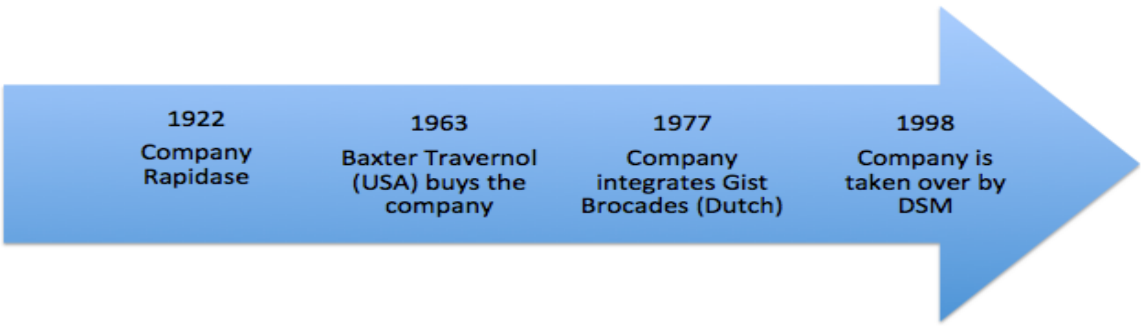

Figure 18: History of DSM Food Specialties Seclin (Documents from the company, 2008)

3)1) DFS Seclin Nowadays

3)1)1) Activity

DFS Seclin is specialized in manufacturing of functional enzymes for the food industry. Its enzymes are present in many food ingredients and contribute to every day food improvement. For instance, they can improve quality (volume, texture, appearance…) and process quality (machine ability, dough tolerance), increase the yield or reduce the production cost as well. That is why they are used in various sectors such as wine industries, food, baking and brewing processes.

3)1)2) Organization structure

The production plant is located in Seclin (France-59) on a site of 2.3 ha for more than 180 employees. It was certified ISO 9002 by AFAQ in 1993, 1996 and 1999 and certified by the new ISO 9001 in 2003 and 2006. Moreover, it is currently on a process of AIB Certification.

The Management Committee (CODIR), whose each member is responsible for one or more services comprising managers, supervisors, technicians and/or operators according to its structure, assists the Site Director.

The organization is based on the cooperation of several departments such as production, engineering, quality service, production support (including Maintenance Services, Planning…), the business units and the communication department.

3)1)3) Production

The production department is mainly composed of [redacted]

The plant produces batch wise every week, 7 days, 24 hours a day in "3/8" (i.e. Organization of work where 3 shifts work 8 hours each to cover 24 hours a day). Thanks to this no-stop production, DSM Seclin manages to produce [redacted]. It has been decided to do batch production because of the diversity of the products. [redacted].

3)1)4) Process description

[redacted]

Figure 19: Schema of the process (Documents from the company, 2008)

Enzyme is an active protein that makes it possible to transform a complex natural substance into simpler and more easily absorbable substance. The industrial ones produced in Seclin are made by fermentation of microorganisms. It can be done with bacteria, yeast and mould.

The process consists in the multiplication of these microorganisms inside the media, which synthesize enzymes in big quantity. It is necessary then to extract only enzymes and perform packaging. [redacted]

[redacted]

[redacted]

[redacted]

Figure 20: Steps in the fermentation phase (Documents from the company, 2008)

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Figure 21: Steps of the extraction phase (Documents from the company, 2008)

[redacted]

[redacted]

[redacted]

[redacted]

Figure 22: Different types of enzyme production (Documents from the company, 2008)

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Figure 23: Plate filtration phase (Documents from the company, 2008)

[redacted]

[redacted]

[redacted]

- [redacted]
- [redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Figure 24: Formulation and packaging phase (Documents from the company, 2008)

[redacted]

[redacted]

[redacted]

[redacted]

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[redacted]

[redacted]

[redacted]

Appendix 2: Flow of information in the Supply chain

[redacted]

Legend:

Planning — Department or person

Information from Delft

Feedback

Link between the departments

Scope of the project

a) Description of the flow of information

[redacted]

b) Communication

Communication is the activity of conveying information. Communication requires a sender, a message, and an intended recipient. The communication process is complete once the receiver has understood the message of the sender. Feedback is critical to effective communication between parties.

It is important that the communication between all the departments is good. Indeed, if Quality does not give the results on time, the formulation cannot start and the production is delayed.
Strong links between all involved departments can lead to a better use of the production capacity. Strengthening the communication between the different departments can lead to a more reliable Supply Chain.

The links between the planning department and the other departments (maintenance, quality, logistic, production) have been studied via interviews. Questions have been prepared and validated in advance with the company supervisor. Meetings have been scheduled with the different departments. Data are gathered.

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Appendix 3 : Cost of a rework per kilogram

Variables:

c_{rl} : cost of rework for a liquid product
c_{rs} : cost of rework for a solid product
c_{sl}: standard cost for production of a liquid product
c_{ss} : standard cost for production of a solid product

To compute this cost, we have focused on the finished products because non-conformed products concern finished products.
We have used the top 20 produced finished products during the three first trimesters of 2011.
Separate costs for liquid and solid have been computed because there are losses of materials during a rework of liquid whereas for the solid, the losses are insignificant.

I) Liquid

[redacted]

Figure 25: Added activities done for a rework of a liquid product

It is assumed that all the products can be reworked.

(1) The standard production cost per kilogram for the complete process can be found in SAP (transaction ck13n).

For each product, the standard cost has been multiplied by the quantity produced for this product. The standard cost per kilogram for a random liquid $\mathbf{c_{sl}}$ has been computed by adding all the previous calculations and dividing by the total quantity produced this year. It is equal to: [redacted].

(2) Taking into account the additional activities: [redacted], the cost per kilogram for a rework $\mathbf{c_{rl}}$ has been computed on a pro rata basis of the quantity produced (same method as in (1)).

(3) For a rework of liquid end products are stored either in drums or in containers, [redacted] of the total volume is left in the packaging because the product is pumped and it is impossible to pump everything.

On average, [redacted] of products are lost during a pumping (pump, pipes…). Using [redacted] reworks, we have computed the average volume that is pumped. It is equal to [redacted]. [redacted] of the pumped volume is lost on average due to the pumping.

(4) During the filtration, there is an enzymatic loss. It has been estimated by the person in charge of the process that [redacted] are lost during a filtration.

(5) In total, [redacted] of the end product is lost during rework.

[redacted] are losses due to rework.

(6) The additional cost per kilogram of a rework of **liquid** end product is equal to the additional cost due to rework (losses) and the added costs for filtration and packaging: [redacted].

II) Solid

[redacted]

Figure 26: Added activities done for a rework of a solid product

[redacted]

(7) For each product, the standard cost has been multiplied by the quantity produced for this product. The standard cost per kilogram for a random liquid $\mathbf{c_{sl}}$ has been computed by adding the standard cost multiplied by the quantity produced for the top 10 solid produced finished products and dividing by the total quantity produced this year.

The standard cost per kilogram for a random solid $\mathbf{c_{ss}}$ has been computed on a pro rata basis of the quantity produced. It is equal to: [redacted].

(8) Additional cost $\mathbf{c_{rs}}$ is computed taking into account all the costs for the steps in the production that are redone: [redacted]. There are no losses due to rework. The additional cost for a **solid** is equal to [redacted].

Appendix 4: Key Performance Indicator (KPI) Maintenance weeks 1-35 2011

Week	Work Orders done on time / Total WO planned
35	[redacted]
34	[redacted]
33	[redacted]
32	[redacted]
31	[redacted]
30	[redacted]
29	[redacted]
28	[redacted]
27	[redacted]
26	[redacted]
25	[redacted]
24	[redacted]
23	[redacted]
22	[redacted]
21	[redacted]
20	[redacted]
19	[redacted]
18	[redacted]
17	[redacted]
16	[redacted]
15	[redacted]
14	[redacted]
13	[redacted]
12	[redacted]
11	[redacted]
10	[redacted]
9	[redacted]
8	[redacted]
7	[redacted]
6	[redacted]
5	[redacted]
4	[redacted]
3	[redacted]
2	[redacted]
1	[redacted]

Appendix 5: Data concerning the failures of [redacted] during years 2010 and 2011

Date when a corrective maintenance occurs	Duration of the maintenance activity (hour)	Time between two successive corrective maintenance activities (days)
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
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Appendix 6: Data concerning [redacted]

Time between two successive failures (days)	Number of occurrences	Time between two successive failures (days)	Number of occurrences	Time between two successive failures (days)	Number of occurrences
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
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Appendix 7: Time when breakdowns happened

Breakdown happened at day [redacted], at day [redacted], at day [redacted] and so on…

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Appendix 8: Estimation of the failure time distribution

Using the method pages 356-360 in Montgomery et al. (1999)

Time between two successive corrective maintenance activities (days)	Number of occurrences	Expected number of occurrences computed using the exponential distribution
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
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