The Importance of the Holistic View

A Production System Analysis at Lysi hf.

Master of Science Thesis

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Cover:
The cover picture shows Lysi's logo.

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ABSTRACT

In today's competitive industry it is common to look for higher efficiency and productivity in one's factory. Extensive pre-study projects historically determine the success factors for increase in productivity for different industries.

The purpose of this thesis is to prepare Lysi hf, a fish oil company in Iceland, for a productivity increase, by analyzing the whole production system. Lysi has currently reached the limit of its production systems when it comes to productivity. Therefore, the goal is to get a holistic view of the production and create a solution that has a positive effect on the productivity. This was done by using a combination of quantitative and qualitative approaches, by interviewing various employees and analyzing numerical data obtained from the production system database. The conclusion of the thesis gives a suggestion to where the company should focus their improvement efforts.

Different tools have been used in the project, including lean tools, bottleneck analysis and process mapping. In order to find the main constraint or bottleneck, that is, what hinders the increase in productivity, different approaches were taken such as utilization analysis, value stream mapping and comparison of cycle times. This resulted in an extensive overview of the current production system and its flow as well as a suggested approach for Lysi on how to increase productivity including organizational changes and capacity investments.

The production system at Lysi is in many ways unique; it is a mixture between batch production and process industry and between a push and a pull system. This project views how the solutions traditionally aimed at assembly production will fit for other types of production systems.

Key words: *bottleneck detection, productivity gain, utilization analysis, Value Stream Map, production flow, utilization analysis*

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Caroline Dedering & Guðbjörg Rist Jónsdóttir

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NOTATIONS

TERMINOLOGY

API	American Petroleum Institute. Certification used to ensure fulfillment of international requirements.
Availability	Time when a process is available for production.
Batch	A set quantity produced in one run in a machine.
Blocked	When a process cannot perform its work, since the sequential machine or buffer cannot receive material.
Bottleneck	An element of the production system that hinders the system from working at a higher productivity.
Buffer	An intermediate stock, between process steps.
Constraint	See "Bottleneck".
Cycle time	The average time it takes a process to deliver a single processed product.
Down time	Shown as maintenance in the following report.
GMP	Good Manufacturing Practice. Certification used to ensure quality in production of pharmaceuticals.
Idle	When a machine is not processing because it is being blocked or starved.
Loss	Material that is removed in the production, both deliberately and not, and will not be used for the final product.
Lot	Group of batches of the same material produced sequentially in the same process step.
Processing	The time a machine is completing the transformation of the product.
Processing time	The time it takes one product to go through a process.
Retrospective study	Study using historical data.
Set-up	The time it takes to prepare a machine for producing the next lot.
Scrap	Finished or semi – finished product, that is defected in some way and needs to be thrown away or re-worked.
Starved	When the machine is not fed any material to work with.
Takt time	The average time interval between deliveries of finished products, based on customer demand.
Time study	Study that, in detail, observes and documents the time of a specific task.
Utilization	The time a machine is occupied, either by working time, cleaning and set-up time, or maintenance time, as a percentage of the total available time.

1 INTRODUCTION

The following thesis work was carried out as a project at Lysi hf., a fish-oil producer in Iceland. The company has in recent years faced a major increase in demand, which is why an increase in productivity is needed in order to stay competitive. An increased productivity can be reached in numerous ways; by investments to increase capacity, by shortening processing times, or by organizational changes in order to increase efficiency. The goal of the project was to find where the improvement is needed and in what way it could be reached.

1.1 Company introduction

Lysi is a well-established, family owned, company founded in 1938 and with its headquarters in Reykjavik, Iceland. There, the company also operates its refinery, packaging of bulk and consumer products, warehouse, sales and marketing, quality department, administration and laboratory. Lysi also operates a site in Þorlákshöfn, Iceland, where crude cod liver oil is produced as well as dried fish products and pet-food. Currently, there are about 140 people employed at Lysi.

The fish oil is mainly produced as bulk products, packaged in 190 kg drums up to 25 ton containers. Sales in consumer markets make up only about 10% of the total sales. Lysi's customers are all over the world in various sectors including pharmaceuticals, dietary supplements, food production, and cosmetics.

The company has grown rapidly over the past 10 years, with sales growing by roughly 20 % a year, resulting in a turnover of 60 million USD in 2012, as seen in figure 1. That is why a new refinery plant was built in 2005 and a big addition was made to the plant in 2012, building up to a capacity of 13 000 tons of fish oil a year. Their product portfolio is very wide and made from various types of fish oils, such as Omega, Cod, Cod liver, Tuna, Salmon, Capelin and Shark.

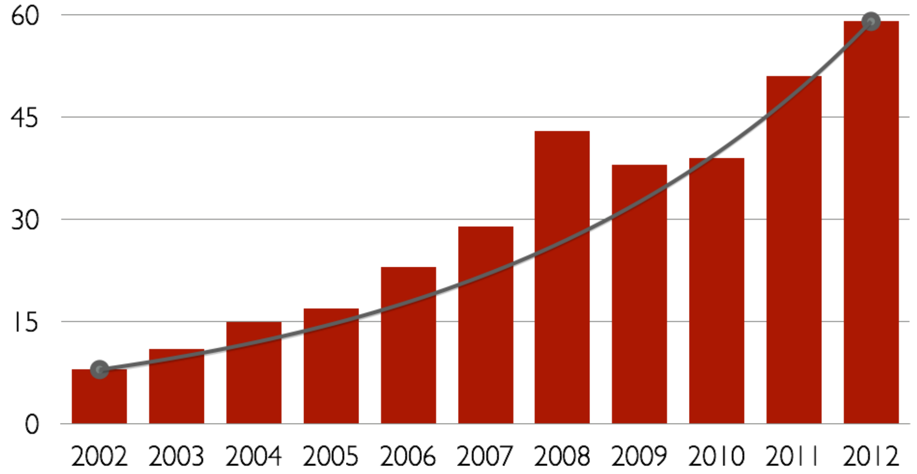

Figure 1. Sales at Lysi, in thousands of dollars, during the years 2002-2012.

Quality is of highest importance for Lysi. They are GMP, API, ISO 9001 and ISO 22000 certified, ensuring clear and defined manufacturing processes in addition to guaranteeing quality products.

1.1.1 Processes

The production consists of six main processes, as seen in Figure 2. where the crude oil is processed and refined, giving the right color and taste to the oil by removing for example free fatty acids, heavy metals and contaminants. Furthermore there are two side processes in the refinery, ethyl ester production and distillation, which are only used for specialty products, and therefore not included in this project. The oil is stored in buffer tanks between each step, to compensate for different batch sizes and balancing losses in the system. The whole system is based on production of lots, where the lot sizes vary throughout the flow, but also between product types. The lots are usually largest in the first steps, but are gradually split up throughout the production. The general rule is that the restocking of the buffer tanks is used to pull the production through the first steps, but actual orders then pull through the last steps. The process described in figure 2 is the usual process. However, it is possible to skip certain steps or change the sequence, to fulfill highly specialized costumer orders. This, in combination with a variation of raw materials, where the lot sizes and processing times vary between types and even within the same type of oil, makes the production planning very complex.

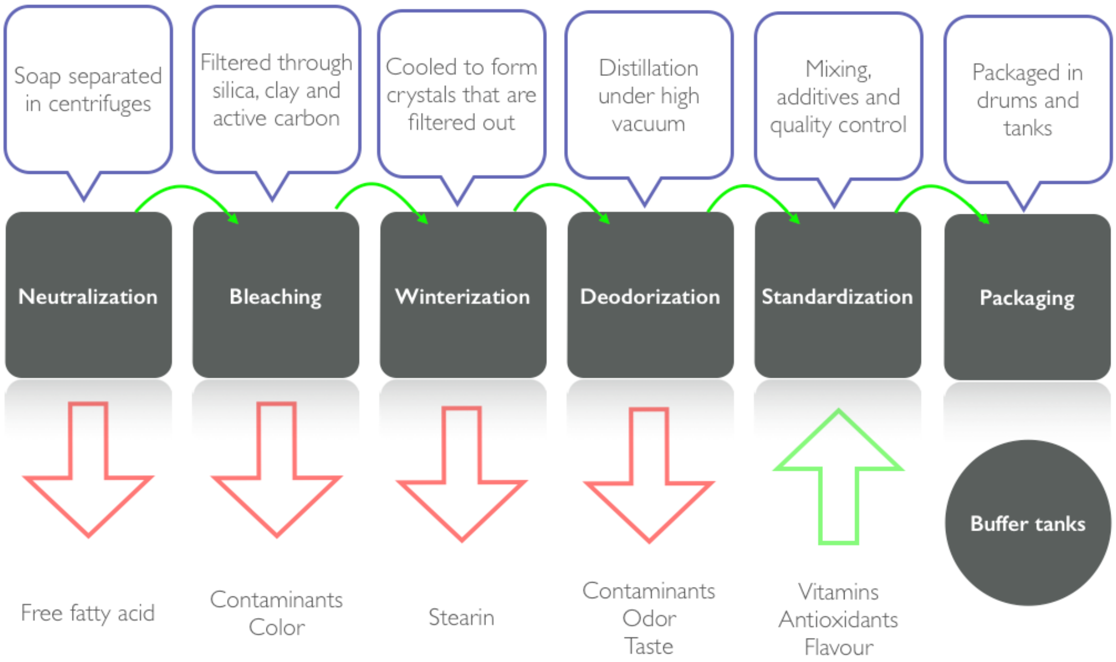

Figure 2. Flow chart of the production at Lysi.

Neutralization is an automated, continuous process run in one machine in the production. The purpose is to remove the free fatty acids, which is done by first turning them into soap and then washing them out of the oil in centrifugal separators. The free fatty acids are not wanted in the oil since they give a rancid taste and encourage oxidation.

Bleaching is an automated, batch process run in two machines in the production. The purpose is to remove contaminants and color by filtering the oil through absorbents; clay, silica and active carbon.

Winterization is an automated, batch process run in two machines in the production. The purpose is to cool down the oil in order to form crystals that are then filtered out, to ensure that the oil is clear in cool storage.

Deodorization is an automated, semi-continuous flow run in two machines in the production. The purpose is to reduce the taste, odor, and contaminants by distillation under high vacuum.

Standardization is a manual process where the oil is mixed to product specification and additives, such as vitamins, are added to the oil. A sample is then taken and measured in the laboratory and when all specifications have been met the batch can be packaged. There are approximately fifteen dedicated tanks for this process but the option exists to use buffer tanks as well.

Packaging: The oil is packaged in two semi-manual stations; one for drums and small containers, referred to as drumming and another for tank containers, referred to as tank filling or reception.

Buffer tanks: There are currently about 20 buffer tanks available to use in between the processes, mainly to compensate for balancing losses. All the processes can be connected to all the buffer tanks.

1.2 Background

Today Lysi is not able to meet the demand, which has been increasing rapidly over the past years. The current productivity is at its maximum and the company needs to improve, investing in new machines or make organizational changes.

There have been various improvements done over the last years at Lysi; a new factory has been built, the quality system has been improved and equipment has been added and upgraded. However, these improvements have mainly been focused on isolated areas, where the holistic view has somewhat been forgotten. The reason is mainly that the knowledge regarding the production system performance is limited at Lysi. The knowledge on the actual production system is not very detailed when it comes to capacity, utilization, cycle times and lead times but the employees rely to a large extend on the design parameters of the system. This has been a barrier when evaluating improvement suggestions and in the production planning. Nevertheless, raw data is automatically collected in the automated processes but since the company is not, to a large extend, used to analyzing them, it is a challenge to make use of it. By deepening the knowledge of the above factors it is possible to build a holistic view in order to structure a more effective system, enabling Lysi to fulfill the increasing demand.

This project aims at giving suggestions on how the system can be improved, by looking at the overall system and identifying investments in different improvement potentials and solutions at Lysi. The company has already suggested an improvement; to buy half a unit addition to the winterization. According to Lysi, the winterization is believed to be the bottleneck, since that process seems to be constantly running. However, they do suspect that there are other processes that will need improvements soon as well, but have a hard time determining what processes. In this project, the whole system is included in a detailed analysis and different solutions are thoroughly explored, to find the most cost efficient way to increase the overall productivity of the production system.

The project emphasizes the importance of a holistic perspective and looks at the whole production system, shown in figure 2, when looking for improvements in productivity. In order to improve productivity all the processes must be taken into consideration. It is common that there is more than one constraint in the system, since the constraint can shift between processes over time and therefore it is crucial to look at the whole system when making the analysis (Roser, Nakano, & Tanaka, 2003).

A project like this is highly contextual, where there are no easy fixes to be found. At Lysi, the production system is complex due to the mix of batch- and continuous flow production. In addition, the project gains certain uniqueness since it doesn't cover the typical assembly production that, very often, is the focus of literature on production system analysis.

Lysi needs a solution that will allow them to increase their productivity, by increasing their total output in accordance with the demand, for as little investment as possible. That is why the project investigates all the different processes, from various perspectives.

1.3 Purpose

The main purpose of this project is to help Lysi to increase their productivity in accordance with their current demand. The secondary purpose is to gain knowledge of the current production system. In addition, the project advances the understanding of applying theoretical methods to a real world problem and how different methods interrelate, which provides a deeper understanding of the subject.

1.4 Objectives

The main objective of the project is to analyze the current production system in order to identify potential improvement areas to be able to provide Lysi with an improvement plan for increased productivity. More concrete, to;

- Provide Lysi with a thorough analysis of the key factors of their current system including utilization, cycle times, processing times etc.
- Provide Lysi with a holistic view of the production system, by mapping.
- Identify and prioritize bottlenecks by analyzing the mapping and key factors.
- Find alternative solutions to Lysi's initial machine investment.
- Identify future improvement areas.

1.5 Scope

The project covers the production system within the plant in Reykjavik, which is the bulk production. Other sites and the consumer products are not taken into consideration. Within the refinery, only the main processes, shown in figure 2, are analyzed, excluding side processes; the ethyl-ester production as well as the distillation, since those processes do not directly affect the main process. The project focuses on static analysis, as opposed to simulation, since the buffers between each step in the production are determined big enough to compensate for balancing losses as well as system losses due to variations and disturbances. Furthermore, for simplification, only the most common oil types are taken into account when mapping the processes and production times. Finally, testing of the solutions is not performed since the students do not have the necessary resources. The main limitation for the project itself is time, but the study length is set to 20 weeks and therefore constant evaluation and prioritizing is crucial, to make sure the time is well spent.

1.6 Disposition

Following the introduction, there is a theory chapter where the theory used in this project is described. The sections include general approaches to productivity increase as well as various productivity improvements.

Chapter three is the method chapter, providing a description of the methods used in the project. It provides a general overview of the approach to the problem and includes more detailed steps of data collection, problem identification and approach of productivity.

In chapter four, the current state of the production system is described. It provides a thorough description and explanation of the analysis made, according to the methods described in chapter three, in order to understand where to put the focus of the improvements.

Chapter five provides a list of all the alternative solutions, based on chapter four and the theory chapter, as well as an evaluation of those solutions.

In chapter six, the chosen solutions are structured in an improvement plan. It includes thoughts about the critical areas and how to improve them, everything based on the analysis previously made.

Following the sixth chapter there is a discussion chapter and finally conclusions, summarizing the project. Lastly, there is a reference chapter and appendices for a more in depth understanding of the project.

2 THEORY

Bryman and Bell (2007) discuss the important role of a literature study in any scientific report since it reviews what research that has already been documented on the specific topic. Furthermore, it includes what others have done when faced with a similar problem, which can be a good guidance in the first steps of the project. The authors also argue that the literature study needs to be performed gradually throughout the project, since most real world projects have vaguely defined problems at the beginning, but get clearer as the analysis and research progresses.

A limited amount of literature was found on the specific problem, meaning literature that linked this type of process industry to increased productivity. Instead, a large portion of the literature is focused on the assembly industry, mainly how to increase productivity, how to create value stream maps as well as the application of lean tools. The methods described in this literature had to be used with care and adapted to the production system in question.

2.1 Constraints of a production system

When faced with the problem of increasing the productivity and efficiency of a production system, there are numerous ways of approaching it. One of the most widely used concepts is the Theory of Constraints, TOC.

Rahman (1998) describes how TOC recognizes a constraint, or a bottleneck, as something positive rather than negative since identifying the constraint gives an opportunity to improve the system. Furthermore, the main idea is to focus on improving the constraint so that no resources are wasted on improvements that will not increase the overall performance of the system. The author emphasizes how TOC focuses on balancing the flow in the system, more than the capacity, mainly by looking at the station before and after the bottleneck. Because after all the system is never stronger than the weakest link, which is the constraint of the system.

In summary, the approach can be described as:

1. Identify the system's constraint(s)
2. Decide how to exploit the system's constraint(s)
3. Subordinate other resources to the constraint(s)
4. Elevate the system's constraint(s)
5. Iterate

(Rahman, 1998)

Roser et al. (2003) discuss how a system's performance is most often bound by the constraints of the system and those constraints will consequently hinder the system from performing at a higher rate. Therefore, a bottleneck analysis should be the first step when exploring ways of increasing the productivity of a system. The authors describe various methods available for bottleneck analysis, and argue that in order to get reliable results, it is best to use a combination and comparison of those methods.

2.2 Bottleneck indicators

Roser et al. (2003) describe how a system constraint or a bottleneck can be identified by looking at various indicators in the system. These indicators include utilization rates, buffer sizes, queuing times, as well as cycle times and processing times.

Utilization rates can be used as a measurement of how well balanced the system is, that is, how leveled and equally distributed the work load is on the different elements of the system (Li, Chang, & Ni, 2009). It is a clear indicator of a poorly balanced flow if the utilization of processes varies a lot within the production system, whereas a balanced flow has less variation in the utilization numbers. KPMG Global Energy Institute (2012) notes that 100% utilization is not common in reality, since there will always be some losses in the system, which is why 90 % utilization is closer to a realistic goal for maximum utilization. Furthermore, one can compare it with the utilization rates in industries in the European Union, which is about 82.5 %.

Buffer sizes can also be used to indicate a bottleneck. Large buffers tend to pile up in front of the bottleneck which is also shown by the buffers after the bottleneck often being small, especially in traditional line production systems such as assembly lines and workshops (Li et al., 2009). In addition, the queuing time gives similar results; the longest queuing times tend to be in front of the bottleneck.

Process and cycle times are also valid measurements of process capability, where a ratio of the two can be used (Roser et al., 2003). Both of them are important since they give different types of required information where the cycle time has to be linked to the takt time of the production, to evaluate if the process cycle time is sufficient to meet the demand (Liker & Meier, 2006). However, it is important not to use only the cycle time, since it does not give any indication of the process availability or utilization.

Large variations and unstable processes are yet other bottleneck indicators. Unstable processes, with many disturbances, can lead to drawbacks in the planning where, at the same time, variance in production is usually a sign of something being wrong (Gupta, Ganesan, & Sivakumar, 2009).

2.3 Improvement tools

When the constraints of the system have been identified, it is time to find a way to elevate those constraints, in order to improve the performance of the system. The most obvious can be to invest in equipment to increase the capacity, but it is also important to look at the organizational aspect. There are many different methods to improve the performance of the organization, for example by the use of different improvement tools. Various tools are identified by the literature such as standardization, visualization, communication, and different planning tools which will be described further in the following section.

2.3.1 Standardization

Liker and Meier (2006) describe the importance and advantages of standardization when it comes to continuous improvements and consistent performance. However, the authors argue that the standardization of work procedures and processes is often seen as a negative effort, by focusing only on the systems performance at the expense of the workers. The authors state that this should not be the aim of standardization but on the contrary that standardization should benefit the workers, since it simply defines the best practice known, both in terms of productivity and workload. Still, there are different degrees of standardization and the level of detail depends on the nature and complexity of the task. It is not always necessary to do time studies and standardizations down to the second for all tasks, rather to standardize the process, responsibilities and procedures in the most efficient way and to eliminate confusion and misunderstanding (Liker & Meier, 2006).

2.3.2 Communication

According to Quirke (2008) communication within the company is crucial in order to reach success. The author argues that not only does communication make it possible to align employee efforts, but also decreases the complexity level of the tasks at hand. Furthermore, internal communication can result in increased competitiveness, reduced cost and better understanding of the business among the employees.

There are different ways of communicating within a company. As Quirke (2008) points out, it is getting more and more common within companies to use various standardized communication tools, instead of only verbal communication. That is in line with his statement that it is essential for the performance of the employees that they are well informed about what is happening within the company. By the use of visualization or digital communication, companies can achieve a higher employee satisfaction, become more efficient, and therefore have a better profitability (Quirke, 2008). Furthermore, it is very important to connect the internal communication with the business itself since companies will have different types of internal communication styles, in order to fit their own needs and purpose.

2.3.3 Visualization

Another crucial improvement tool is visualization and documentation. Parry and Turner (2006) discuss how visualization can to a large extent help to keep an overview of complex processes or decisions. Furthermore, it makes the communication and sharing of information with others much easier if it is all written down. This is common sense, yet so many companies miss it. As Liker and Meier (2006) describe it; the most essential information should be visible to everyone involved. Continuing, the visualization can be used for problem solving or for pure communication purposes.

A popular lean tool is the so-called lean board. It is a board that visualizes and summarizes all the vital information for the workers in that station or department, for example the production plan, maintenance plan, latest brake-downs etc. (Liker & Meier, 2006). The visualization makes it easy for the employees to quickly review a large amount of information, using graphs, histograms and color-coding.

2.3.4 Planning optimization

Well organized planning can be a strong tool to decrease balancing losses in order to increase productivity. There are various factors that have to be considered in the planning. For example, choosing the appropriate lot size can increase the productivity, shorten the lead time or decrease production costs, all depending on what the aim is (Jonsson & Mattsson, 2009).

Other factors that have to be determined are costumer order point and costumer order decoupling point. These factors determine where in the production flow the bill of material of the product becomes costumer specific, where up to that point the production is general and greatly based on forecast (Jonsson & Mattsson, 2009). Furthermore, time fences such as planning- demand- and release fences specify how far in advance different actions need to be made in order to deliver on time. Specifying all these factors can ease standardizing of the planning process.

Finally, there are multiple tools available, mainly software, that are useful for capacity planning by visualizing the upcoming production order, for example in a form of Gantt chart, where different orders are arranged on the right machines at the right time (Jonsson & Mattsson, 2009).

3 METHOD

In order to tackle the problem in an organized and efficient way, the students constructed an approach specialized to the project. The approach is divided into several steps and is all described in detail in the following chapter.

The underlying problems are undefined and therefore the project started by analyzing the current system in order to define the problems at hand. By doing so, it was possible to identify improvement areas and what parts of the system were most limiting. These areas were then prioritized and improvement potentials analyzed on the most important ones. Solutions were thereafter formulated in accordance to the improvement potentials. The alternative solutions were validated, evaluated and finally structured into the most optimal improvement plan. In figure 3, the approach is summarized in a flow chart.

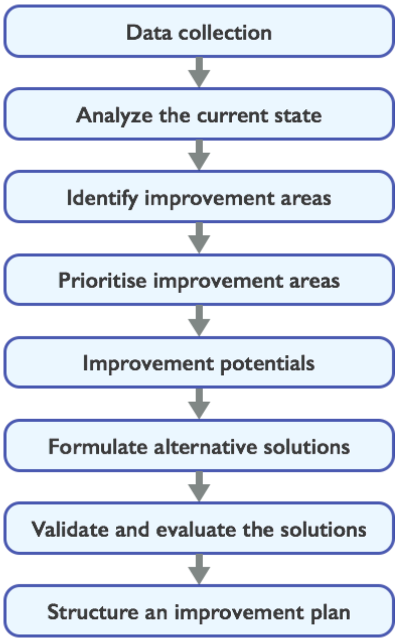

Figure 3. Flow chart of the chosen approach.

3.1 Data Collection

There are two main types of data, qualitative and quantitative. The quantitative data is primarily numerical data obtained either by historical data, experiments or observations, depending on the research subject. Detailed historical data gives a very good idea of how things have worked in the past and that data can be further verified by experiments or observations. The main concern when handling quantitative data is the size and variance of the taken data sample. It needs to be big enough, in relation to the subject, to get a significant conclusion. Also, there were limitations in the numerical data, which is why the students used interviews in combination with the numerical data collection. The data limitations include some set-up times, maintenance hours as well as times for winterization 2.

The qualitative data is used as the base for describing opinions and thoughts. It can be called "softer" data, since it is not often numerical. The main data collection methods are interviews, questionnaires and observations. There are a few variants of interviews; unstructured, semi-structured, and structured, all based on the structure of the predetermined questions in the interview.

It is important to answer and analyze the research questions with various methods in order to get as good result as possible. In other words, the quantitative data collection should be combined with qualitative research methods, in order to become as valid and as correct as possible (Jupp, 2006).

The book "Business Research Methods" (Bryman & Bell, 2007) was used as the main guide for data collection, literature review and interviews.

3.1.1 Quantitative data

Most types of process mapping and bottleneck analysis methods require numerical input, which is why a numerical analysis was needed. When choosing the data to be analyzed it is important to have a large sample in order to include data over a long period of time and to be able to gain validity of the conclusions. However, if the data period is too long, the subject might have changed and there will therefore be a big difference between the data from the beginning of the study to that of the end (Jupp, 2006). The data can be collected in numerous ways; either by accessing it from a database or by performing observations.

The data used in this project is mainly quantitative and was obtained from the production database at the company. The database stores numbers automatically recorded by the machines and includes numbers such as timings, lot sizes, batch sizes, and product numbers as well as, in some cases, detailed recording of processing times. The data was available for all the automatic processes; neutralization, bleaching, winterization, deodorization and drumming. Data was also available for all tanks; listing all pumping made both in and out of a particular tank with times, volumes and product numbers. A detailed overview of the numerical data provided from each process can be found in appendix A.

An important aspect of the quantitative data collection is the descriptive analysis of the data. It is especially important to include statistics such as the standard deviation, to describe the variance of the numbers and how well for example averages represent the data set (Runger, 2007). That is why standard deviation was always calculated when using averages in this project, to determine how reliable and stable the averages are.

A retrospective study was performed by using historical data. Data was extracted from the database for a period of nine months, from September 2012 to May 2013, and with a few exceptions. For drumming only May was used, since that system had been modified in beginning of April and one month still provided a large enough dataset. Similarly, it was considered sufficient to use only data from May for standardization, since the data was collected from ten tanks, and collecting further data would have been extremely time consuming. In winterization 2, September and October were excluded from the data, since the machine was still being installed at that time. No extensive data collecting of new quantitative data was performed, relying only on the historical data stored in the database. It is not unusual to find some errors in the data from a system like this one because of human error, system failure or malfunctioning. These errors are outliers that have to be identified since they will have a high impact on the calculated results (Runger, 2007). That is why a numerical analysis built on databases like in this case should preferably be complimented with a qualitative assessment, which is what the students did.

3.1.2 Qualitative data

To complement the quantitative data, qualitative interviews are conducted in order to fill in the gaps where data is lacking as well as verifying calculated results. According to Marshall and Rossman (2010) a semi-structured interview is a good way to get a general information especially when a problem is still being defined and was therefore used in this project. The semi-structured interview is between the fully structured and unstructured interview, where the interviewer has prepared questions, to guide the interviewee to stay on topic, but allows for a certain amount of freedom (Bryman & Bell, 2007).

In all interviews, the main goal is to get as accurate and unbiased information as possible, where both the phrasing of the questions as well as the appearance of the interviewer are important (Bryman & Bell, 2007). That is why the interviews were all held face-to-face or via Skype, but having interviews face-to-face instead of over the phone or by other methods is a very important factor, since it brings the importance of the subject discussed to a higher level. Face-to-face interviews also make it possible for the interviewer to take advantage of social cues such as voice, intonation, body language etc., all of which can provide additional information on the subject (Opdenakker, 2006). Furthermore, the interviews were conducted in English by both students only when the interviewee had sufficient English skills. When the English skills were not sufficient, the interviews were conducted in Icelandic, only by one of the students.

The interviews were conducted on different stages of the project and with various interviewees. A full list of the interviewees and their positions can be seen in table 1. At the first stage, the managers of the production were interviewed, to get a general understanding of the production system and the data available in the database. When the first numerical analysis was completed, the managers were interviewed again, in addition to operators. At the final stages, when the solutions were forming, employees at the laboratory and quality department were interviewed as well.

Table 1. Overview of the interviews.

Interviewees Position	Interviews
Plant Manager	One interview, to confirm the analysis and get ideas for solutions.
Assistant Plant Manager	Numerous interviews over the course of the project, to confirm analysis and get ideas on how to proceed.
Production Manager	Numerous interviews over the course of the project, to confirm analysis and get ideas on how to proceed.
Sales Manager	One interview, to get estimations of the future sales and trends.
Processing Manager	One interview, to confirm the analysis and give input to the bottleneck analysis.
Maintenance Manager	One interview, to get estimations for time needed for maintenance.
4 Operators	One interview each, to confirm the analysis and give input to the bottleneck analysis.
4 Lab Employees	One interview each, to get information on how the laboratory is organized.
Quality personnel	One interview, to understand how the quality system is organized and linked to the production.

3.2 Analyze the current state

The analysis was to a large extend numerical; where interviews however were conducted to confirm the analysis. The analysis had two main goals: to get a good overview of the production and to get the basic factors for each process and product in the production system. That is why each factor was determined for every process and product type. The analysis was needed before any conclusions could be made about the system in regards to constraints and improvement potentials.

The calculations were made in Excel where pivot tables were a widely used tool since it easily divided times and calculations into different raw materials. Pivot table is a data summarization tool that makes it possible to work with a lot of data in a multidimensional table and to calculate the average, total or a certain count. To see the validity and accuracy of the calculated factors the standard deviation was calculated when possible. In this chapter the method is covered whereas the correspondent results can be found in chapter 4.1.

Product groups
It is important to analyze the demand, to be able to draw correct conclusions from the analysis of the production system and the planning (Jonsson & Mattsson, 2009). At first the products were split up into product groups based on raw material since the processing varies substantially between those different product groups. The volume of deliveries over the data period was split up into the product groups, and only the largest ones were included in the analysis for simplification reasons.

Process maps
Process mapping is used to increase the understanding of the production, by mapping it and braking it down into smaller steps (Conger, 2011). The first step of the analysis was to get a good overview of all the processes, by both mapping the overall flow as well as descripting individual processes. The process maps provide a good understanding of the processes and the relations they have to each other (Kalman, 2002).

There are many different types of process maps, all depending on the purpose. A Value Stream Map (VSM) was used as an overview map, and is described further in chapter 3.3.1. Process maps were created, in order to get a detailed picture of how each process was working (Kalman, 2002).

Loss
The material loss in the system was calculated for each individual process and product group. This loss is though not to be confused with scrap, meaning defected products, since it is the very nature of each process to remove some sort materials from the oil, for example stearin, free fatty acid and other substances. The loss is therefore unavoidable, but it is very important when comparing the capacity or cycle times of processes, since the first process will have to have significantly higher capacity than the later processes. Furthermore, the variance of the loss indicates the stability of the process; if the loss is kept at constant or if it is varying significantly between production runs.

For simplification reasons and since the scrap rate at Lysi is very low, it was neglected in this project.

The loss was found by looking at the extracted data and calculate the difference between the amount of oil pumped into each process and the amount of processed oil pumped out.

Processing times

Processing time is the time it takes for a single job to go through one process (Hopp & Spearman, 2008). In the case of Lysi it is measured in hours, as the time it takes for one batch to complete a specific process.

In neutralization, the processing time was found as the difference in timing of oil pumped in and oil pumped out. In bleaching the processing time was calculated as the time between individual batches in a lot, that is, the time difference between each pumping made into the system in that lot. Since winterization is divided into two main steps, cooling and filtering in step one and squeezing in step two, the processing time was found as either the time for step one or step two, depending on which one was longer. The processing time for deodorization is pre-set in the computer system and was used as given. Processing time in the drumming station was calculated as the interval between the start of individual pumping within an active period, excluding brakes and stops. The processing time in both standardization and the packaging in the reception were estimated based on interviews since no numerical data was available on the actual processing time.

Cycle times

The cycle time, is an important element of the VSM, and can indicate a problem area if the cycle time is very close to the takt time. It is usually presented as time unit per production unit (Hopp & Spearman, 2008) and hours per ton (hr/ton) was considered the most appropriate unit for Lysi.

Due to the loss in each process, the cycle time was found in two different ways – both as hr/ton and as hr/finished ton. The cycle time, hr/ton, was found for each product in each process as the processing time divided by the processed amount, as shown in equation 1.

$$\textit{Cycle time} = \textit{Processing time} / \textit{Processed amount} \quad \text{(Eq. 1)}$$

The ton measured in hr/finished ton takes into consideration the loss that will occur in all the upcoming processes. This was done since the first process will have to produce up to double the amount processed in last process and therefor has to have much larger capacity than the last process. Calculating how much oil needs to be taken into each process in order to get one ton of finished product out at the end of the line and then calculate the time needed to process that amount, is considered as the hr/finished ton for that process. This way it is possible to get a result that is actually comparable between processes.

Set-up time

The set-up time is an important part of the VSM, the utilization analysis and is also important when deciding lot sizes (Jonsson & Mattsson, 2009).

Numerical data in the form of the time between lots was used to some extent, but it was often impossible to differentiate between the set-up time and waiting time in the time-logs. A time study for the set-up times was not feasible for the project, which is why set-up times were mainly estimated by interviewing the operators in charge of the corresponding processes.

3.3 Identifying improvement areas

The factors that have been calculated were then put into context, to enable the identification of improvement areas, that is, where the need for improvement is most pressing. There were three methods used for this analysis: Value Stream Mapping (VSM) to get a clear overview of the whole system, Utilization analysis to indicate bottlenecks and finally interviews to take into account information that was not provided in the numerical analysis.

3.3.1 Value Stream Mapping, VSM

Definition

A value stream map, VSM, is used to visualize the material and information flow through the whole production. The map starts at the supplier, with the incoming raw material and ends at the costumer, with the shipped product. It includes processing times, cycle times, lead times and buffer levels as well as information flows. The purpose of the VSM is to show where the value adding tasks are occurring and give an overview of the current state. It is crucial to see the production as a single flow when analyzing a system and to improve the different parts of the system in harmony since one will only "get a fraction of the benefit by improving isolated areas" (Liker & Meier, 2006).

In order to show the current state, it is important to use a clear and systematic manner so the map is easily understood and provides the intended purpose: to give a holistic perspective of the production in addition to detailed information on certain parts of the system (Bergman & Klefsjö, 2010). The aim is to visualize the data, and highlight what parts need the most attention (Damelio, 2011).

The VSM is a good starting point in an improvement effort, since it is aimed at improving individual processes to support the overall flow. The main purpose in this project is to provide a map that will help analyzing bottlenecks and detect unevenness in the flow. It is also very important to keep in mind that a current state VSM only provides a snapshot of the system, in other words, it is very important to combine the analysis with other theories and methods to get a sufficient conclusion (Liker & Meier, 2006).

The eight questions

There are eight questions that are used to define and create the future state of the system. Since a future state map was not provided, these questions, found below, were instead used as a base when analyzing and identifying potential improvement areas (Rother & Shook, 2003).

1. What is the takt-time/demand?
2. Produced to direct delivery or a final stock?
3. Where can we produce in a continuous flow?
4. Where do we place supermarket/pull-systems?
5. Where in the flow is the pacemaker?
6. How do we level the production mix?
7. In which batch size should we produce?
8. Which process improvements are needed?

Lysi's Value Stream Map

The main purpose of the VSM in this project was to serve as a holistic picture of the production, in order to identify improvement areas. That is why a future state map was not provided in this project.

One VSM was created for each raw material as well as one with the weighted averages. The VSMs were based on interviews, own experience, and numbers from the data analysis. The maps include substantial information that was used for further analysis, such as, what the overall production flow looks like, how the flow is evened out, and how the different processes communicate with each other.

In the VSM, cycle time was calculated as a bottleneck indicator. Analysis of buffers and queuing times was not carried out, both because that information was too tricky to extract from the data provided, as well as those are not as clear indicators of a bottleneck when the production system in question is not a single product production, or a first in – first out type of system (Liker & Meier, 2006).

3.3.2 Utilization analysis

Utilization analysis is a common method of bottleneck detection. This method analyzes how long time the processes are active and converts it to a percentage of the available time. Active time includes all occupied time, that is, processing, maintenance, disturbances, set-up, and cleaning. A high percentage of active time is a clear bottleneck indicator (Roser et al., 2003).

The utilization was calculated from numbers that were mostly gathered from the database. Processing time was simply determined as the sum of all processing times for the whole data period. The sum of set-up times was estimated, based on the specific set-up time for each process, multiplied by the number of lots. Abnormal processing times, everything out side of the average plus two standard deviations, were calculated and classified as disturbances. These disturbances include small stoppages, smaller breakdowns and slow processing. The time used for maintenance was estimated, based on interviews with both operators and the maintenance manager, since there are no process specific time logs kept on maintenance. The time left was then considered as waiting time or idle time, but it was not possible to see from the data if the particular processes were being starved or blocked.

The time for each activity; processing, set-up, disturbances and maintenance were calculated as a percentage of the sum of available time during the period. Those percentages were all summarized in a single histogram, in order to compare the utilization between the processes. By visualizing the brake down of the utilization in a histogram a better analysis can be carried out. By looking at the machines with the highest utilization, one can identify the bottlenecks (Rahman, 1998).

In addition to this time-based utilization, it was possible to calculate capacity utilization for two of the processes; winterization and standardization, and use it to compliment the time utilization. When calculating that, the average batch sizes were compared to the maximum batch sizes in each process.

3.3.3 Interviews

It can be very important to get additional input from interviews since the numerical data is often incomplete and can give a very simplified image of the production (Bryman & Bell, 2007). Therefore, there were special held interviews at this stage of the project, aimed at adding information to the numerical bottleneck analysis, everything to make sure that all aspects had been taken into consideration.

Semi structured interviews were conducted with a number of employees, as seen in table 1, to confirm the numerical analysis as well as to get additional input. Both operators and managers were interviewed for this purpose, to get their input in to the bottleneck analysis and to see their view of what processes are problematic.

3.4 Prioritize improvement areas

The results from the VSM, utilization analysis and interviews were summarized and improvement areas identified. The prioritization of those improvement areas was done in a qualitative manner, in cooperation between the authors and the company's representatives, to prioritize the problems.

3.5 Improvement potentials

Each area of improvement had to be thoroughly analyzed, to identify the improvement potential, that is, what factors can be improved in the process in order to improve the overall system. This is done by root cause analysis, mainly using the "5-why" method, where five why questions are asked and answered in order to find the root-cause (Liker & Meier, 2006). The utilization graphs and process maps were mainly used to recognize these whys for each process, but it was important to remember to look at the holistic picture.

3.6 Formulate alternative solutions

The search for solutions started with interviews. Operators as well as managers were asked for ideas on how to solve the problems at hand, based on the identified improvement areas. The students are not specialists when it comes to the specific chemical processes in question and therefore sought ideas from the company.

To be able to evaluate and fully develop the solutions the processes were analyzed further with process maps. Those maps enhance the understanding of the processes and clarify how each solution can improve them.

The solutions were judged feasible or not in cooperation with the management team in the production, where elements like cost are taken into account. In other words, the decision was based on a combination of qualitative and quantitative methods since the implementation ability is as important as the cost and productivity increase potentials.

3.7 Validate and evaluate solutions

In order to determine which one of these solutions are the best they have to be evaluated and validated.

3.7.1 Evaluation

The evaluation was mainly done in a qualitative process in cooperation with Lysi, where the main requirements were identified. Interviews were used to evaluate what solutions were most likely to be successful as well as to estimate the investment and time needed to implement each solution.

The solutions are weighted based on the requirements, by building an evaluation matrix, as described by Zandin (2001). The solutions are then graded in relation to each other for each requirement. The grade is multiplied with the importance of the requirement factor, giving a total sum. It is possible to weight the different solution against each other, serving as the basis when deciding on an improvement plan for the project. The matrix is a very good tool to quantify the information in order to choose the best possible solution for the specific project (Zandin, 2001). Constructing such a matrix, and deciding the weights and rankings has to be done with care. It was therefore important to get input from various directions, in order to get as unbiased conclusion as possible. The matrix is though only to be used as a base for the evaluation, but if many solutions score close to the highest one, they should all be investigated further, to determine what other factors come in play. That further analysis looked for example at how well each solution solved the root-cause of the problem. For example, if the root-cause is simply too small capacity it would result in an evaluation of capacity expansion suggestions whereas if the problem is an inefficient process solution regarding organization and process improvements are investigated.

3.7.2 Validation

Validation is important in order to add support to the outcome of the project. The solutions of the project will be validated or tested by the company since the knowledge and resources are not in the hands of the students. However, using triangulation the results of the system analysis were validated by having various sources of data as well as combining multiple methods in the analysis. By using interviews from different perspectives, from workers with different responsibilities (see table 1 with interviews), the validity of the project has reached a higher level.

Interviews were also used for initial ideas for improvement ideas (Patel & Davidson, 2003), which is why the solutions have a good degree of validation. The best way to support and verify the outcome of a solution would be to test it, either in the real system or in a controlled environment such as a testing plant. Suggestions on testing methods are included in the improvement plan.

3.8 Structure an improvement plan

The final step in this project was to construct an improvement plan, where the improvements were prioritized. It includes suggestions for the implementation of the most important improvements as well as suggestions on further studies and analysis within Lysi.

4 ANALYSIS OF THE CURRENT STATE

In the following chapter the analysis of the current state will be described. The process included an analysis of the current system, identification of improvement areas, in addition to finding the improvement potentials in isolated areas. In order to make the analysis as thorough and accurate as possible, literature, quantitative methods, as well as qualitative methods have been used.

4.1 The current system

In the next subchapter a short description is provided of the main factors identified for the current system.

4.1.1 Product groups

In order to find the distribution between different raw materials and products, the demand over the data period is analyzed. The results are presented in table 2 and show how the four raw materials cod (COD), cod liver (CLO), omega (OME), and tuna (TUN) make up 94 % of the production volume. Note that COD and CLO have been combined since they are normally mixed in the final product. These material groups were then used in further analysis of the system. Note that although tuna makes up only 4 % of the production volume it has much longer processing time and higher value than the other products and was therefore included in the analysis. The biggest product groups that are left are not only very small, but also highly specialized, and were therefore not analyzed further.

Table 2. Production volumes divided into product groups.

Raw material/ Product group	Product names	% of product group	% of whole portfolio
COD/CLO	HB602, HB603, HC340, HC341	38	12
	HC255	26	8
	Other	36	11
	Total	**100**	**31**
OME	HO307, HO339, HO348, HO368	41	24
	HO404, HO405	27	16
	Other	32	19
	Total	**100**	**59**
TUN			**4**
Other			**6**

4.1.2 Process maps

The process maps of the analyzed processes can be found in Appendix B and were mostly created from the information gained from the interviews. It is worth noticing how the processes work and how the steps are built up, in order to fully understand them and see the improvement potentials. The maps were mainly used to improve the understanding of the overall system and were therefore heavily used in the beginning of the project as well as during the analysis.

4.1.3 Factors

All the factors were calculated for each process and product group separately since many of them vary significantly between different products. Below are the main remarks on each factor.

Loss

As expected, each process had a significant amount of loss, except standardization. There was though large standard deviation on most of the factors, suggesting that the loss varies substantially and that it is therefore hard to use average loss in each process for further calculations, for example when planning the production. When confirming the numbers with operators, it was evident that the loss reported for deodorization is not correct, probably as a result of a badly calibrated tank.

Cycle-time/Processing time

The weighted average of the cycle times, normalized and compared to the takt time of the system are presented in figure 4. The cycle times and processing times were all more or less as expected, as confirmed by the operators, except the cycle time for standardization. It is most likely because the processing time for standardization is fixed, but the lot sizes have a large variation, resulting in the cycle times to have a large variation as well. Neutralization on the other hand had small standard deviation, suggesting a very stable process. It is clear from figure 4, that winterization and standardization have cycle times close to the takt time, indicating possible bottlenecks.

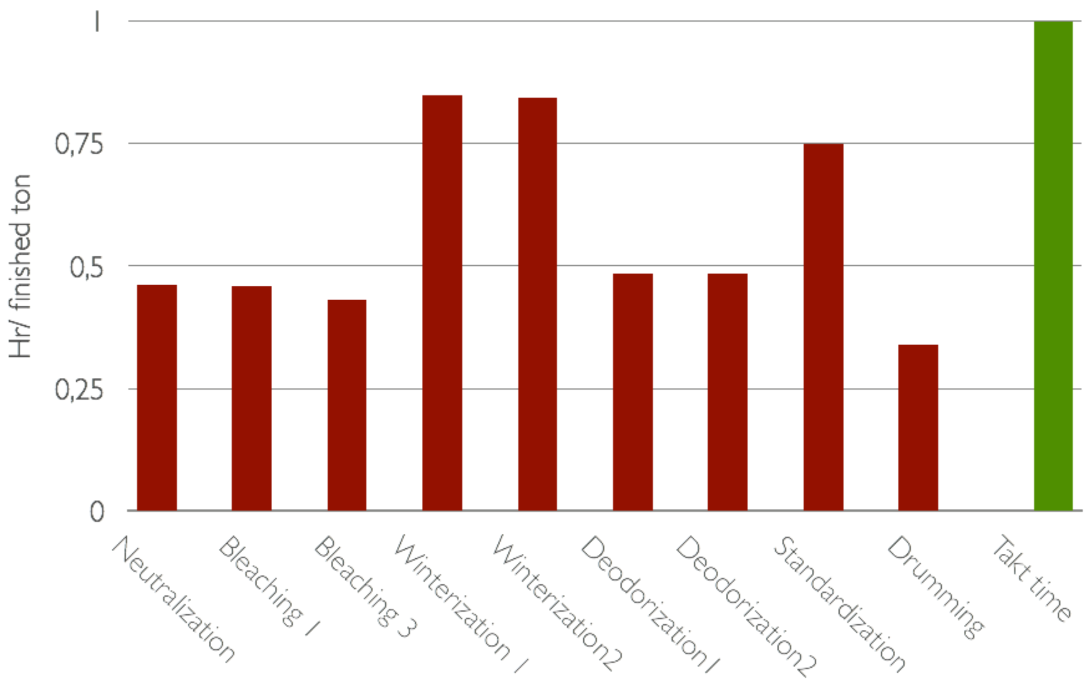

Figure 4. Weighted average of cycle times compared to the takt time.

Set-up time

The set-up times are expressed as set-up time per lot in all processes except in winterization. In winterization, the set-up time corresponds to cleaning time, which is unrelated to the lots. The other set-up times are large enough to have considerable effect on the lot sizes and will in that way affect the production planning.

Variance

The variance of the factors can indicate the process stability, and thereby if they are likely to become a problem area or not. The standard deviation was therefore calculated on all factors that were determined from averages, and that revealed bleaching and standardization having the largest variances in cycle times, and bleaching also the largest variance in loss. Furthermore, it was evident that tuna oil had large variance in loss in all processes that could perhaps be explained by the natural diversity in the raw material.

4.2 Identifying improvement areas

Three different methods were used to identify the improvement areas, a Value Stream Map, utilization analysis and interviews with employees. The results from the different methods are presented in the following chapter.

4.2.1 Value Stream Map

One VSM was created for each raw material; cod, cod liver, omega, and tuna, as well as one combined map with weighted averages. The VSM based on averages, can be found in Appendix C. The map with weighted averages has taken the volume of each product group into account and given it a weight in order to show the comparable times in each of the processes.

In accordance with theory, the maps provided a good overview of the flow and showed the processes in a way it had not been looked at before at the company. It provided a good understanding of the flow and how all the processes were connected.

The cycle times presented in the Value Stream Maps are the cycle times for each finished ton. In other words, it has taken into account the losses along the way and sees how long it takes to produce one finished ton for neutralization for example and then along each process. The most interesting findings were the large differences in cycle times between processes and product types, as well as how it relates to the overall takt time. With that being said, it was evident that the system is unbalanced.

4.2.2 Utilization

The utilization numbers from all the processes were combined in a single graph, shown in figure 5, in order to analyze it further. In order to get a sense of what activity takes the longest time, the columns were distributed into different activities; full processing, disturbances, set-up/cleaning, maintenance and cleaning, each shown in different colors. The idle time can show both starved and blocked processes, but it was not possible to distinguish between those with the data available.

It is worth noting that disturbances were only recorded for three processes. There are of course some disturbances and abnormally long processing times in the other processes, but by looking at the variances in process times it was evident that those disturbances were minimal. Also, as the variation of process and cycle times were very large in the recorded three processes indicating disturbances and it was therefore considered necessary to calculate them.

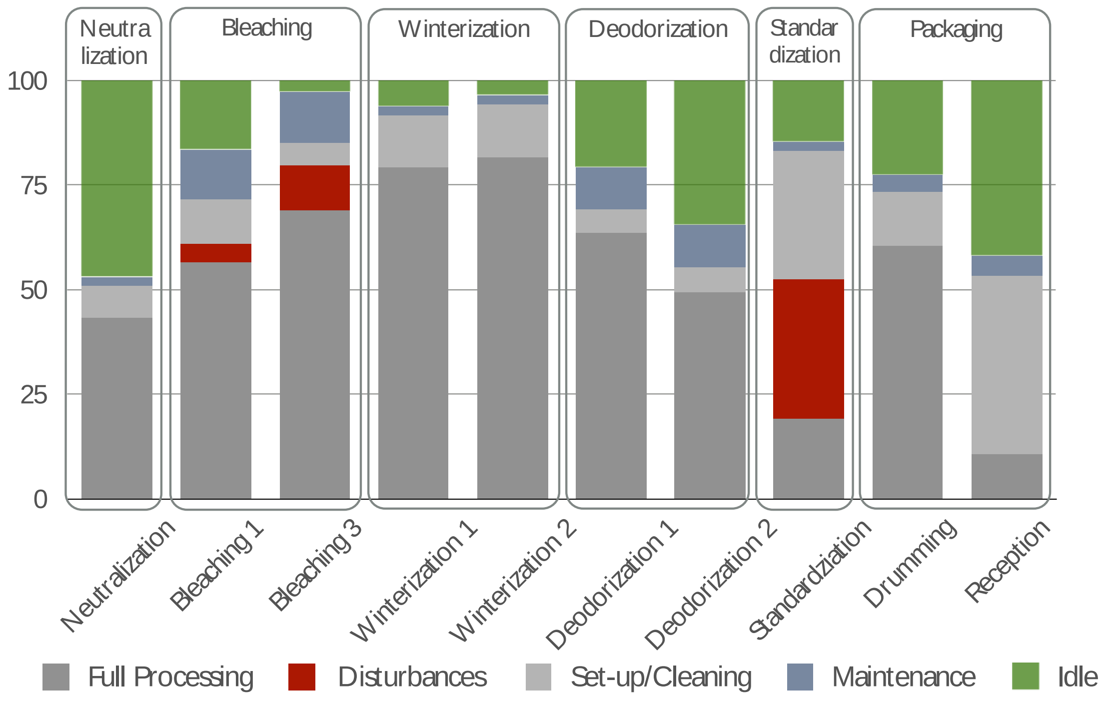

Figure 5. Time utilization.

A high utilization is a clear indicator of a bottleneck (Roser et al., 2003) and from the graph in figure 5, it is rather obvious that Winterization is the primary bottleneck, with utilization around 95%. It is much harder to identify a secondary bottleneck, or foresee what process is likely to become the problem when the primary bottleneck has been elevated. However, it is evident by looking at the graph that Neutralization, Deodorization and Reception have long waiting periods and are therefore unlikely to become secondary bottlenecks. The other processes; Bleaching, Standardization and Drumming, could all be a secondary bottlenecks and should therefore be analyzed further.

In addition, the capacity utilization was presented and analyzed for two of the processes, winterization and standardization. The results were that winterization used 88 % of its capacity, which will be hard to improve, and that standardization used 48 %, since the order sizes fit rather badly into the standardization tanks.

4.2.3 Interviews

The interviews confirmed the utilization analysis; that winterization is the main bottleneck. When it comes to the secondary bottleneck, drumming was excluded after interviewing an operator at the drumming station. The operator explained that due to the fact that the station is to a large extend manual, the work is not performed at a hundred percent performance rate when it is not needed. In other words, if a higher productivity is needed from the drumming station, they can increase the performance rate to meet that demand.

Conversely, bleaching was mentioned as a troublemaker in the production, due to frequent breakdowns. The operators had previously focused on bleaching 1 and managed to decrease those problems dramatically, but in bleaching 3 no systematic improvement efforts have been carried out at this point.

Interestingly, none of the operators mentioned standardization as a big problem. However, the lab personnel as well as the managers did, mainly regarding the lack of effective communication between the production department and the laboratory. The general thought in the factory seems to be that standardization is not really considered a full process step but rather a buffer or simply a part of the drumming procedure, which could be a reason for the lack of comments. Nevertheless, it was evident in the interviews that standardization is a complex process that no one has a thorough overview over, which can cause problems if the production is increased significantly.

4.2.4 Prioritizing improvement

The three areas that were identified for improvements were winterization, bleaching, and standardization. The winterization was determined as the first priority since it is the current bottleneck, and bleaching as well as standardization were estimated to have equal importance, since it is hard to estimate which of those processes will first become the secondary bottleneck.

4.3 Improvement potentials

When the improvement potentials for each area were found, it was important to keep in mind that only improving one area will result in limited improvement for the overall system. With that being said, it is crucial to look at the production flow and connections of the different processes.

4.3.1 Winterization

When the information gained from the VSM, utilization graph and the interviews is summarized, it is clear that the only way to considerably increase the productivity of the system is to increase the capacity of winterization. It is not realistic to increase the utilization since it is already around 95 %. Furthermore, the capacity utilization is about 88 % and cannot be increased significantly either.

4.3.2 Bleaching

The biggest issue in bleaching seems to be the long processing which is still present in bleaching 3 and somewhat in bleaching 1. Long processing is the category where processing takes longer time than it should. It can be due to non-careful enough monitoring by the operators as well as too little standard procedures in case of breakdowns, according to interviews. However, this long processing has been largely reduced in bleaching 1 in the last six months, which is the reason the students assume that the same thing can be done in bleaching 3.

4.3.3 Standardization

The time utilization revealed that a big part of the standardization has abnormally long processing times. There seem to be four different reasons for this; waiting on results from the lab, waiting on approval from a costumer, waiting for drumming because of uneven load or waiting on production orders.

The capacity utilization was only 48% on average; mainly because the customer orders did not fit well into the standardization tanks and the lack of an overview makes it hard to combine orders in standardization in order to use the tank space better.

In addition, the interviews showed that the standardization process is a complex and rather unstandardized process, involving various departments and employees. There is currently no overview available of the process or the status of the different standardization tanks in addition to the communication between the employees involved being limited and hectic.

In summary, there are four main improvement potentials: better planning, improved communication, better fit between order and tank sizes as well as faster processing.

5 FORMULATING ALTERNATIVE SOLUTIONS

In the following chapter the different feasible solutions are introduced and discussed. When the solutions were formulated there were many ideas for winterization and standardization, but only one for bleaching. The reasons are described further in chapter *5.1 Feasible solutions.*

In order to evaluate and fully develop the solutions for winterization and standardization, the processes were analyzed further, with help of the process maps and with additional interviews. In order to choose and compare the different solutions, the students interviewed the production management team and the operators and summarized the solutions in evaluation matrices, described further in *5.2 Validating and evaluating improvement suggestions.*

5.1 Feasible solutions

By interviewing the operators and the management team in addition to looking at the productivity improvement potentials, the students evaluated whether a solution was feasible or not. The feasible solutions were the ones confirmed possible by at least one worker and which had a better productivity gain per dollar spent than the initial solution of a half a winterization. That initial solution was provided by Lysi and consists of one cooling tank and one press. In the analysis of the solutions the students also took into consideration how much of an organizational change or implementation effort would be needed.

The feasible solutions were further developed, as seen in tables 3-5. The main elements of each solution are listed as well as cost, possible productivity gain and a short description. In the right column a reference is given to Appendix D where further information about the solution can be found, including methods of calculation and a more thorough description.

Table 3. Alternative improvement solutions for winterization

Winterization	Appendix
<u>Invest in ½ new winterization</u> **Cost:** ~120 mISK **Productivity gain:** Maximum 25% **Description:** Adding ½ winterization to winterization 2, identical to the existing one, increasing the capacity of winterization by 25 %	**D1**
<u>Invest in two extra filtration tanks</u> **Cost:** ~12 mISK each, total 24 mISK **Productivity gain:** Maximum 9% **Description:** Adding an extra tank to each process, between the cooling tank and the press in order to move the filtration from the cooling tank, which will reduce the processing time.	**D2**
<u>Invest in new cooling tank</u> **Cost:** ~35 mISK for one tank **Productivity gain:** Maximum 21%, Minimum 10% **Description:** Adding a single cooling tank to winterization 2 in order to increase the cooling capacity for the types of oils that could be processed in bigger batches in the squeezes.	**D3**

Table 4. Improvement solution for bleaching.

Bleaching	Appendix
<u>Eliminate long processing</u> **Cost:** Very low **Productivity gain:** Maximum 15 - 20% **Description:** Reduce long processing times in bleaching by careful monitoring and more standardized tasks.	**D4**

Table 5. Alternative improvement solutions for standardization.

Standardization	Appendix
<u>Enlarge standardization tanks</u> **Cost:** ~5-10 mISK each tank **Productivity gain:** Maximum 7% **Description:** By enlarging the 27 ton tanks to 32 tons, 7 % of the orders would be able to fit into one tank instead of two.	**D5**
<u>Reorganize buffer tanks</u> **Cost**: Very low **Productivity gain:** N/A **Description:** Re-organizing buffer tanks in order to assign more tanks to standardization, which will make it possible to standardize more orders at the same time.	**D6**
<u>Samples taken by operators</u> **Cost:** Internal cost in form of training **Productivity gain:** N/A **Description:** Letting the operators on all shifts take samples and turn them in to the lab before the day shift will result in production and the lab being more synchronized.	**D7**
<u>Invest in a faster vitamin measurement equipment</u> **Cost:** Low **Productivity gain:** N/A **Description:** By modifying the vitamin measurement equipment, the run time of each sample would be shorten by approximately 67 % which will make it possible to run two vitamin measurements per day.	**D8**
<u>Invest in planning and visualization tool(s)</u> **Cost:** ~5 mISK **Productivity gain:** N/A **Description:** Investing in a software for planning and visualization purposes will provide an overview of the standardization process and will make it possible to have a more balanced production due to more efficient planning.	**D9**

5.2 Validating and evaluating improvement suggestions

In the following section the different evaluation matrixes are described. Each matrix consists of the different solutions, their weight as well as the factors taken into consideration in the evaluation. The factors used were investment cost, productivity gain, as well as implementation effort and time. The largest weight is on the productivity gain and investment cost and the lowest on the implementation time and effort, everything in accordance with the purpose and goal of the project which was decided upon in cooperation with the management team at Lysi. That being said, the following factors set the base for the grading system:

Requirement factors in the evaluation matrixes:
- **Productivity gain.** Approximated increase in productivity of the specific process.
- **Investment cost.** Total cost of the equipment needed.
- **Internal cost.** Estimation of the internal cost of the solution.
- **Implementation effort.** Total effort required by the organization in the implementation.
- **Implementation time.** How much time that is needed, from the decision and until the solution is fully implemented.

The solutions were then given grades in each category on a scale of 1-5 where 5 is given to the best solution and 1 to the one with the least potential. The rest is graded in relation to the extreme conditions (boundaries) and based on the descriptions of the solutions, shown in Appendix D.

5.2.1 Evaluation matrix for winterization improvement

The evaluation matrix for winterization is presented in table 6. The last solution, adding a new cooling tank, receives the highest grade and will therefore be used in the improvement plan. It should also be noted, that although solution 1 has the biggest potential for increased production, that potential could not be reached in the near future, since other processes would have to be improved simultaneously. Also, the two later solutions have not been fully validated, due to lack of knowledge and resources of the students. However, the validation will be done at, and by, the company prior to implementation. The information in the parenthesis shows where in the appendix further information can be found.

Table 6. Evaluation matrix for winterization.

Evaluation factor	**Weight**	**1/2 new winterization (D1)**	**Extra filtration tanks (D2)**	**Extra cooling tank (D3)**
Productivity gain	45	5	1	3
Investment cost	30	1	5	3
Implementation effort	15	1	3	5
Implementation time	10	1	5	3
Total	**100**	**280**	**290**	**330**

5.2.2 Evaluation of bleaching

Since there was only one solution identified as feasible in the project, an evaluation matrix was not needed.

5.2.3 Evaluation matrix for standardization improvements

The evaluation matrix for standardization is presented in table 7. The numbering of the solutions refers to the appendix number they can be found in. The top three solutions were then analyzed further and the idea came up, to combine them all together to provide an even stronger solution. Since the solution is a combination of the three best solutions it was the recommendation the students suggested to the company to put the main focus on.

Table 7. Evaluation matrix for standardization improvements.

Evaluation factor	**Weight**	**D5**	**D6**	**D7**	**D8**	**D9**
Productivity	45	3	2	1	4	5
Investment cost	30	1	4	5	3	2
Implementation effort	15	2	3	4	5	1
Implementation time	10	4	2	5	3	1
Total	**100**	**235**	**275**	**305**	**375**	**310**

6 IMPROVEMENT PLAN

In the following section the improvement plans are described, including pure capacity changes as well as organizational ones. The improvement plan consists of the improvement of three processes – winterization, bleaching and standardization and is based on *Chapter 5: Formulating Alternative Solutions*. The main focus is on winterization since it is very important to start at the primary bottleneck, as described in the theory. However, it is crucial to understand that the other improvements will take long time and should therefore be implemented simultaneously in order to be in place when they are needed. By doing so, the system will be able to reach its full improvement potential in the least required time. In table 8, a summary of the improvements is provided.

Table 8. Summary of improvements.

Winterization	Bleaching	Standardization
– Invest in a new cooling tank	– Eliminate long processing	– Organizational changes – Planning/Visualization tool

6.1 Winterization

Table 9. Summary of improvements for winterization.

Improvement	Implementation	Appendix
Invest in a new cooling tank	– Purchase tank – Install the tank	D3

The company should start by investing in a new cooling tank. The tank will use the space available in the factory that originally was intended for the third winterization process. The first task that needs to be performed is to find out if the new process works for all types of oil or only specific ones since they have different properties. The company is confident that this will not be an improvement for TUN and COD but will most likely be very efficient for CLO, and hopefully OME as well. If it only works for CLO, the improvement will be much smaller, but still evident and probably enough to elevate the bottleneck. In order to gain the full potential, some changes need to be made to the system – the computer system needs to be updated as well as the work standards in addition to a new planning approach. To gain the full potential of the investment the students suggest that the new lot size is a multiply of 15 tons, preferably 75 tons, since it would fit both into the new winterization process as well as the buffer tanks.

6.2 Bleaching

Table 10. Summary of improvement for bleaching.

Improvement	Implementation	Appendix
Eliminate long processing	– Inform operators	D4

The bleaching system needs more attention since, as soon as the improvement of the winterization has started, the bleaching will be a potential bottleneck. The focus needs to be put on eliminating the long processing times. It will be important to realize what is causing the longer processing times and small disturbances and find a way to minimize them, by careful monitoring and use of standard procedures. The first step will be to inform the operators, so that they are aware of the problem. This improvement work should be fairly easy, since a similar improvement has already been started in bleaching 1. When the improvement work has started, it will be important to follow it up in a systematic manner, similar to what was done in bleaching 1, in order to see if the improvements are giving the expected results.

6.3 Standardization

Table 11. Summary of improvements for standardization.

Improvement	Implementation	Appendix
New standardized work process	– Inform everyone about the change – Create new and updated forms – Create new standards	E
Samples taken by operators	– Inform and train the operators	D7
Invest in a faster vitamin measurement equipment	– Calibrate vitamin measure equipment	D8
Invest in a planning and visualization tool	– Invest in a planning software – Install – Train workers	D9

Standardization has to be improved, in synchronization with the other improvements. This is the most complex improvement since it consists of a number of changes, including multiple departments and employees. Also, it is complex since the different parts of the process take part in different physical locations. The change has two main parts that are though interrelated; an organizational part and a changed planning strategy part.

As described in chapter *2.3.1 Standardization*, standardization is a strong improvement tool. Therefore, the organizational changes will include a complete reorganization and standardization of the process where all processing times, responsibilities and lines of communications are well defined, as seen in appendix E. In order for this change to go smoothly, it is important to include all the employees from the start and take into account different opinions and prioritizations. As a part of the suggested change, the operators should take the samples, so that they can be at the lab before 8 o'clock in the morning. Furthermore, the lab needs to implement a faster vitamin analysis tool, which requires calibration and validation. This means an extensive cooperation between the lab and production department, which really needs to be handled with care. It could be beneficiary if an agreement can be made to categorize this part of the lab work as a part of the standardization process, in other words, as a part of a production process.

The other part of the change is in the planning, based on the chapter *2.3.4 Planning optimization*. At the moment the planning is not written down and is on a day-to day basis. This makes it very hard to optimize the planning, in order to combine orders in the tanks and to level out the load on drumming and the lab. The suggested solution is a planning-software that shows at what step in the process each standardization tank is at the moment and, as described in chapter *2.3.3 Visualization,* visualizes the plan for that tank in the near future, an example of what such software can be found in appendix F. It could be a very useful tool in order to increase both the capacity- and time utilization. Also, the program could provide the lab personnel and operators in production and drumming with an overview of upcoming tasks, to be able to organize their internal work more efficiently. That would improve the communication, which is an important part according to chapter *2.3.2 Communication,* since everyone would have access to the same information from their location. Implementing such a program will take time, since it is highly customized and it will therefore take some time to get the desired design and layout. When the software is ready, it will take time for the employees to learn how to use it in a correct manner.

Since the standardization process is of high importance when it comes to the quality control of the products, all the improvements have to be run by the quality department. Special care needs to be taken that all the changes are in line with the quality standards and certificates the company uses in the production. These standards are also changing and those need to be synchronized, so that the standardization process can run smoothly in accordance to all quality standards.

All these improvements will take a long time to implement and will improve gradually over time, which is why it is important to start right away and include all the employees from the very beginning.

6.4 Further improvements

Depending on how the implementation goes, Lysi hf might need to explore further improvement options. Not only can these be looked at in the case of failed implementations, or with lower results than expected, but also if further improvements are needed in the case of further increase in demand. With that being said, the most important part is that Lysi performs a new bottleneck analysis in order to see where the focus should be put next.

If there is a need to improve the productivity of winterization further, the first thought should be to invest in, and install, two new filtration tanks in winterization. However, this requires some testing first in order to make sure the solution works as intended. The testing can be done in a pilot plant at the equipment supplier and once the results are received, a plan can be created. If the tanks are purchased an update of the software will be needed and the planning and organization will need to be rethought once again. The planning tool can also be extended to the whole production, with a pull oriented planning, which can lead to improved utilization, more leveled production and less buffers.

The mentioned improvements are all depended on how the rest of the recommended improvements go. In addition to that, there are further improvements that could be done in the sense of decreased lead time and sustainability. With that being said, there are always improvements that could be done in productivity and lead time, meaning how processes can work better together, how the cooperation between the steps can work in the best possible way etc. Also, sustainability is a subject that is a highly discussed topic in today's society (Berlin et. Al. 2013) and something that should be looked at from an improvement potential's point of view. That being said, how sustainable is the system? Will it last for an unlimited amount of time or is it about to get worn out? The last comment is something that could be improved if trying to look at leveled production as well as standardization.

7 DISCUSSION

The project provides a solution to the presented problem of increasing the productivity at Lysi hf. A primary bottleneck was detected along with probable secondary bottlenecks and suggestions were provided on how to elevate the bottlenecks in order to increase the overall productivity of the plant. In general, both the students and the company consider the project a success but the project had good support at the company, making it easy to access data and all workers were very cooperative.

The initial analysis of the production system was performed with a holistic perspective where all processes were included, but that was new for the company. Simply summarizing all the main factors of the system in one place, for example in a Value Stream Map, can substantially enhance the understanding of the system. When the system is viewed in this holistic way, it is fairly easy to spot the weakest links and problem areas and then analyze those further. It is also important not to get carried away in finding solutions before the real problem has been properly identified. That will save time and reduce the risk of overlooking the most pressing problems.

It is always a concern whether the data used for the project is sufficient and accurate enough. This project is no exception, but this extensive analysis of the whole production system requires large amounts of various data. That is why there was limited sampling and more use of whole collections. The chosen data period was the largest period available for the current system, but the system had recently been modified and including data from before the modification would severely skew the results. Some preventive measures were also performed to verify that the data was correct by interviewing operators and the management team that were familiar with those numbers. The uncertainty is not only in the data itself, if there are any systematic errors or wrong documentation, but also the interpretation of the available data. That is why a considerably long time was dedicated to learning about the systems in order to truly understand what the time logs recorded in the database stood for. The database was though user-friendly and the extraction of the data was fairly easy.

As with every project, there is always some data missing which is why some assumptions have to be made and some numbers estimated. The biggest data gap was in winterization two, but that system is newly installed and had not been properly connected to the database, resulting in very limited data. Since it is a duplicate of winterization one, the assumption was made that factors such as processing times were the same for both processes.

There were three main methods used in the bottleneck analysis: Value Stream Mapping (VSM), utilization analysis and interviews. Since the results from the three methods were consistent, the students are confident that the right conclusion was made. The methods are all useful for the purpose of bottleneck detection, but do however have their pros and cons. The VSM does not offer that extensive numerical analysis for bottleneck detection, but does give a holistic picture of the system, is easily understood and is a great communication aid when talking about the system. The utilization analysis on the other hand is purely analytical, but the operators did not for example relate as well to it as the VSM, possibly because they are not used to this view of the production. The interviews were a great help and are very important to shed a new light on the numerical results. It is however not as easy as it sounds to obtain all the necessary information in an interview. It was evident that people quickly become defensive of their work and decisions and it is almost impossible to get unbiased information from an interview.

Another important conclusion, from a theoretical point of view, is how various methods, such as the value stream map and utilization analysis, fit for this type of industry, as opposed to the traditional assembly production. Most of the methods were useful, although the full potential of the VSM was not reached, since the buffer sizes in a given moment, did not provide much useful information for the analysis. As could be expected, the theory is much simplified, and it was therefore necessary to combine different methods to obtain valid results. The students had hoped that the VSM could provide better analysis than it did, but it was evident that the VSM is better suited for assembly production, or similar, rather than this sort of processing industry.

There were some simplifications made in the final stages of the project, to evaluate the improvement suggestions. For example, it assumed that the balancing losses would not increase significantly with increased productivity, since the students had no means of testing that. Furthermore, some of the solutions have not been fully validated, the ones that have to be tested in a real system or a pilot plant, since the students do not have the resources necessary for such testing. Therefore, the testing is left to the company. When evaluating the solutions some costs of implementations, such as cost of partly shutting down the plant, were not taken into consideration purely for simplification reasons.

The initial suggestion from the company was to buy a half winterization to increase the productivity. It was therefore interesting to see that combining two other solutions that came up in the project, increasing the capacity of the system by more than by investing in a half line, with only about half of the cost. This way the implementation can also be taken step-by-step, distributing the investment over a longer period of time. This alternative solution is though yet to be fully validated, but the students do not have the knowledge of chemistry needed to fully evaluate the likelihood of the success of different solutions. The solution that was chosen did though appeal, since it is rather simple in implementation, and the fact that a press could be added on later if needed, filling up to the full solution of a half a winterization.

Another interesting finding is the importance of organizational changes. It is evident that the “hard” solution, that is, investing and improving machinery is much easier to justify than organizational change. The organizational changes are softer matters and it can be very hard to evaluate the exact productivity gain from such an improvement. The students are confident that creating a platform for communication between departments and shifts could be greatly beneficial and hope that the management team realizes the importance of a strong organization. In addition, it is important to understand that it is always hard to quantify a change not involving any numbers or capacity changes. That is why the students tried to focus more on showing the importance of standardizing tasks when performing such changes instead of relying solely on putting a specific number on the improvements.

There are though some complications to the improvement of the standardization process, mainly in relation to the quality standards. The standardization is of high priority when it comes to quality control of the product, so the improvement has to be fully validated by the quality department before the process can be changed. There are furthermore some changes foreseen in the quality standards used by Lysi, which will mean changed requirements on the process that could affect the improvement potentials. Even so, the students are confident that standardizing the process in a simpler and clearer way, clarifying responsibilities and timeframes, and improving the communication by the help of visualization tools, will always be beneficial. It is also in line with the theory, that the standardization of a process is not something that is set in stone, but on the contrary, a base to for improvements and prepares the ground for future changes.

In summary, the students managed to shed some light on the need for improved overview of the production, to improve various processes at once. If focused only on one step in the production at each time, it is a risk to oversee other improvements that might be more pressing. The thesis did provides a good overview of the production system at Lysi hf., its weakest links and how to strengthen those links. It will be important to keep the holistic view of the system and not to underestimate the potential of organizational improvements.

8 CONCLUSION

In conclusion, the thesis answered the problem definition and provided Lysi with a solution for allowing them to increase their productivity, for as little investment as possible, and in accordance with the demand.

The main finding was that winterization is the primary bottleneck and needs immediate capacity improvement. In addition, bleaching and standardization were addressed as secondary bottlenecks. The improvement suggestions included organizational changes, standardization and communication improvements.

Furthermore, from a theoretical point of view, the importance of a holistic view of a production system was explored. The project shows how one cannot focus on an isolated task when improving the flow of a production system, but that the improvements need to be planed in synchronization with one and other.

The company will need to modify some of the solutions suggested in the report, so that it will fit perfectly into their organization, but by carrying out the chosen improvement suggestions, the company could increase the productivity by up to 20%, with an investment cost of approximately 40 Million ISK. The full implementation plan will take time, but should in the end provide a successful improvement and higher productivity.

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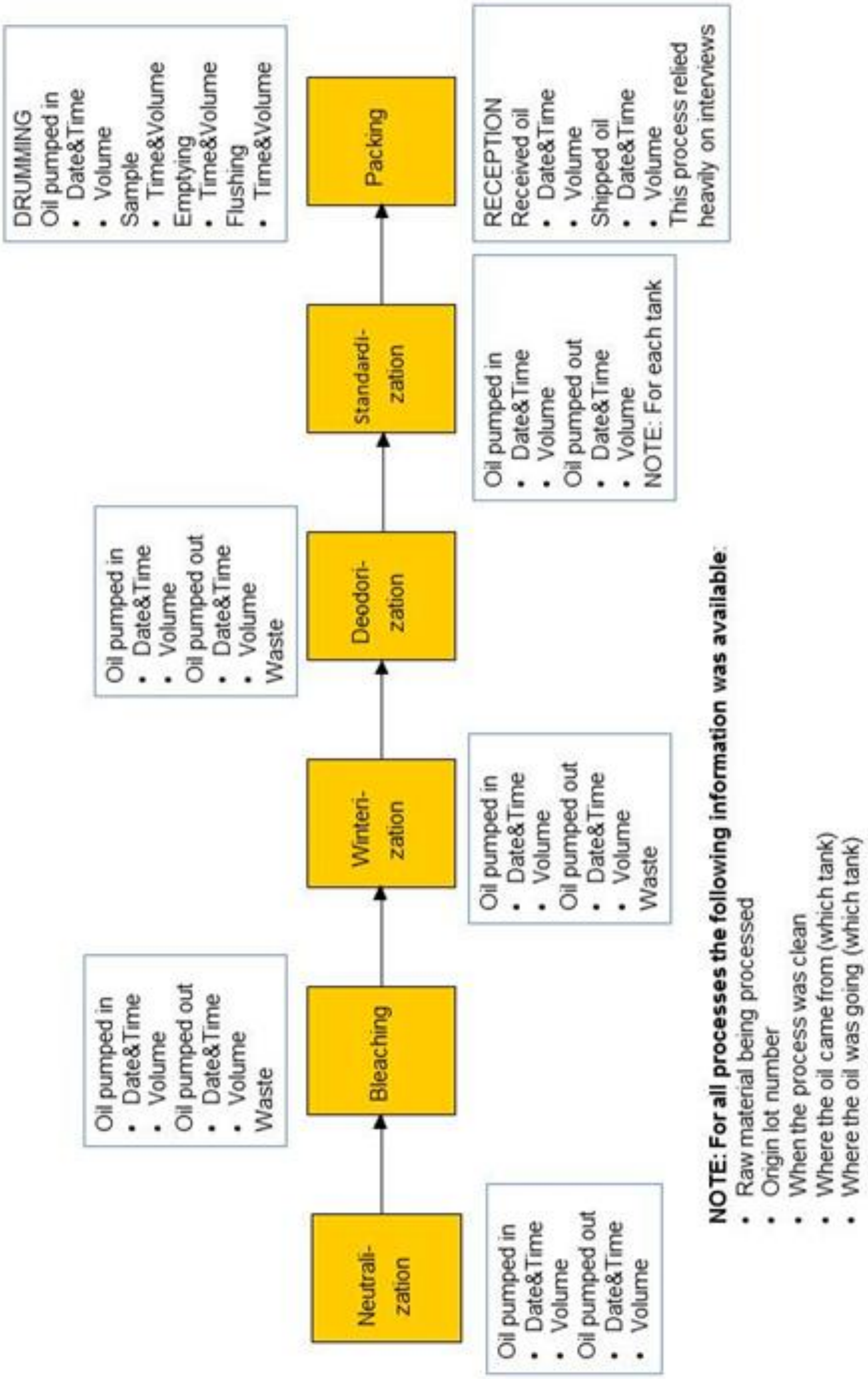
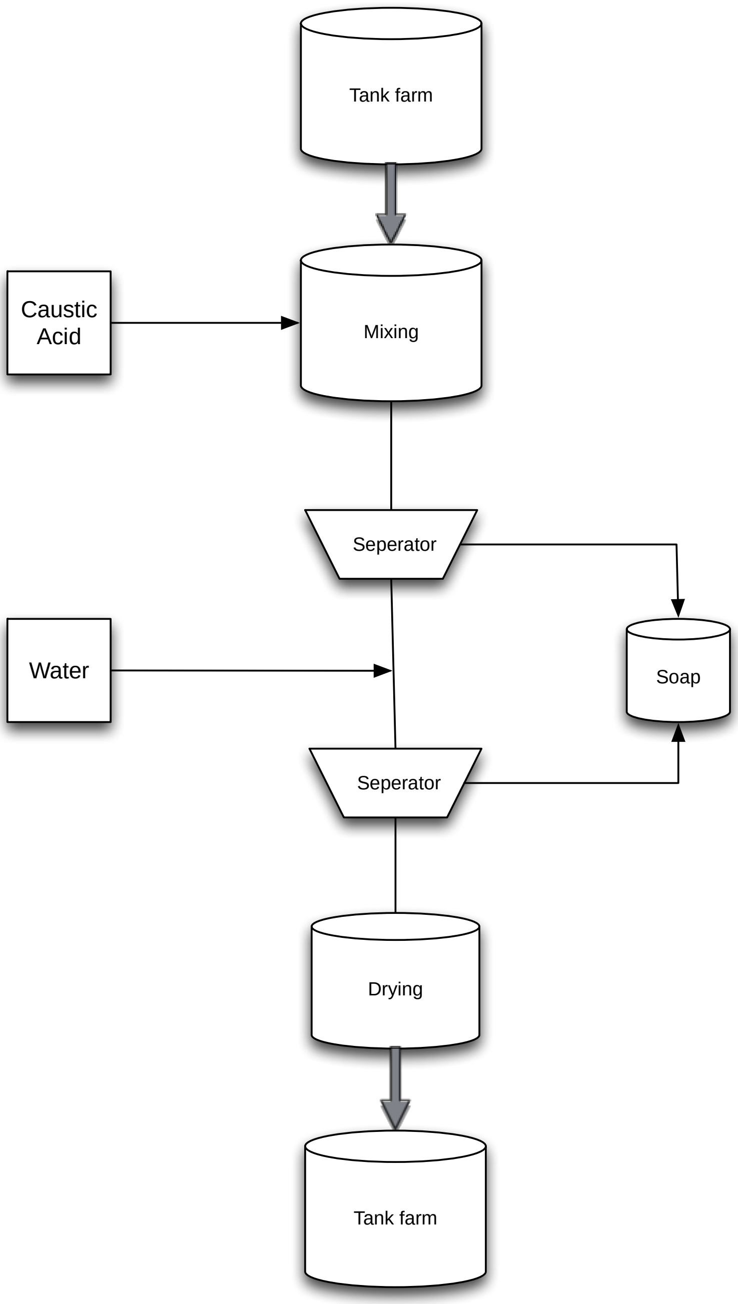
APPENDIX A

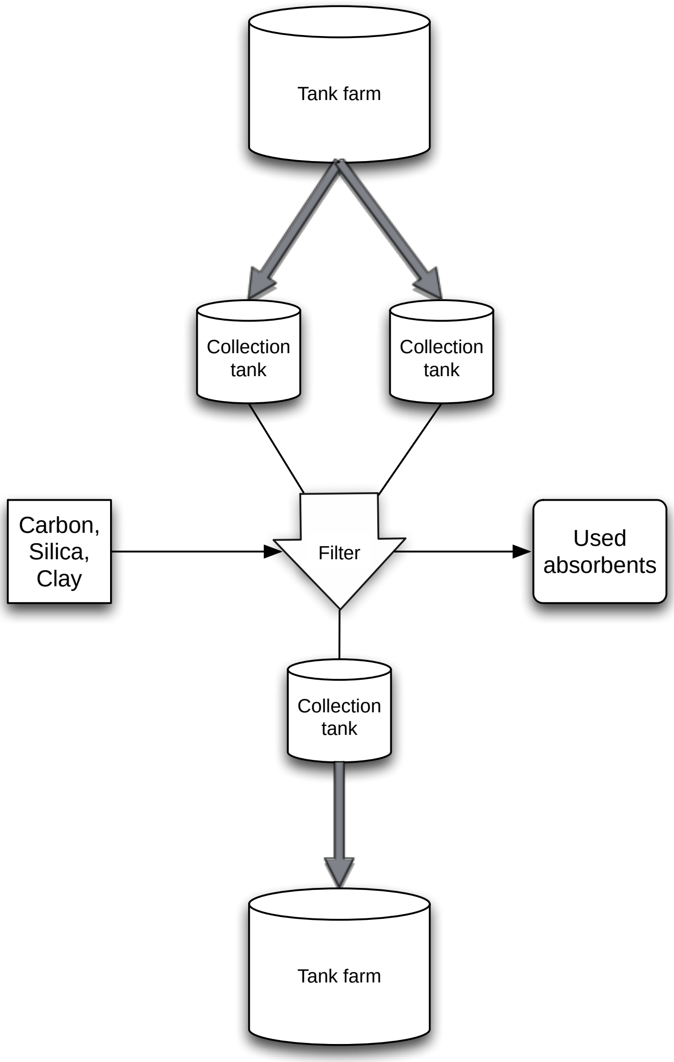

Neutrali-zation
Oil pumped in
• Date&Time
• Volume
Oil pumped out
• Date&Time
• Volume
Bleaching
Oil pumped in
• Date&Time
• Volume
Oil pumped out
• Date&Time
• Volume
Waste
Winteri-zation
Oil pumped in
• Date&Time
• Volume
Oil pumped out
• Date&Time
• Volume
Waste
Deodori-zation
Oil pumped in
• Date&Time
• Volume
Oil pumped out
• Date&Time
• Volume
Waste
Standardi-zation
Oil pumped in
• Date&Time
• Volume
Oil pumped out
• Date&Time
• Volume
NOTE: For each tank
Packing
DRUMMING
Oil pumped in
• Date&Time
• Volume
Sample
• Time&Volume
Emptying
• Time&Volume
Flushing
• Time&Volume
RECEPTION
Received oil
• Date&Time
• Volume
Shipped oil
• Date&Time
• Volume
This process relied heavily on interviews
NOTE: For all processes the following information was available:
• Raw material being processed
• Origin lot number
• When the process was clean
• Where the oil came from (which tank)
• Where the oil was going (which tank)

APPENDIX B

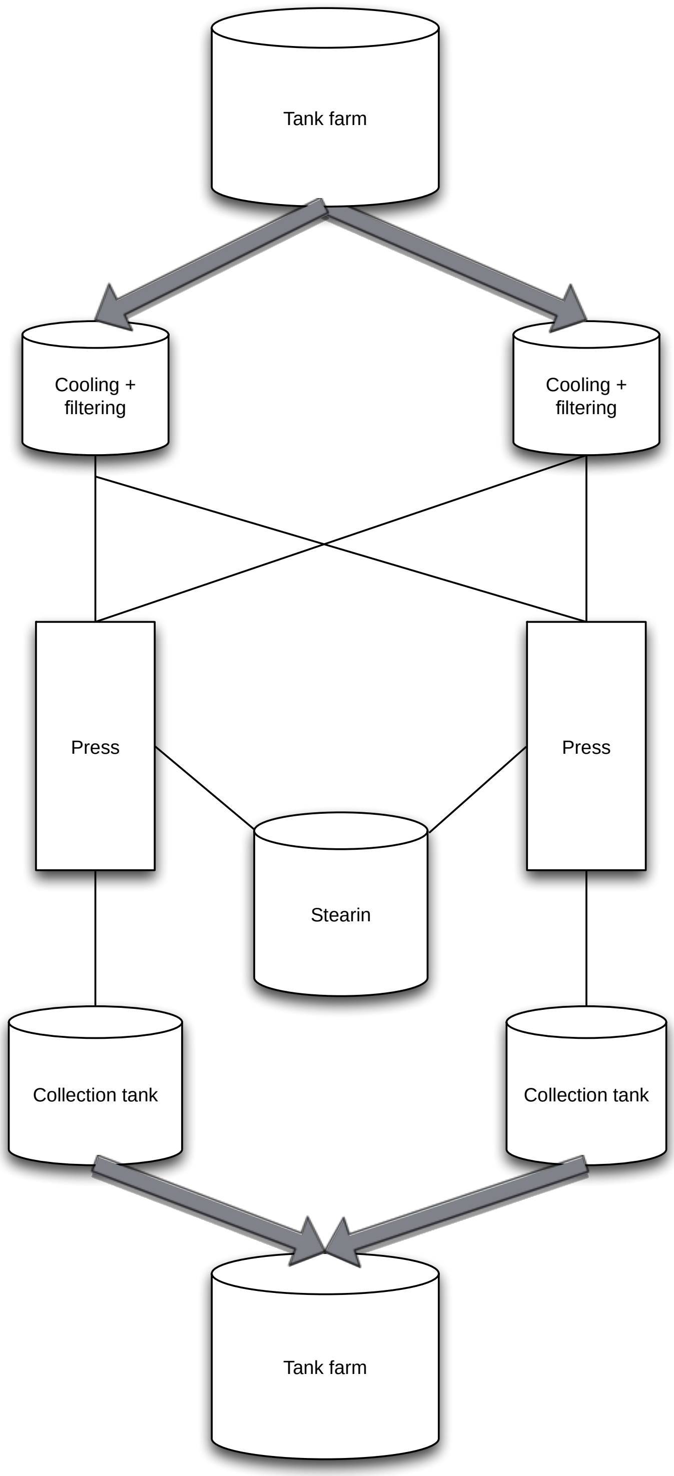
Appendix B 1 Neutralization



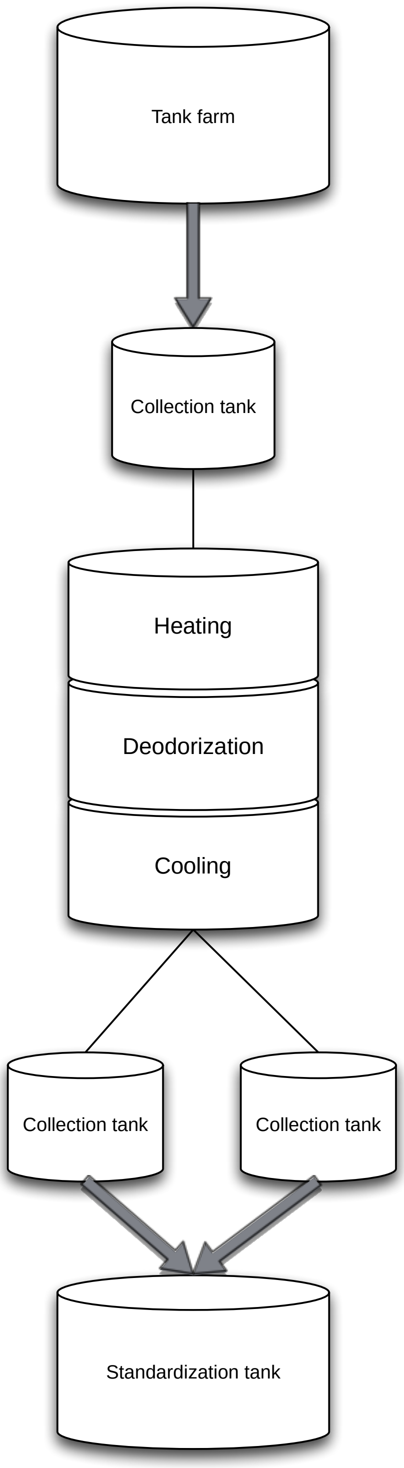
Appendix B 2 Bleaching



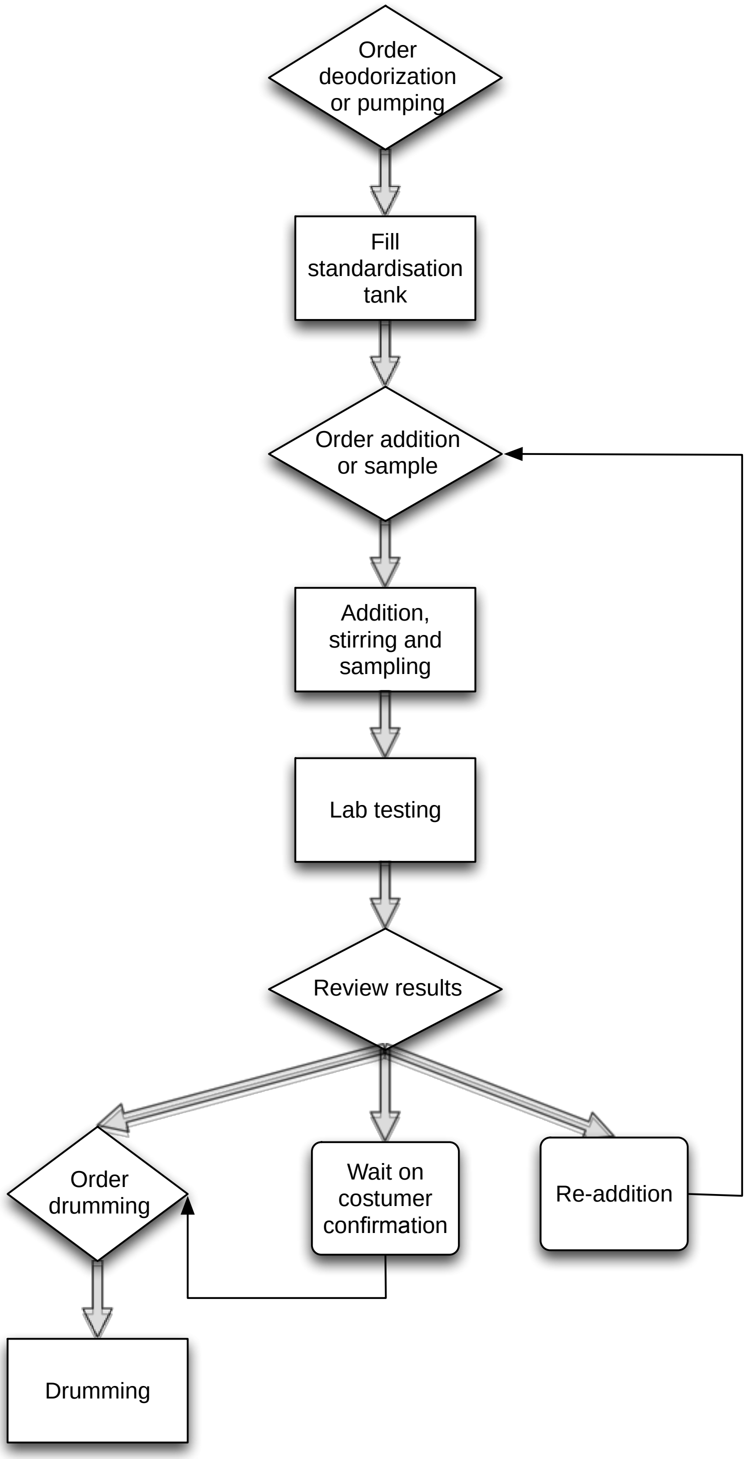
Appendix B 3 Winterization



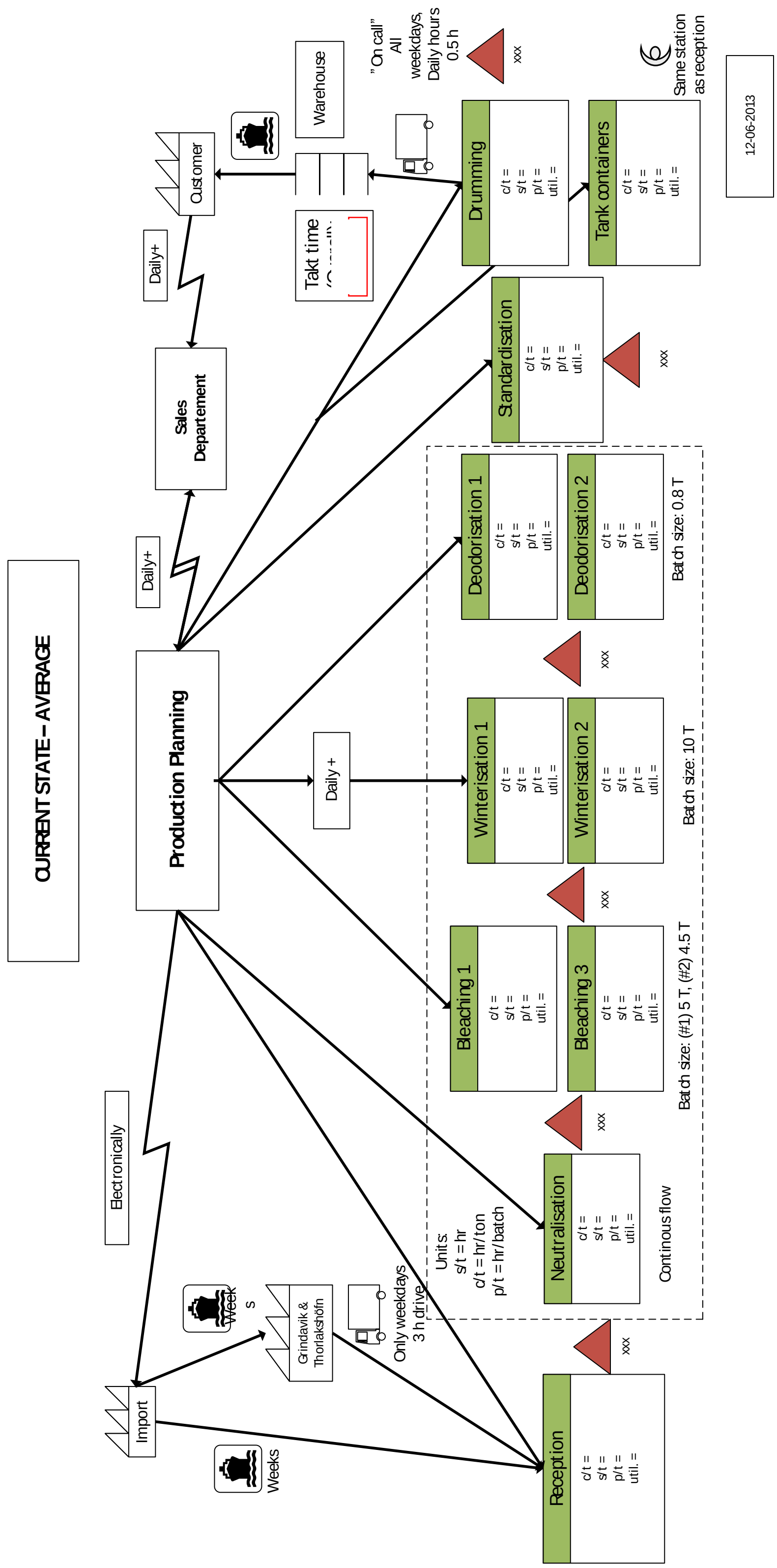
Appendix B 4 Deodorization



Appendix B 5 Standardization



APPENDIX C Value Stream Map



APPENDIX D

Appendix D 1

<u>Invest in ½ new winterization</u>

Possible productivity gain: 25 %

Cost: 120 mISK

Description: Adding ½ winterization line (cooling tank, filter, press, and stearin tank) to winterization 2 in order to increase capacity. Overall, it would be OME that would be processed in the unit.

Calculations: Assuming that batch sizes would be adapted to the system, the potential productivity gain would be 50 % in the process, resulting in 25 % in winterization overall. However, due to new bottlenecks coming up new improvements will be needed to reach the full improvement potential.

Advantages:

- It is a fairly known process, due to the "copy-paste" action
- OME is increasing in demand, which corresponds to the solution
- Will eliminate winterization from being the bottleneck for at least a 25 % productivity gain

Complications:

- Expensive
- Complex and time consuming if the full potential of the improvement is to be achieved

Implementation time:

High. Space and system update might be needed.

Implementation effort: High.

Comments: If very high productivity increase of the Winterization is desired (25 %) and if the investment budget is large, this is the best solution. However, the solution itself is a very expensive one and the outcome (productivity gain) compared to the input (investment) is much lower than for the rest of the solutions. Therefore, it should be thought of, as a future solution and not something the company should do now.

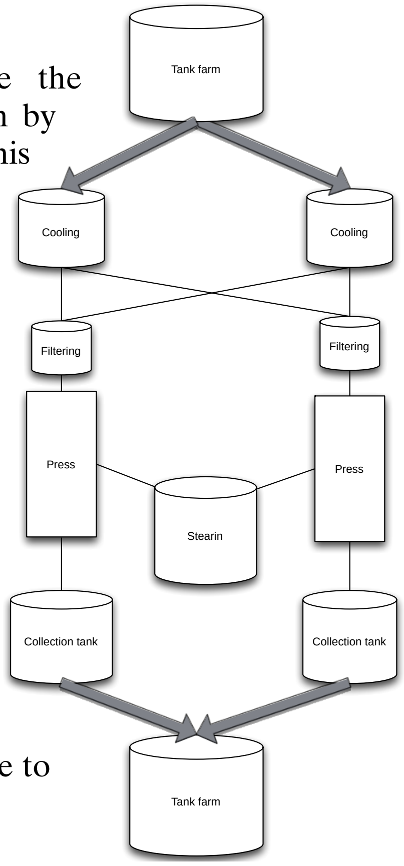
Appendix D 2

<u>Invest in two extra filtration tanks</u>

Possible productivity gain: 9 %

Cost: 12 mISK each, total 24 mISK

Description: It would be possible to eliminate the filtration time from the cycle time in winterization by adding two extra tanks after the cooling tanks. This would result in a parallel process instead of one where everything is performed in series.



Calculations: The cycle time will be reduced by about 9 %. In addition, the time for cleaning (abnormal times spent in filtration) will be reduced since the long filtration time will be counted towards the squeezing instead which means that the cooling tanks can still be working at 100 %. By using the given numbers (normalized):

Cooling tanks time = 104 min
Filtration time = 10 min
Squeezing time = 45 min
Where filtration + squeezing = 55 min

The performed calculations showed that it is possible to reduce the time for long processing times by 12 % .

By reducing the cycle times according to the numbers above, one can argue that it is possible to reduce the total processing time, resulting in a volume increase of 9 % if the same utilization is considered.

Advantages:

- Solid productivity gain compared to investment
- Similar to existing system
- Does not require any further improvements in order to reach the full potential

Complications:

- Impact on crystallization is not fully known (OME/COD should not be a problem but perhaps TUN/CLO since they are more sensitive)
- Space is needed

Risk assessment

- OME might be the only material accepting the change

Implementation time: Ordering, space and training is needed.

Implementation effort: Low. System will have to be shut down for some days but training will not be extensive.

Comments: For a quick implementation and for a very good price for each %-gain, this is a good option.

Appendix D 3

<u>Invest in a new cooling tank</u>

Gain: 10-21%, depending on the usability

Cost: 35 mISK for one tank

Description: A new cooling tank would make it possible to cool in three tanks in winterization 2, expanding the capacity by 50 % in the tanks. There is a big chance of improvement here since the cooling time is usually what determines the cycle time. It is not clear if it would work for OME, but it is confirmed that it works or CLO.

Calculations: Calculations were performed to see how often the cycle time was determined by the cooling time. Also, it is taken consideration that more production will require more cleaning. Two calculation approaches were performed;

CLO: 30 % of the products would be able to go through 50 % faster, resulting in an overall productivity gain of 10-15 %.

OME/CLO: Both OME and CLO would be able to go faster, resulting in a productivity gain of 21 %.

Advantages:

- High productivity increase
- Known process

Complications:

- Not confirmed how cleaning will be handled with the large increase

Risk assessment

- The solution will only work for CLO
- The squeezing will not be able handle the large increase

Implementation time: Medium. The thinking process for planning needs to be changed.

Implementation effort: Low. Should be able to run the whole capacity during the implementation time. Operators have to be informed about the new process.

Comments: If the implementation can reach its full potential, this solution is the most valid option.

Appendix D 4

Eliminate long processing

Possible productivity gain: 15 – 20 %

Cost: Low. Probably some for improved maintenance equipment etc.

Cost/% productivity gain: Not applicable. This is a required improvement.

Description: By combining better monitoring of the system, so any problems are spotted immediately in addition to a quick response in addressing them, and using standards procedures for it, it should be possible to eliminate the long processing times in both the bleaching processes, the same way it has been done so far in bleaching 1.

Calculations: Not applicable. Reducing the long processing times and splitting them up in the required areas: processing and waiting, gave the productivity gain.

Advantages:
- Low cost
- Done before, can use the same approach and the gained experience

Complications:
- Training might be needed

Implementation time:
- Medium. It will be spread out and improved gradually.

Implementation effort:
- High. Since it is not a pure equipment improvement, this is all about the operators and their work effort.

Comments: A hard-to-define but very important improvement option. It should be started parallel to the winterization process investment and the cost should be relatively low.

Appendix D 5

<u>Enlarge standardization tanks</u>

Gain:

7 % of the drumming orders would fit perfectly into one tank

28 % of the drumming orders are of 80 drums size (140-160)

Cost: Approximately 5-10 mISK per tank

Cost/% productivity gain: Not applicable. Hard to define since it is not certain how many of the orders would fit into the tank. The 28 % are just potential ones.

Description: By adding tank space on top of the tanks, approximately 5 T more would fit into each one of them, making it possible to reduce the amount of used standardization tanks.

Calculations: Calculations were performed in order to see what orders that potentially would take advantage of this. With that being said, the percentage of orders being of 80 drums size or 140-160 drums were found.

Advantages:
- Increased capacity of tanks
- More orders could be standardized parallel
- Known procedure

Complications:
- Relatively expensive
- Tanks will need to be shut down during the implementation
- New planning approach is required

Risk assessment:
- The potential of the actual usage is not known
- Might not be worth the extra planning effort that is required

Implementation time: Medium. Installation time will require some time.

Implementation effort: Low/medium. The planning process needs to be changed.

Comments: Simple solution for an increase in capacity. However, it requires implementation effort and investments as well as planning process rethinking.

Appendix D 6

<u>Reorganize buffer tanks</u>

Gain: The standardization procedures would be able to be more parallel and it could also be very useful for the big batches in OME.

Cost: No investment cost.

Cost/% productivity gain: Not applicable.

Description: By reorganizing some tanks it would be possible to use some of the buffer tanks (as for today) as standardization tanks instead.

Calculations: Not applicable.

Advantages:

- No investments needed
- No process procedure changes
- Increased capacity for standardization

Complications:

- Some planning changes are needed
- Reduced buffer sizes/levels are needed

Risk assessment:

- Not being able to reduce buffer levels, reducing in reduced productivity earlier in the production
- Complications with breakdowns with the reduced buffer sizes

Implementation time: Low. Can be done right away, after some preparation time. Planning will however require some time and effort.

Implementation effort: Low/Medium. The planning needs to change.

Comments: The solution has low cost and will increase capacity in standardization with the existing equipment. However, it will require some efforts to reduce the buffer sizes which mean the problem will just be moved.

Appendix D 7

<u>Samples taken by operators</u>

Gain: Better synchronization with the lab.

Cost: Training cost and possibly new forms.

Cost/% productivity gain: Not applicable.

Description: Operators could be trained to take samples during their shifts, giving the lab the opportunity to have the sample at 8 am in the morning and results ready in the afternoon. Also, it could be possible for the lab to do two sample runs/day.

Calculations: Not applicable.

Advantages:
- Faster throughput time for samples
- Better organization between processes
- Low cost

Complications:
- Training needed
- Reorganization/rescheduling of the lab procedures is needed
- More responsibilities for operators

Risk assessment:
- Operators having resistance to change and to gain more responsibility
- The lab having resistance to change due to the risk of more work

Implementation time: Medium. Preparation time for training and information meetings as well as reorganization will be needed.

Implementation effort: Medium/high. The implementation will be all about the operators/workers and their procedures. Therefore, it is important and required to get everyone on board and agree on the changes, in order to make it a possible and sustainable solution.

Comments: Would speed up the standardization procedure, to a low cost. However, the solution requires a good effort from the workers and operators in the sense of informing, training and getting everyone involved, which will require some time.

Appendix D 8

<u>Invest in a faster vitamin measurement equipment</u>

Gain: Would be possible to do two sample-runs a day, speeding up the standardization process.

Cost: Low.

Cost/% productivity gain: Not applicable.

Description: By investing in faster vitamin measurement equipment, it would be possible to reduce the time for analysis from 40 min/sample to 15 min/sample. This would help the productivity majorly if done in parallel with two sample runs/day.

Calculations: Not applicable.

Advantages:
- Faster throughput time for samples
- Low cost
- Less waiting time, more efficient
- Simple procedure

Complications:
- Acceptance from quality department
- Calibration of the machine is required

Risk assessment:
- Not approved by quality department
- Resistance from workers due to risk of having to do more work

Implementation time: Low. Only time needed is the calibration time.

Implementation effort: Low. The procedure will not change.

Comments: As long as the quality department says yes, this improvement should definitely be implemented. In order to give room for improvements in other areas it should be implemented as soon as possible.

Appendix D 9

<u>Invest in planning and visualization tool(s)</u>

Gain: Better planning would result in more leveled production and gained productivity. Also, a visualization tool would make it possible for standardization to plan better in addition to providing everyone with an overview.

Cost: Approximately 5 mISK for software

Cost/% productivity gain: Not applicable.

Description: A planning tool would make it possible to make planning more simple, and smarter – resulting in a more leveled production, the opportunity to add lots together etc. This would mean a more efficient production where the capacity could be used smarter, resulting in an increased productivity. By providing all the employees with an overview of what is going on, the preparation and planning of processes will be improved. Also, communication between the departments and processes will be increased.

Calculations: Not applicable.

Advantages:

- More leveled production
- Simpler planning
- Improved information flows, resulting in better preparation
- Capacity utilization will be maximized

Complications:

- Implementation time and effort will be large

Risk assessment:

- Workers not accepting the change, like it the way it is

Implementation time: High. Will gradually improve but to reach the full potential of the system some time is required.

Implementation effort: High. Rethinking and time for data input from the managers will be needed.

Comments: Time consuming but the outcome can be extremely good. The solution takes into consideration many different aspects from the interviews – all from standardized the planning procedure, visualization of production, as well as suggestions from the students: to use the standardization tanks smarter. A suggested improvement based on the different departments' views

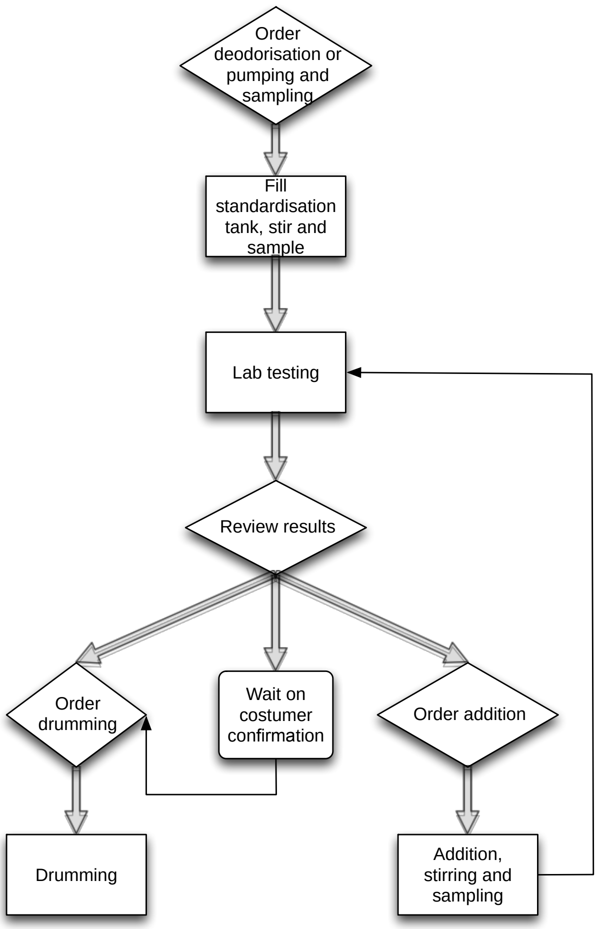
APPENDIX E

<u>New standardized work process</u>

Cost: Around 5 mISK.

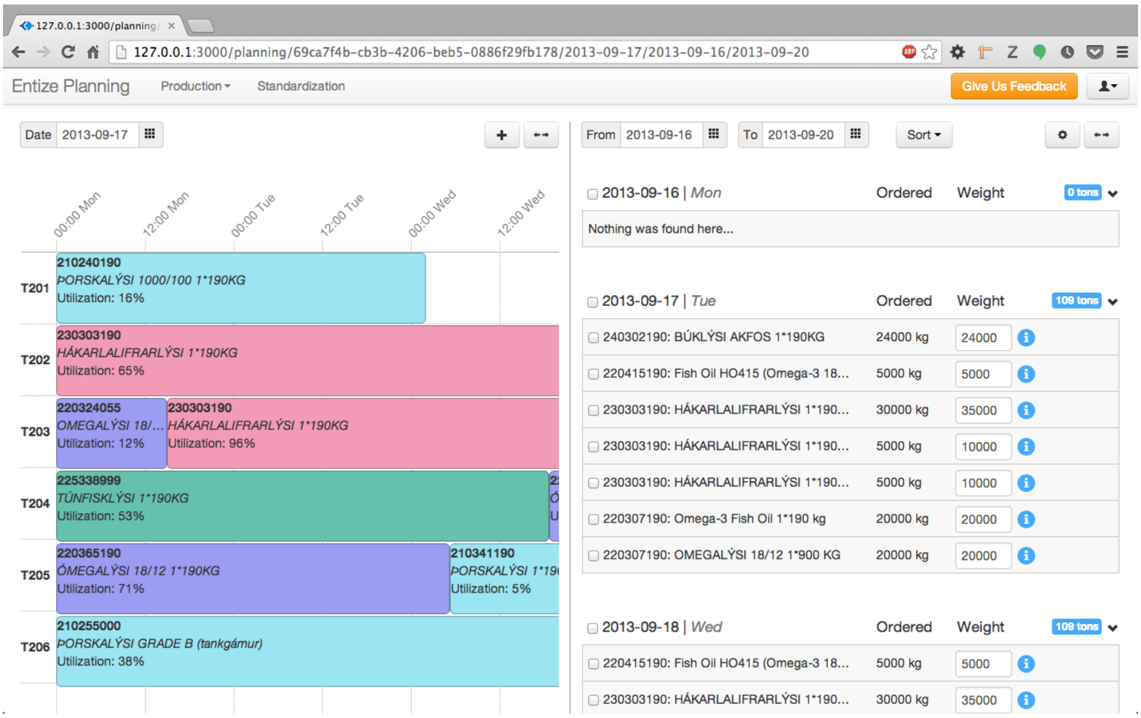
Productivity gain: Combining the three solutions, explained in appendices D7 – D9, a whole new process map and re-organization can be done. The processing time of samples in the lab will decrease and a better overview and flow is provided.

Description: Re-organizing and standardizing the whole procedure by combining samples taken by operators, a faster vitamin analysis and a planning tool.



APPENDIX F

Planning of the standardization process



Communication with the lab